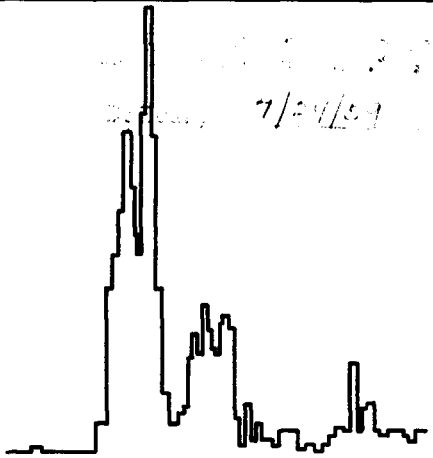

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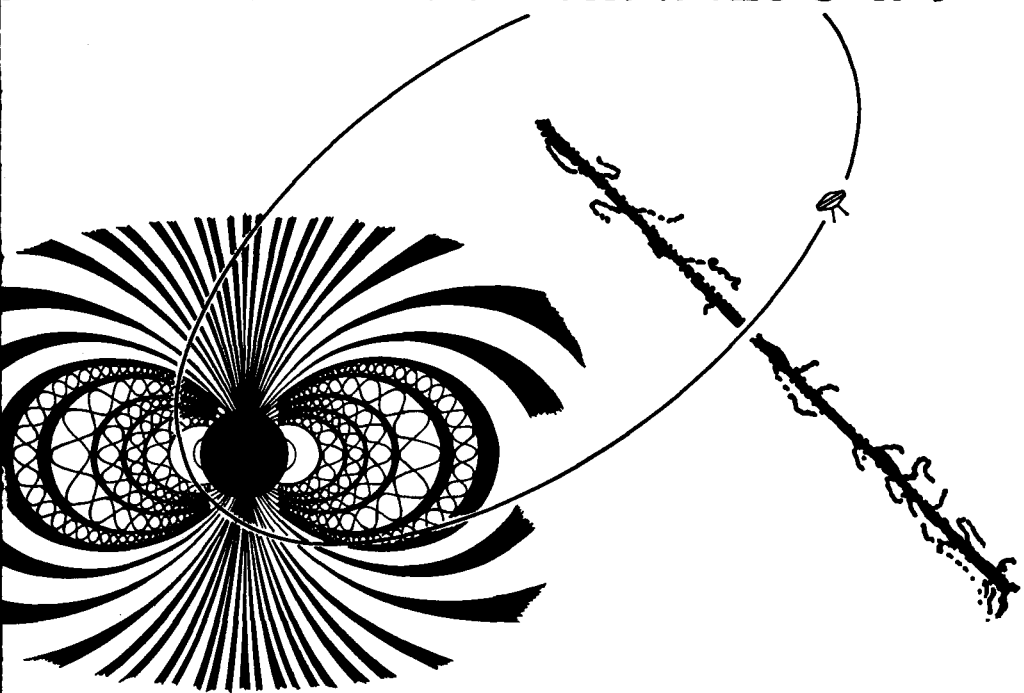
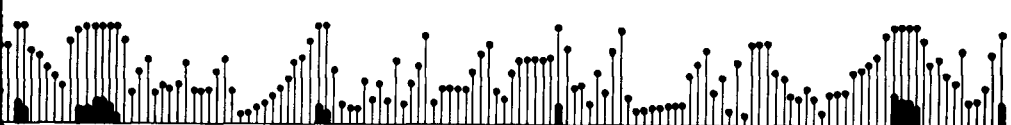
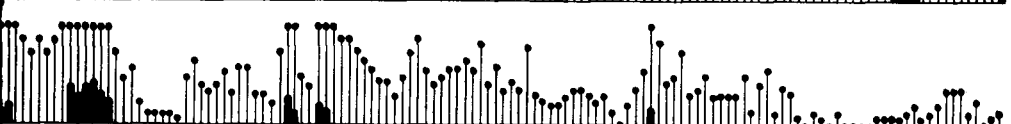
UNIVERSITY OF MINNESOTA



Institute of Technology 1959–1961





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, registration procedure, types of academic work, and academic standards; student personnel services, student activities, employment services, financial assistance, and opportunities for postgraduate degrees.

II. 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.

III. 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 only by number (prereq 89) is always in the department offering the course being described.

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

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

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

ON THE COVER—The bulletin cover symbolizes progress in cosmic physics during the IGY period at the University of Minnesota and elsewhere. The sky-scraper structure in the upper right-hand corner is an exact copy of a record of X rays produced by a bright aurora over Minneapolis obtained on a high-flying balloon on the first day of the IGY. The dense hairy track represents a heavy primary cosmic ray as observed in a nuclear emulsion carried on a balloon. These primary particles were discovered by the University of Minnesota and their behavior has been followed in detail during the IGY period. The earth and its magnetic field is pictured to show one of the great surprises of the IGY, namely the existence of a radiation belt trapped in the magnetic lines around the earth. These radiation belts were discovered by instruments carried in satellite experiments. At the bottom of the page is a "musical" diagram of changes in the earth's surface magnetism during successive rotations of the sun. The surface magnetism is sensitive to solar eruptions and the passage near the earth of clouds of high speed gas.

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College of Engineering, 133 Main Engineering

School of Architecture, 310 Main Engineering

School of Chemistry, 139 Chemistry

School of Mines and Metallurgy, 105 Mines and Metallurgy Building

School of Physics, 148 Physics

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Institute of Technology

I. GENERAL INFORMATION

General Objectives and Curriculums

Organization and Objectives—The Institute of Technology consolidates five related curricular units:

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

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

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

Curriculums and Degrees—In its programs for the Bachelor's degree, the Institute of Technology offers a 5-year curriculum in the various branches of engineering and in architecture, and a 4-year curriculum in chemistry and in physics. The colleges and schools and the degree curriculums they offer are:

College of Engineering—Aeronautical, agricultural, civil, electrical, and mechanical engineering; applied mathematics

School of Architecture—Architecture

School of Chemistry—Chemical engineering, chemistry (4-year curriculum), metallurgy

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

School of Physics—Physics (4-year curriculum)

Optional work in industrial engineering may replace some of the regular engineering study which leads to a 5-year professional degree. This option accommodates students who plan a career in engineering joined with industrial organization, scientific management, and operational research.

Also offered are combined curriculums with the Graduate School, the School of Business Administration, and the Law School.

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 in any of the 5-year programs except architecture. The student may then begin a graduate program in his fifth year.

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

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

The Institute of Technology divides its undergraduate curriculums into a Lower Division and an Upper Division. Upon satisfactory completion of the requirements of the Lower Division, a student may, upon application, be awarded a certificate in science. For further information regarding this program see the section on "Academic Standards."

Admission Requirements

High School Course Requirements—Entering students are admitted to the Lower Division of the Institute of Technology. To be admitted, a high school graduate must be in the top half of his class and meet the special mathematics requirement. The admission requirements are detailed in the *Bulletin of General Information.*

It is extremely important that the student complete as much mathematics as possible before entering the Institute, including higher algebra, solid geometry, and trigonometry.

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

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

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

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

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

(a) Correspondence study (see *Bulletin of Correspondence Study Courses*).

(b) Evening extension classes (see *Bulletin of Evening and Special Classes*).

(c) Registering in ITM 8 (information available at the College of Engineering Office, 133 Main Engineering). A fee of $21 is charged.

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

Students not eligible for admission to the Institute of Technology directly may apply for transfer to the Institute of Technology after 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 earn a later transfer to the Institute of Technology must consult with the counselors in that college at the very beginning of the school year in order to plan for this transfer and to receive help in planning their programs in relation to this goal.

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. Preferably this work shall include *mathematics,* English, physics, and chemistry as outlined in the curriculums for the Institute of Technology.

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

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

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

Registration and Types of Academic Work

Registration for Credit in Regular Courses—In order to register, all new students must present an admission certificate and an English classification card (freshmen only) or a record of advanced standing (transfer students). Those entering the College of Engineering, the School of Architecture, or the School of Physics will begin their registration in the Main Engineering building (E 135). Those entering the School of Chemistry will begin in the

Chemistry building (C 127), those entering the School of Mines and Metallurgy in 105 Mines and Metallurgy building, and those entering the Metallurgy Department of the School of Chemistry in 425 Mines and Metallurgy building. Registration instructions furnished by the Institute of Technology Registration Committee and placed on bulletin boards in the buildings mentioned above should be followed.

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

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

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

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

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

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

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

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

Evening and Correspondence Courses—Many Institute of Technology courses are offered by the General Extension Division of the University in evening classes and by correspondence study. Those who are unable to attend the regular University courses may thus obtain valuable instruction

after working hours or by mail. Information as to the credits which will be accepted toward a degree in the Institute of Technology appears on page 71 of this bulletin and in the General Extension bulletin.

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

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

Reserve Officers Training Corps—Information concerning requirements, opportunities, and courses in air science, military science and tactics, and naval science may be procured in the *Bulletin of the Army-Navy-Air 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 a committee of the faculty designated as the Scholastic Standards Committee. Occasionally these regulations may work a hardship on a particular student. In this event he may ask for an exemption by submitting a petition to the Scholastic Standards Committee. The committee is empowered to make exceptions to a requirement provided the exemptions work to the educational advantage of the student. Regular petition blanks are available in the various college offices listed in the section on "Registration." When the petition form has been completed, it should be left in the college office for the appropriate action. When the committee has taken action, the reply will be mailed to the student's city address.

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

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

Class Attendance—All students are expected to be punctual and regular in attendance at all class exercises and to do all the work of their courses. Irregularities in attendance or habitual tardiness will be sufficient reason for exclusion from class. Any student who has unexcused absences equal to the number of credits in a course, but in no case less than two, may be dropped from the class with a record of failure in the course.

To obtain an official excuse, the student secures a "Request for Excuse" form from his college office, i.e., E 133 for College of Engineering students. He leaves the completely filled-out form with the clerk. Application for an excuse should be made immediately upon return to school. Undue

delay in applying may result in refusal to grant an excuse. An excuse for an absence does not exempt the student from completing the work missed while he was absent.

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

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

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

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

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

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

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

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

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

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

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

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

The grade point average for determining probationary status is defined as the total number of earned grade points divided by the total number of credits earned and failed. Only credits and grade points earned while registered in the Institute of Technology at the University of Minnesota are

used in calculating the grade point average. For example, assume that the following grades were received 1 quarter:

3 credits of A—3 × 4 =	12 grade points
3 credits of B—3 × 3 =	9 grade points
5 credits of C—5 × 2 =	10 grade points
2 credits of D—2 × 1 =	2 grade points
3 credits of F—3 × 0 =	0 grade points
16 credits	33 grade points

The grade point average would be: $\frac{33}{16} = 2.06$

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

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

Requirements for Graduation—The Bachelor's degree with departmental designation will be recommended for those students with grade point averages of 2.00 or better who have completed all of the required work and have the total number of credits specified in their curriculums. The grade point average required for graduation from the Institute of Technology is based on the number of credits earned and failed in the University which are listed on the student's Institute record.

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

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

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

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

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

(a) Grade point average of 2.80 or better.

(b) Completion of the first 4 years of the curriculum including the proportional part of the nontechnical required courses (37 credits, including English).

(c) Approval of petition made to the Scholastic Standards Committee in the third quarter of the fourth year.

(d) Recommendation of the departmental faculty.

(e) Certificate of acceptance by the Graduate School. Graduate work may be taken in the student's original department or any other department of the Institute.

Probation and Exclusion from College—A grade point average of 2.00 is required for graduation. Students whose accumulative grade point average is less than a minimum schedule approved by the various colleges and schools of the Institute of Technology are placed on probation. After a probationary period of 1 quarter, they are required to appear before the Scho-

lastic Standards Committee and will be subject to exclusion from college. Experience has shown that a period spent away from college and employed in productive work permits some students to mature and to do satisfactory college work on re-entry at a later time.

Students whose grade point deficiency is greater than that indicated below are subject to exclusion from college.

Year	Completed Credits (earned and failed)	Tolerated Grade Point Deficiency	Corresponding Accumulative Grade Point Average
1	16	10	1.375
1	33	16	1.51
1	49	20	1.59
2	66	20	1.70
2	83	20	1.76
2	100	20	1.80
3	117	20	1.83
3	134	20	1.85
3	150	20	1.86
4	167	17	1.90
4	184	15	1.92
4	200	11	1.94
5	217	5	1.98
5	234	0	2.00
5	250	0	2.00

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

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

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

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

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

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

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

A student may be discontinued for cause at any time. A discontinued student may be readmitted if and when the Scholastic Standards Committee

is satisfied that the conditions which limited achievement have been changed sufficiently to permit success. Students who return to college under this provision shall be admitted on probation.

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

Special Requirements of the School of Chemistry—A grade point average of at least 2.00 is required for each year. This is a prerequisite to entrance into the required courses of the next year.

As a special recognition of superior work, quality credits may be earned in the School of Chemistry on the basis of 1 credit for every 10 honor points in excess of a C average for work taken in this University. Quality credits may apply toward the credit requirement for graduation.

Student Personnel Services

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

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

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

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

All-University Personnel Services—In addition to the counseling within the college, the University provides several specialized personnel services for the student. He may consult any of them either with or without referral from his adviser. These services are described more fully in the *Bulletin of General Information.*

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

Student Activities

Professional Societies—Branches of the following national professional societies are maintained at the University of Minnesota by students and faculty members: American Chemical Society, American Institute of Chemical Engineers, American Institute of Mining and Metallurgical Engineers, American Institute of Physics, American Society of Civil Engineers, Ameri-

can Society of Mechanical Engineers, American Society of Agricultural Engineers, and the Institute of the Aeronautical Sciences. In addition there are the Architectural Society, the School of Mines and Metallurgy Society, and the University of Minnesota Flying Club.

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 (Aeronautical Engineering). These fraternities normally elect their undergraduate members from the fourth- and fifth-year class on the basis of scholarship as measured by class rank and of character as judged by fellow students and faculty.

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

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

Minnesota Technolog and Technolog Board—The *Minnesota Technolog* is the undergraduate technical magazine of the Institute of Technology. It is a monthly publication produced by the students under the direction of an editorial and business staff selected from the student body. The policies of the magazine are determined by the Technolog Board of 14 members, 11 students, and 3 faculty members. The Technolog Board selects the manager-editor, editor in chief, and business manager and assists them in their work. The *Minnesota Technolog* is a member of the 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 Bureau of Student Loans and Scholarships, 201 Eddy Hall.

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

ALL DIVISIONS

Alcoa Foundation Scholarships: For undergraduates who have completed at least 1 year in college and are working toward a degree in agricultural, chemical, civil, mechanical engineering; or metallurgy. Amount is $500. One award in each field annually.

Associated General Contractors of Minnesota Scholarships: For undergraduate students who have bona fide interests in construction and contracting work. Candidates must have been residents of Minnesota prior to attending the University of Minnesota. Amount is $300 for 5 awards annually. Amount is $100 for 15 awards to entering freshmen.

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

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

Ellerbe and Company Engineering Scholarships: For undergraduates in the Institute of Technology. Amount is $300-$400. Three awards annually.

Hamilton Watch Award: 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. Hamilton watch awarded to a graduating senior in engineering.

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

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

Harlow C. Richardson Scholarship: For undergraduates in the Institute of Technology with demonstrated interest in the humanities. Amount is $300-$500. One or more awards annually.

Sigma Xi Scholarship (Minnesota Chapter, University of Minnesota): For undergraduate with aptitude and proficiency in some field of scientific endeavor. Amount is $150.

Alfred P. Sloan Foundation Scholarships: For male juniors in physical science, mathematics, physics, engineering and business administration. Amount is $200-$700. Five awards annually.

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

Texaco Company Scholarship: For any science student who is interested in the future of the petroleum industry. Amount is tuition, incidental fees, and $75 for books. Two awards annually.

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

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

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

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

AERONAUTICAL ENGINEERING

Aero-Alumni Scholarship: For students with advanced standing in aeronautical engineering. Amount is up to $500.

James B. Burroughs Memorial Scholarship in Aeronautical Engineering: For aeronautical engineering student with advanced standing. Amount varies.

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

AGRICULTURAL ENGINEERING

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

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

O. W. Kromer Company Agricultural Engineering Scholarship: For entering freshman in agricultural engineering. Amount is $300.

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

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

ARCHITECTURE

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

Flour City Architectural Education Scholarships (Flour City Ornamental Iron Company, Minneapolis): For undergraduates with advanced standing in architecture. Amount is $1,000. Awards of $100-$400 annually.

C. H. Johnston Scholarship (C. H. Johnston, Architects and Engineers, St. Paul): For advanced students in architecture. Amount is $200.

Magney, Tusler and Setter Scholarship (Architects and Engineers, Minneapolis): For advanced students in architecture. Amount is $200.

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

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

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

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

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

Gargoyle Club Prize (Gargoyle Club, St. Paul): For best thesis submitted during academic year. Amount is $50 (in books).

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

George B. Melcher Prize (Flour City Ornamental Iron Company, Minneapolis): For best work in design problem involving use of metal. Amount is $100.

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

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

CHEMICAL ENGINEERING and CHEMISTRY

Archer-Daniels-Midland Company Scholarship: For senior students in chemical engineering or 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 $300-$1,000. One or more awards annually.

Monsanto Chemical Company Scholarship: For fourth- or fifth-year students in chemical engineering. Amount is $500.

Rayette Incorporated Chemical Engineering Scholarship: For students with advanced standing in chemical engineering. Amount is $500.

Twin City Testing and Engineering Laboratory, Inc., Scholarship: For chemistry major. Amount is $500.

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.

CIVIL ENGINEERING

Associated General Contractors Scholarship: See description under "All Divisions."

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

Minnesota Surveyors and Engineers Society Highway Engineering Scholarships: For undergraduates in civil engineering with emphasis on highway engineering. *Entering freshmen:* $100 plus opportunity for summer work, 10 awards annually. *Advanced undergraduates:* $200-$300, 3 or more awards annually.

ELECTRICAL ENGINEERING

Collins Radio Company Scholarships: See description under "All Divisions."

Crossley Associates, Incorporated Scholarship: For junior students studying electronics or physics. Amount is $250 offered fall of 1960-61 and alternate years.

Douglas Aircraft Scholarship: See description under "Aeronautical Engineering" scholarships.

Colonel Robert H. Morse Scholarship: See description under "Mechanical Engineering" scholarships.

Northern States Power Company Scholarship: For advanced students in electrical engineering, with special preference to those emphasizing power option and atomic research. Amount is $300. Two awards annually.

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

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

MECHANICAL ENGINEERING

Collins Radio Company Scholarships: See description under "All Divisions."

Douglas Aircraft Scholarship: See description under "Aeronautical Engineering" scholarships.

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

Maytag Scholarship in Engineering: Male undergraduate in mechanical or industrial engineering, the scholarship to be used during senior year. Amount is $200.

Colonel Robert H. Morse Scholarship (Colonel Robert H. Morse Foundation, Chicago, Illinois): For fourth-year students in mechanical or electrical engineering; award renewable for fifth year. Amount is $500. Three fourth-year awards annually; 3 fifth-year awards annually.

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

Pioneer Engineering Division of Poor and Company, Incorporated Scholarship: For resident high school graduates and junior college graduates wanting to major in mechanical engineering who are in the upper 10 per cent of their

class and who without financial assistance will not be able to further their education. Amount is $500.

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

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

MINING, METALLURGICAL ENGINEERING, AND METALLURGY (School of Chemistry)

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

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

American Society for Metals Foundation for Education and Research Scholarship (Cambridge, Massachusetts): For students having 2 years of engineering and acceptance for advanced work in metallurgy or metallurgical engineering. Amount is $400.

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

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

M. A. Hanna Company Scholarships: For students enrolled or interested in pursuing a course in mineral technology. Preferential consideration to employees or members of families working for the Hanna Company. Amount is $500.

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

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

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

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

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

Mesabi Tire Scholarships: For students in the School of Mines and Metallurgy or geological engineering who are from the Minnesota Iron Range, including Duluth. Amount is $1,000. Two or more awards annually.

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

Reserve Mining Company Taconite Scholarships: For graduates of junior colleges located in Minnesota Iron Range who pursue advanced study in engineering or science pertinent to the taconite industry; renewable for fourth and fifth years. Amount is $500. Six awards annually: 2 third-year, 2 fourth-year, 2 fifth-year.

Sigma Rho Alumni Association, Beta Chapter, Scholarship: For undergraduates in the School of Mines and Metallurgy, or high school graduates who wish to enroll in the School of Mines and Metallurgy. Amount is up to $500.

Universal Oil Products Company Scholarships: See description under "Chemical Engineering and Chemistry" scholarships.

SCHOOL OF PHYSICS

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

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

Postgraduate Degrees

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

Graduate Credit for Undergraduates—If at the beginning of a quarter not more than 9 undergraduate credits are lacking for graduation (taking into account required and sequence courses), an undergraduate may carry a limited amount of graduate work (approved courses numbered above 99) for graduate credit. Such credit is not applicable toward an undergraduate degree. Transfer of credit must be arranged by petition to the Graduate School.

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

Graduate Fellowships and Assistantships—Numerous fellowships and assistantships in the Institute of Technology are open to graduates pursuing advanced degrees in aeronautical engineering, agricultural engineering, chemical engineering, chemistry, civil engineering, electrical engineering, industrial engineering, applied mathematics, mechanics and materials, mechanical engineering, mines and metallurgy, and physics. Fellowships carry stipends from $1,400 to $2,700 and assistantships have stipends of $2,043 for one-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.

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. CURRICULUMS

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

A. College of Engineering and School of Mines and Metallurgy

B. School of Architecture

C. School of Chemistry

D. School of Physics

COLLEGE OF ENGINEERING and SCHOOL OF MINES AND METALLURGY

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

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

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

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

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

Work in the *social-humanistic area* (nontechnical electives) is required throughout the entire engineering program. This is intended to broaden viewpoints and to add perspective.

It is important that the student be aware of this whole educational pattern so that he may understand better the interrelationships among the various courses he takes. Only then can he see the reason for courses which at times might seem quite remote to his principal core interests.

LOWER DIVISION

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

First Year

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

ITM 8, Solid Geometry, 0 credits, must be taken before EG 14 if solid geometry is not presented as an entrance unit.

Students will be advised with respect to the choice between English 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 and/or literature. A student who makes a grade of D in either quarter of 1A or 2A (upper course) must register for the succeeding quarter of the 1B-2B-3B sequence (the lower course) unless his instructor recommends otherwise.

ITM 9, Higher Algebra, 0 credits, or equivalent, must be taken before ITM 11 if higher algebra is not presented as an entrance unit.

Second Year

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

Completion of any set of laboratory requirements will be accepted by all departments; transfer students may use any physical science laboratory credits, or may petition to substitute other credits.

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

preliminary background for deciding among the various electives offered, the nature of the engineer's job and its general relationship to the engineering curriculum is discussed on succeeding pages.

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

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

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

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

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

UPPER DIVISION

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

Aeronautical Engineering
Agricultural Engineering
Civil Engineering
Electrical Engineering (and Industrial Engineering Option)
Engineering and Business Administration
Geological Engineering (Mining Option and Petroleum Option)
Geophysics
Mathematics, Applied
Mechanical Engineering (and Industrial Engineering Option)
Metallurgical Engineering
Mining Engineering (Mining Option and Petroleum Option)

Aeronautical Engineering

Aeronautical engineers are concerned primarily with vehicular systems and all associated technology. In aeronautical engineering the main emphasis is on manned and unmanned vehicles not in mechanical contact with the earth's surface. Since such systems include aircraft of all types, ballistic and guided missiles, and space vehicles the term "aero-space" engineering is perhaps more appropriate.

The objective of the aeronautical engineering curriculum is to adequately prepare students to handle the broad range of problems encountered in aero-space systems and to cope with the rapidly changing objectives and new situations characteristic of an engineering field so close to the frontiers of science. The curriculum is therefore designed to emphasize a broad engineering science base rather than to develop a finished product in any specialty. Specific knowledge on specialized devices is likely to become obsolete during the students' professional life but a broad engineering science background will generally remain applicable to the solution of the ever-changing problems 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.

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

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

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

Fifth Year—In addition to further study in engineering sciences and analyses important in aero-space engineering, work in "design" is offered to provide training in the synthesis of various engineering sciences. A "case" approach involving an aero-space system is generally used for this purpose.

In addition to the required courses sufficient electives are offered to permit students to develop their area or functional interests as explained in "Technical Electives" after the fifth-year curriculum. Thus, students who are strongly motivated in such areas as vertical take-off vehicles, meteorology, or space vehicles, or in such engineering functions as research, development, design, production, operation, application, or management are advised to select electives to develop such individual interests.

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

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

LOWER DIVISION

First Year

See first-year curriculum for College of Engineering.

Second Year

See second-year curriculum for College of Engineering.

The following courses are recommended for students in aeronautical engineering:

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

UPPER DIVISION

Third Year

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

Fourth Year

		Credits—f, w, s	
Aero 102A—Theoretical Aerodynamics III	3	.....	.....
Aero 106A-107A—Applied Aerodynamics I, II (see statement below)	.....	3	3
MM 150—Rheology and Strength of Solids	3	.....	.....
MM 142—Experimental Mechanics	2	.....	.....
Aero 114—Analysis of Structural Components (see statement below)	.....	.....	3
ME 133—Heat Transmission	.....	3	.....
EE 36-37-38—Elements of Electrical Engineering (see statement below)	3	3	3
EE 37A-38A—Electrical Engineering Laboratory (see statement below)	.....	1	1
Technical electives (see statement following fifth-year curriculum)	3	3	3
Nontech. Req.—Group III (see Index for "Nontechnical Required Courses")	3	3	3-4
Total credits	17	16	16-17

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

Students may substitute ME 199 for EE 38 and EE 38A with permission of their advisers.

Fifth Year

		Credits—f, w, s	
Aero 108—Applied Aerodynamics III	3	.....	.....
Aero 110—Compressible Viscous Flow	.....	3	.....
Aero 141—Experimental Aerodynamics	.....	.....	3
Aero 115A—Structural System Analysis I	3	.....	.....
ME 146—An Introduction to Combustion	3	.....	.....
ME 143—Turbomachinery (see statement below)	.....	3	.....
Aero 130A-131A-132A—Aero-Space System Design	4	4	4
Technical electives (see statement below)	3	3	5
Engl 85-86—Advanced Technical Communication	.....	3	3
Total credits	16	16	15

Students may substitute ME 150 or ME 155 or ME 157 for ME 143 with permission of their advisers.

Technical Electives—At least 3 credits of technical electives are included each quarter of the third, fourth, and fifth year. Students should carefully consider their functional and area interests and discuss with their adviser the selection of a co-ordinated sequence of electives to develop their interests. Students should be prepared to explain to their adviser the objectives and justification for the specific courses scheduled in their technical elective program. Those who intend to take graduate work in preparation for a career in research or teaching are encouraged to consider course sequences in mathematics, physics, chemistry, and mechanics for technical electives. Students interested in business and management functions in engineering should consider course sequences in economics, industrial engineering, and business. It should be emphasized that a conglomeration of unrelated courses will generally not be acceptable in the technical elective sequence.

Agricultural Engineering

A 5-year curriculum, in co-operation with the College of Agriculture, Forestry, and Home Economics, is offered which leads to the degree of bachelor of agricultural engineering, B.Ag.E.

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

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

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

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

LOWER DIVISION

First Year

See first-year curriculum for College of Engineering.

Second Year

See second-year curriculum for College of Engineering.

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

	Credits—f, w, s		
AgEn 8, 9, 10—Laboratory	1	1	1
Agro 1—Introduction to Agronomy	....	....	3
Bot 1, 2—General Botany	3	3	....
Phys 51—Intermediate General Physics (or) OrCh 16—Carbon Compounds	....	....	4

The nontechnical requirements in Group I are to be satisfied with Bot 1, 2, and Agro 1.

UPPER DIVISION

Third Year

	Credits—f, w, s		
AgEn 62—Farm Structures	....	3	....
AgEn 72—Principles of Farm Machinery	....	....	3
AgEn 82—Introduction to Soil and Water Management	3	....	....
CE 18-20—Surveying	3	....	3
Econ 1T-2T—Principles of Economics	3	....	3
Hydr 103—Fluid Mechanics	....	5	....
Hydr 104—Fluid Mechanics Laboratory	....	1	....
ME 21—Kinematics and Mechanisms	3	....	....
ME 24—Elements of Machine Design	....	....	3
MM 28, 29—Rigid-Body Mechanics II, III	3	3	....
MM 40, 41—Deformable-Body Mechanics I, II	3	3	....
MM 142—Experimental Mechanics	....	2	....
Soil 19—Intermediate Soils	....	....	4
Total credits	18	17	16

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 37—Elementary Structural Engineering	3	....	....
EE 36—Elements of Electrical Engineering	....	....	3
ME 30-31—Thermodynamics	3	3	....
ME 121—Machine Design	....	3	....
ME 133—Heat Transmission	....	....	3
ME 150—Internal Combustion Engines	....	....	3
Met 56—Physical Metallurgy	3	....	....
Rhet 22—Public Speaking	3	....	....
Technical electives (a minimum of 6 cr selected from AgEn 167, 171, 172, 176, 180, 181 required for graduation)	....	3	3
Nontech. Req.—Group III (see Index for "Nontechnical Required Courses")	3	3	....
Total credits	18	18	15

Fifth Year

	Credits—f, w, s		
AgEn 159—Agricultural Engineering Instrumentation	....	....	3
AgEn 170—Agricultural Tractors	....	3	....
AgEn 179—Agricultural Process Engineering	....	3	....
EE 37—Elements of Electrical Engineering	3	....	....
EE 37A—Electrical Engineering Laboratory	1	....	....
Engl 85-86—Advanced Technical Communications	3	3	....
GE 101—Contracts and Specifications	....	....	3
ME 160—Psychrometrics and Air Conditioning	3	....	....
Soil 123—Fertilizers and Soil Fertility (Soil 20 or Agro 21 may be substituted for Soil 123)	....	3	....
Soil 126—Soil Physics	4	....	....
Technical electives	3	3	6
Nontech. Req. (see Index for "Nontechnical Required Courses")	....	....	4
Total credits	17	15	16

Civil Engineering

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

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

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

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

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

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

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

LOWER DIVISION

First Year

See first-year curriculum for College of Engineering.

Second Year

See second-year curriculum for College of Engineering.

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

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

UPPER DIVISION

Third Year

		Credits—f, w, s	
CE 18, 19, 20—Surveying	3	3	3
CE 31—Elementary Structural Analysis	3	.....	.....
CE 32, 33—Elementary Structural Design	.....	3	3
CE 34—Drafting Room Practice	.....	.....	2
Geol 5-6—Geology for Engineers	3	3	.....
Hydr 103—Fluid Mechanics	.....	5	.....
Hydr 104—Fluid Mechanics Laboratory	.....	1	.....
MM 40, 41—Deformable-Body Mechanics I, II	3	3	.....
MM 28, 29—Rigid-Body Mechanics II, III	3	.....	3

		Credits—f, w, s	
MM 142—Experimental Mechanics	.....	.....	2
Nontech. Req.—Group II or I (see Index for "Nontechnical Required Courses")	3	.....	.....
Nontech. Req. or CE 160—Applied Hydraulics (see statement below)	.....	.....	3
Total credits	18	18	16

Students who take CE 160 should take Plan A 4th-year program. Those taking Nontech. Req. should take Plan B 4th-year program.

Summer Camp

CE 23—Surveying Camp ..... 9 credits

Fourth Year

		Credits—f, w, s	
CE 51-52—Highways and Pavements	3	3	.....
CE 53—Elements of Soil Mechanics	.....	.....	3
CE 130, 131, 132—Statically Indeterminate Structures; Structural Analysis; Structural Design	3	2	2
ME 30—Thermodynamics	.....	3	.....
ME 31—Thermodynamics (or) ITM 90—Elementary Engineering Statistics (or) Hydr 187—Intermediate Fluid Mechanics	.....	.....	3
Technical elective (taken in the Institute of Technology, or others by departmental approval)	.....	.....	3

Plan A:

CE 146—Concrete and Concrete Materials	.....	.....	3
CE 161—Hydrology	3	.....	.....
CE 170, 171—Water Supply; Sewerage and Sewage Treatment	3	3	.....
Nontech. Req.—Group II or III (see Index for "Nontechnical Required Courses")	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 Sewage Treatment	.....	3	3
Nontech. Req.—Group III (see Index for "Nontechnical Required Courses")	3	3	3
Total credits	15	17	17

Fifth Year

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

Sanitary Engineering Option—The option in sanitary engineering should be selected by the beginning of the fifth year in the civil engineering curriculum. If the selection of this option is made before or during the fourth year, CE 172, Bact 53, PubH 100A and 102 in the list of fifth-year courses in sanitary engineering may be substituted, upon approval, for one of the following: CE 34, 52, 146. This selection would permit a wider choice of fifth-year elective courses or early entrance to the Graduate School.

Fifth Year

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

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

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

First Year

See first-year curriculum for College of Engineering.

Second Year

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

Third Year

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

Fourth Year

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

Electrical Engineering

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

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

There are elective courses offered in the fifth year in various specialized fields.

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.

A 2-year sequence of study in electrical engineering is offered to strongly motivated and exceptionally able students (GPA = 2.80 or better). The corresponding class sections are referred to as Honors Sections in the printed schedule of classes. The Honors work is similar but more flexible than that

given in the regular curriculum, and class size is regulated to permit greater freedom of idea interchange between student and instructor. Enrollment is voluntary but must have the approval of the Honors Course adviser.

The 2-year sequence may be entered only at the beginning of the junior year by "regular" students who are regular in the electrical engineering curriculum. Transfer students are eligible as well as those previously in residence.

A curriculum combined with law is offered enabling the student to obtain two degrees, a bachelor of science degree and a bachelor of law degree. This program normally will take 7 years.

LOWER DIVISION

First Year

See first-year curriculum for College of Engineering.

Second Year

See second-year curriculum for College of Engineering.

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

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

UPPER DIVISION

Third Year

	Credits—f, w, s		
EE 51-53-55—Electrical Engineering	5	5	5
EE 52-54-56—Electrical Engineering Laboratory	1	1	1
EE 52A-54A-56A—Electrical Engineering Problem Solving Laboratory	1	1	1
EE 57-59—Engineering Electronics	....	3	3
EE 58-60—Engineering Electronics Laboratory	....	1	1
Hydr 101—Fluid Mechanics	....	....	3
MM 28, 29—Rigid-Body Mechanics II, III	3	3	....
MM 40—Deformable-Body Mechanics I	3	....	....
Nontech. Req.—Group I or II (see Index for "Nontechnical Required Courses")	3	3	4-3
Total credits	16	17	18-17

Fourth Year

	Credits—f, w, s		
EE 109—Electromagnetic Fields	3	....	....
EE 109A—Electromagnetic Fields Laboratory	1	....	....
EE 121-123-125—Analysis of Electromagnetic Devices	3	3	3
EE 122-124-126—Experimental Study of Electromagnetic Devices	1	1	1
EE 141—Electrical Engineering Materials	....	....	3
EE 141A—Electrical Engineering Materials Laboratory	....	....	1
EE 161-162-163—Electrical Engineering Networks	3	3	3
EE 161A-162A-163A—Networks Laboratory	1	1	1
ME 30—Thermodynamics	....	3	....
Electives	3	3	3
Nontech. Req.—Group III (see Index for "Nontechnical Required Courses")	3	3	3
Total credits	18	17	18

Fifth Year

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

Electrical Engineering Electives—A minimum of two sequences must be completed from the following list (eligible students may use 100-series courses from the Advanced Course List):

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

100-Series Courses on the Advanced Course List—These sequences include in addition to other prerequisites the notation ♯—meaning "consent of instructor required":

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

Industrial Engineering Option (see also section on Industrial Engineering)—To accommodate students who are looking forward to a career in electrical engineering concerned with industrial organization, the following industrial engineering option is offered:

In the second year Psy 1-2, 155 are recommended. In the third year add ITM 90; and take Econ 1T-2T, BA 52 for the nontechnical requirements in Group II.

Fourth Year

	Credits—f, w, s		
EE 109—Electromagnetic Fields	3	.....	.....
EE 109A—Electromagnetic Fields Laboratory	1	.....	.....
EE 121-123-125—Analysis of Electromagnetic Devices	3	3	3
EE 122-124-126—Experimental Study of Electromagnetic Devices	1	1	1
EE 141—Electrical Engineering Materials	.....	.....	3
EE 141A—Electrical Engineering Materials Laboratory	.....	.....	1
EE 161-162-163—Electrical Engineering Networks	3	3	3
EE 161A-162A-163A—Networks Laboratory	1	1	1
BA 55A—Elementary Accounting	4	.....	.....
BA 55C—Managerial Costs	.....	3	.....
IE 50—Elements of Industrial Engineering and Management	3	.....	.....
IE 153—Methods Engineering and Work Measurement	.....	3	.....
IE 170—Production Planning and Control	.....	.....	3
Nontech. Req. (see Index for "Nontechnical Required Courses")	.....	2	2
Total credits	19	16	17

Fifth Year

	Credits—f, w, s		
EE 187-188-189—Problems in Electrical Engineering	3	3	3
Engl 85-86—Advanced Technical Communication	3	3	.....
Minimum of 6 credits from IE 154, 155, 163, 165, 173	3	.....	3
IE 171—Quality Control	.....	3	.....
IE 190—Industrial Engineering Seminar	.....	.....	1
IE 194—Applied Industrial Engineering	.....	.....	3
ME 30—Thermodynamics	.....	3	.....
Industrial engineering electives	3	3	3
Nontech. Req. (see Index for "Nontechnical Required Courses")	3	.....	3
Total credits	15	15	16

Engineering and Business Administration

As a result of the vast industrial expansion which has taken place in the United States, a need has arisen for engineers with more training in economics and business administration than is normally possible in the regular engineering curriculums. To meet this need two special curriculums have been developed, the combined curriculums in engineering and business administration, and the 4-year program in engineering and business administration (industrial administration).

Combined Curriculums in Engineering and Business Administration—The combined curriculums in engineering and business administration enable the student to complete the requirements for 2 degrees, 1 in the Institute of Technology and 1 in the School of Business Administration in a period of approximately 5 years. In the Institute of Technology the Aeronautical, Agricultural, Chemical, Civil, Geological, Metallurgical, and Mining Engineering Departments, and the Mathematics Department will allow business courses to be substituted for natural science, social science, humanities, Engl 85, 86 and electives to satisfy the requirements for the Bachelor's degree unless indicated to the contrary in the curriculum. The School of Business Administration accepts 75 credits of business subjects (as listed in the curriculum) which satisfy the requirements for the degree of bachelor of business administration. Required courses have been waived in both colleges with the understanding that the courses in the two colleges will be carried simultaneously and supplement each other. The work is to be completed as a unit and both degrees obtained at the same commencement period.

Application for admission to this program may be made by filing a petition with the Scholastic Standards Committee for the combined engineering and business curriculums, located in 133 Main Engineering building. A grade point average of 2.50 in each field, i.e., engineering and business, based on at least 2 quarters of work in the Institute of Technology, is required for entrance into and for continuation in this program. Freshmen should submit applications at the beginning of their third quarter in school while advanced standing students should apply after completing 2 quarters in the Institute of Technology.

After being officially admitted, the student will be registered in both the Institute of Technology and the School of Business Administration for the entire program. Registration each quarter is subject to the approval of the advisers in both the School of Business Administration and the Institute of Technology. The business courses are intended to be spread over the last 4 years as indicated below. Not more than 28 credits of business subjects should be left to the fifth year.

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

First Year

See first-year curriculum for College of Engineering.

Second Year

It is recommended that students in the combined curriculums in engineering and business administration elect the following courses in the second year in addition to those recommended by the departments in which they desire to major. These courses are in lieu of nontechnical requirements.

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

Third Year

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

Fourth Year

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

Fifth Year

		Credits—f, w, s	
BA 53—Insurance Principles	3	.....	.....
BA 54—Transportation I: Principles	3	.....	.....
Econ 67—Money and Banking	3	.....	.....
Econ 68—Elements of Public Finance	.....	3	.....
Econ 69—Government Regulation of Business	.....	3	.....
BA 60—Business Policy and Management Control	.....	.....	3
Business and economics electives (suggested courses follow):	6	3	3
BA 197—Purchasing			
BA 117—Sales Management			
BA 175A—Standard Costs			
BA 176—Investments			
BA 76—Finance Management			
BA 72—Modern Industrial Relations: Manpower Management			
BA 97—Market Anaiysis and Research I			
BA 110—Systems and Procedures Analysis; Work Measurement			
Total credits for 2nd to 5th years		75	

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

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

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

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

All programs will include:

1. 21 hours in 5 basic areas: quantitative approaches to administrative problems (6 credits), policy formulation and administration (3 credits), executive leadership (3 credits), government and business enter-

prise (6 credits), and business research methods and techniques (3 credits);

2. Twenty-four credits selected from courses in at least 4 of the following 9 fields, with a minimum of 6 credits each in at least 2 fields and a maximum of 9 credits in any 1 field. The 9 fields are accounting, finance, industrial management and administration, industrial relations, insurance, marketing, office management, statistics, and transportation. Any department of the Graduate School may be substituted for *1* of the 9 fields in business administration.

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

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

A foreign language is not required.

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

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

Four-Year Curriculum in Engineering and Business Administration (Industrial Administration)—This curriculum has been arranged for students who wish to prepare for positions in industry which require some basic technical training plus instruction in business administration. Such positions are found in fields of purchasing, sales and sales promotion, cost accounting, employment and rate setting, and production control.

The work in the first 2 years of this curriculum is taken in the Institute of Technology. The work in the last 2 years is taken in the School of Business Administration.

Transfer is made to the School of Business Administration at the beginning of the junior year. A minimum of 95 credits including a grade point average of 2.00 is required for admission.

Elective credits earned in the Institute of Technology or any other accredited school during the first 2 years may be applied toward the elective requirement in the junior and senior years of this curriculum.

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

First Year (same curriculum as the first year in the College of Engineering)

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

ITM 8, Solid Geometry, 0 credits, must be taken before EG 14 if solid geometry is not presented as an entrance unit.

Students will be advised 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 and/or literature. A student who makes a grade of D in either quarter of

1A or 2A (the upper course) must register for the succeeding quarter of the 1B-2B-3B sequence (the lower course) unless his instructor recommends otherwise.

ITM 9, Higher Algebra, 0 credits, or equivalent, must be taken before ITM 11 if higher algebra is not presented as an entrance unit.

Second Year

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

Third and Fourth Years

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

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

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

1. Core Group Requirements—42 credits

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

2. Business and economics electives—18 credits

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

3. Additional electives—30 credits

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

Total credits, groups 1-3—90

4. Electives Outside the School of Business Administration

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

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

Geological Engineering

A 5-year curriculum is offered which leads to the degree of bachelor of geological engineering, B.Geol.E. There are two options: mining and petroleum.

A total of 248 credits, exclusive of summer field trips, is required for graduation.

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

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

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

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

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

Students taking the combined curriculum with business administration may substitute business courses for nontechnical required courses, Group I, Group II, and Group III (see section on Nontechnical Required Courses), and electives.

LOWER DIVISION

First Year

See first-year curriculum for College of Engineering.

Second Year

See second-year curriculum for College of Engineering.

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

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

UPPER DIVISION

Third Year

	Credits—f, w, s		
Geol 51, 2—Principles of Physical Geology; General Geology (Historical) (counts toward nontechnical requirements)	3	3	.....
Geol 23-24, 25—Mineralogy; Rock Study	4	4	2
MinE 13—Mine Surveying	.....	.....	3
MinE 111, 112, 113—Mineral Deposits: Exploration, Development, Exploitation (or) PetE 111, 112, and Tech. Elect.—Oil Field Development; Oil Field Production; a technical elective	3	3	3
CE 18, 20—Surveying	3	.....	3
Hydr 103—Fluid Mechanics	.....	.....	5
Hydr 104—Fluid Mechanics Laboratory	.....	.....	1
MM 28—Rigid-Body Mechanics II	3	.....	.....
MM 40, 142—Deformable-Body Mechanics I; Experimental Mechanics	.....	3	2
IE 50—Elements of Industrial Engineering and Management	.....	3	.....
Total credits	16	16	19

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

Summer Field Trip

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

Fourth Year

	Credits—f, w, s		
Geol 106—Petrography	3	.....	.....
Geol 107—Invertebrate Paleontology	3	.....	.....
Geol 110-111—Economic Geology	.....	3	3
Geol 125—Structural Geology	4	.....	.....
Geol 131—Petrology	.....	4	.....
Geol 151—Stratigraphy I	.....	3	.....
Geology electives (numbered 100 or over)	.....	.....	3-4
MinE 16—Mine Maps	.....	.....	1
GPhy 110—Introduction to Exploration Geophysics	.....	.....	3
MetE 110, 111—Mineral Dressing	4	4	.....
PCh 101-102—Physical Chemistry	4	4	.....
Nontech. Req. (see Index for "Nontechnical Required Courses")	.....	.....	6
Total credits	18	18	16-17

Summer Field Trip

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

Fifth Year

	Credits—f, w, s		
Geol 118—Geomorphology	3	.....	.....
Geol 166—Mineralography	.....	3	.....

		Credits—f, w, s	
Geol 171—Geologic Report	1		
Geology electives (numbered 100 or over)	3		
GPhy 108—Introduction to General Geophysics	3		
MinE 131-132—Rock Mechanics I, II	3	3	
MinE 141—Mineral Economics	3		
MinE 180—Geochemical Exploration		3	
CE 53—Elements of Soil Mechanics			3
Engl 85-86—Advanced Technical Communication		3	3
Technical electives			3
Nontechnical electives	2	2	3
Total credits	18	14	12

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

IT: AnCh 57; CE 19; GE 101; IE 153, 173, 180; ME 128, 198; EE 36; MetE 12, 106, 112, 121, 122; Met 56; MinE 121, 122, 132, 133, 142, 160; PetE 111, 112, 135; Phys 51

BA: Econ 1T, 2T; BA 55A, 55B

SLA: Geol 101, 112, 114, 120, 121, 132, 140, 145, 153, 161, 167

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

Third Year Summer Field Trip

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

Fourth Year

		Credits—f, w, s	
Geol 106—Petrography	3		
Geol 107—Invertebrate Paleontology	3		
Geol 118—Geomorphology	3		
Geol 125—Structural Geology	4		
Geol 131—Petrology		4	
Geol 151, 152—Stratigraphy		3	3
GPhy 110—Introduction to Exploration Geophysics			3
MinE 16—Mine Maps			1
PetE 131—Reservoir Mechanics			3
PetE 134—Natural Gas Engineering		2	
PCh 101-102—Physical Chemistry	4	4	
Nontech. Req. (see Index for "Nontechnical Required Courses")		3	3
Total credits	17	16	13

Summer Field Trip

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

Fifth Year

		Credits—f, w, s	
Geol 101—Sedimentation	3		
Geol 112—Petroleum Geology	3		
Geol 171—Preparation of Geologic Report	1		
Geology electives (numbered 100 or over)		3	3
GPhy 108—Introduction to General Geophysics	3		
MinE 131—Rock Mechanics I	3		
MinE 141—Mineral Economics	3		
PetE 152-153-154—Petroleum Production Technology	3	3	3
CE 53—Elements of Soil Mechanics			3
Engl 85-86—Advanced Technical Communication		3	3
Technical electives		3	
Nontechnical electives		4	3
Total credits	19	16	15

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

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

BA: Econ 1T, 2T; BA 55A, 55B

SLA: Geol 102, 110, 111, 121, 132, 140, 153, 166

Geophysics

A 5-year curriculum is offered which leads to the degree of bachelor of geophysics, B.Geophys. A total of 244 credits, exclusive of field trips, is required for graduation.

Geophysics means physics of the earth, and is concerned with the application of the laws and techniques of physics to earth problems. In practice, a division is made between problems dealing with the entire earth or large portions of it and local problems which arise in exploration for minerals or petroleum. In the former category are topics such as the age, shape, and internal construction of the earth, gravitational and magnetic fields, isostasy, tides, and poles; particular emphasis is placed on earthquake study because of the valuable data supplied by it to the fields of physics and geology. Exploration geophysics makes use of differences in physical properties of rocks to provide information on materials buried hundreds or thousands of feet beneath the surface. Courses in geophysics attempt to provide not only geophysical data but also the evidence on which such data are based.

Both the geophysics curriculum and individual geophysics courses place primary emphasis on basic principles and techniques. The curriculum provides a thorough background in geology, physics, and mathematics. It prepares students either for graduate work in geophysics and related fields, or for responsible positions in geophysical companies, oil or mining companies, or research institutions. The program may also be taken by students interested chiefly in a broad scientific training.

LOWER DIVISION

First Year

See first-year curriculum for the College of Engineering.

Second Year

Follow second-year curriculum for either School of Physics or College of Engineering. Recommended laboratory sequence is Phys 14A, 50A, and 51A.

UPPER DIVISION

Third Year

	Credits—f, w, s		
Geol 51, 2—General Geology (Physical and Historical)	3	....	3
Geol 23-24—Mineralogy	4	4	....
Geol 25—Rock Study	....	....	2
ITM 150A—Ordinary Differential Equations	....	....	3
ITM 151A—Calculus V: Intermediate Calculus	....	3	....
Phys 107-109-111—Modern Physics	3	3	3
Electives	6	3	3
Nontech. Req.—Group II or III (see Index for "Nontechnical Required Courses")	....	3	3
Total credits	16	16	17

Fourth Year

		Credits—f, w, s	
GPhy 109—Elementary Seismology		3	
CE 17—Surveying			3
Geol 125—Structural Geology	4		
Phys 100-102-104—Mechanics and Electromagnetism	4	4	4
Phys 144—Electrical Measurements	4		
Phys 146—Physics of Vacuum Tubes and Associated Circuits		4	
Phys 148—Application of Electronic Circuits			4
Electives	6	3	3
Technical electives		2	
Total credits	18	16	14

Summer Field Trip

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

Fifth Year

		Credits—f, w, s	
GPhy 108—Introduction to General Geophysics	3		
GPhy 125—Principles of Gravity and Magnetic Exploration	2		
GPhy 126—Principles of Seismic Exploration		2	
GPhys 127—Principles of Electrical Exploration			2
Engl 85-86—Advanced Technical Communication	3		3
Geol 110—Economic Geology		3	
Phys 123-124-125—Thermodynamics, Statistical Mechanics, and Theories of the Structure of Matter	3	3	3
Electives	6	6	6
Total credits	17	14	14

Suggested electives: Geol 112, 131, 137, 151; Phys 121, 122; ITM 152, 153; EE 57-59, 58-60, 143-144-145; InCh 11; PCh 101-102-103.

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. Psy 1, 2, and 155 are recommended for Group I of nontechnical requirements.

UPPER DIVISION

Third, Fourth, and Fifth Years

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

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

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

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

Mathematics, Applied

A 5-year curriculum is offered which leads to the degree of bachelor of applied mathematics, B.Appl.Math.

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

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

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. Alternatively he may pursue the regular work of the applied mathematics curriculum leading to the degree of bachelor of applied mathematics at the end of the fifth year.

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

LOWER DIVISION

First Year

See first-year curriculum for College of Engineering.

Second Year

See second-year curriculum for College of Engineering.

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

	Credits—f, w, s		
ITM 14—Laboratory	....	....	1
Phys 14A, 50A—Physics Laboratory	1	1	....
Phys 51—Intermediate General Physics	....	....	4

UPPER DIVISION

Third Year

	Credits—f, w, s		
ITM 150A—Ordinary Differential Equations	....	3	....
ITM 151A—Calculus V: Intermediate Calculus	3	....	....
ITM 152, 153—Calculus VI, VII: Advanced Calculus	....	3	3
Hydr 101—Fluid Mechanics	....	....	3
Hydr 104—Fluid Mechanics Laboratory	....	....	1
MM 28, 29—Rigid-Body Mechanics II, III	3	3	....
MM 40—Deformable-Body Mechanics I	3	....	....
Technical option—(to be selected from one of the departments in Institute of Technology with help of an adviser)	3	3	3
Electives	2	2	2
Nontech. Req. (see Index for "Nontechnical Required Courses")	3	3	4
Total credits	17	17	16

Fourth Year

	Credits—f, w, s		
ITM 99—Mathematical Problem Seminar	....	....	3
ITM 132—Introduction to Statistics and Probability	3	....	....
ITM 133-134—Statistics with Engineering Applications	....	3	3
ITM 142-143—Vector and Matrix Theory with Applications	3	3	....
ITM 173—Elementary Partial Differential Equations	3	....	....
ITM 174—Elementary Theory of Complex Variables	....	3	....

	Credits—f, w, s		
ITM 175—Integral Transforms	....	....	3
ITM 184, 185-186—Numerical Analysis in Engineering	3	3	3
Electives	2	2	2
Nontech. Req. (see Index for "Nontechnical Required Courses")	3	3	3
Total credits	17	17	17

Fifth Year

	Credits—f, w, s		
Mathematics option (see Mathematics Option following fifth-year curriculum	6	6	6
ITM 168B—Applications of Complex Variables (or) ITM 169—Mathematical Theory of Fluid Flow (or) ITM 180—Finite Groups	....	....	3
Engl 85-86—Advanced Technical Communication	3	3	....
Phys 102-104—Mechanics and Electromagnetism	....	4	4
Electives	7	3	3
Total credits	16	16	16

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

ITM 161-162-163—Analytical Dynamics	3	3	3
ITM 164-165-166—Theory and Programming of Modern Digital Computers	3	3	3
ITM 190A-190B-190C—Combinatorial Topology	3	3	3
ITM 227-228-229—Mathematics of Computers and Control Devices	3	3	3
MM 180, 181, 182—Introduction to Theory of Elasticity; Deformable-Body Mechanics III, IV	3	3	3

Mechanical Engineering

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

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

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

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

UPPER DIVISION

Third Year

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

Fourth Year

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

Fifth Year

	Credits—f, w, s		
ME 125—Machine Design Laboratory ME 159—Heat Power Laboratory ME 169—Air Conditioning and Refrigeration Laboratory	2	2	2
ME 121—Machine Design ME 143—Turbomachinery ME 180—Mechanical Refrigeration (two courses required)	6	....	....
ME 198—Industrial Instrumentation and Automatic Control	....	3	....
Engineering design group (minimum of 3 credits from ME 122, 147, 161, IE 163)	....	....	3

		Credits—f, w, s	
EE 37-38—Elements of Electrical Engineering	3	3	.....
EE 37A-38A—Electrical Engineering Laboratory	1	1	.....
Engl 85-86—Advanced Technical Communication	3	3	.....
Technical electives (see statement below)	3	3	3
Nontech. Req. (see Index for "Nontechnical Required Courses")	.....	.....	3
Electives (sufficient to complete a total of at least 250 credits for graduation)	.....	.....	5
Total credits	18	15	16

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

Industrial Engineering Option—Mechanical engineering training with specialization in industrial engineering is provided by this option. Students who follow this option are also eligible to apply for the bachelor of science degree or for the co-operative 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.

Psy 1, 2, and 155 are recommended for Group I of the nontechnical requirements.

Third Year

See third-year curriculum for Mechanical Engineering.

Econ 1T, 2T and BA 52 are recommended for Group II of the nontechnical requirements.

Fourth Year

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

Fifth Year

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

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

The first industrial assignment is made during the summer or fall term following the completion of the first 3 years' work. The student is registered in the University during the work periods, and at all times is considered a regular full-time University student.

The awarding of the Bachelor's degree with departmental designation will require the satisfactory completion of all the basic required University work as designated in the regular 5-year mechanical engineering curriculum including 4 alternate quarters of supervised industrial experience.

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

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

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

Metallurgical Engineering

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

A total of 250 credits is required for graduation.

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

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

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

The extraction of metals from ores and concentrates, and the refining of these metals, involve processes which are necessarily chemical in nature. As such processes encompass a wide variety of chemical reactions, the metallurgical engineer must be familiar with the fundamentals of chemical reaction between solids, liquids and gases, and with the driving forces which make these reactions possible. In industrial operations, large quantities of material must be processed, so that the metallurgical engineer is required to apply both scientific and engineering principles.

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

Students taking the combined course with business administration may substitute business courses for nontechnical required courses (see section on Nontechnical Required Courses) and electives.

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

LOWER DIVISION

First Year

See first-year curriculum for College of Engineering.

Second Year

See second-year curriculum for College of Engineering.

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

For the laboratory sequence, the following courses are recommended:

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

UPPER DIVISION

Third Year

	Credits	f	w	s
MetE 11—Elements of Metallurgical Engineering	3	....	....	
AnCh 57—Quantitative Analysis	4	....	....	

		Credits—f, w, s	
OrCh 16—Carbon Compounds			4
PCh 101-102-103—Physical Chemistry	4	4	4
Geol 23-24—Mineralogy	4	4	
ITM 90—Elementary Engineering Statistics			3
MM 28—Rigid-Body Mechanics II	3		
MM 40, 142—Deformable-Body Mechanics I; Experimental Mechanics		3	2
Technical elective (see list of recommended electives below)		3	
Nontech. Req. (see Index for "Nontechnical Required Courses")		3	3
Total credits	18	17	16

Fourth Year

		Credits—f, w, s	
MetE 106, 107, 108—Principles of Process Metallurgy	3	4	4
MetE 110, 111, 112—Mineral Dressing	4	4	4
ChEn 101, 102—Principles of Chemical Engineering	5	5	
Geol 106—Petrography	3		
Met 53, 154, 155—Principles of Physical Metallurgy I, II, III	3	3	3
Nontech. Req. (see Index for "Nontechnical Required Courses")		2-3	4-6
Total credits	18	18-19	15-17

Field Trip

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

Students who are primarily interested in mineral dressing may take part of the mining inspection trip in lieu of the metallurgical inspection trip.

Fifth Year

		Credits—f, w, s	
MetE 121, 122, 123—Iron Ore Beneficiation; Advanced Mineral Dressing	3	3	3
MetE 134, 135, 136—Metallurgical Unit Processes	3	3	3
EE 36-37-38—Elements of Electrical Engineering	3	3	3
EE 37A-38A—Electrical Engineering Laboratory		1	1
Engl 85-86—Advanced Technical Communication		3	3
MinE 141—Mineral Economics	3		
Nontech. Req. (see Index for "Nontechnical Required Courses") or technical electives (see list of recommended electives below)	3	2	2
Total credits	15	15	15

Credits beyond the curriculum requirements may be taken with special permission. Recommended technical electives:

MetE 124-125-126, 138, 141-142-143, 144; Phys 107-109-111, 144; InCh 112; ChEn 111, 112, 119-120; Geol 51, 2; GE 101; IE 50; ME 24, 198; Met 53A, 154A, 155A, 161, 162, 165; ITM 150A, 151A, 152.

Mining Engineering

A 5-year curriculum is offered which leads to the degree of bachelor of mining engineering, B.Min.E. There are two options: mining and petroleum.

A total of 248 credits, exclusive of summer field trips, is required for graduation.

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

must also include plane and mine surveying, mapping, mineral dressing, and ore testing.

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

The petroleum engineer must be familiar with oil geology involving a knowledge of geological ages during which oil was formed, geological conditions under which the oil was collected in pools, and the methods of interpreting geological data to determine whether a given locality contains such pools. He must know the principles of pumping with gas lift and mechanical pumps, and the methods of gasoline recovery. The basic training must, therefore, include thorough courses in mathematics, drafting, chemistry, physics, and geology, including in particular, a thorough knowledge of sedimentary deposits. It must also include surveying and mapping.

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

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

Students taking the combined curriculum with business administration may substitute business courses for nontechnical required courses, Group I, Group II, Group III (see section on Nontechnical Required Courses), and electives.

LOWER DIVISION

First Year

See first-year curriculum for College of Engineering.

Second Year

See second-year curriculum for College of Engineering.

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

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

UPPER DIVISION

Third Year

	Credits—f, w, s		
MinE 111, 112, 113—Mineral Deposits: Exploration, Development, Exploitation (or) PetE 111, 112, and Tech. Elect.—Oil Field Development; Oil Field Production; a technical elective	3	3	3
MinE 13—Mine Surveying	.....	.....	3

	Credits—f, w, s		
Geol 51, 2—General Geology (Physical and Historical) (counts toward nontechnical requirements)	3	3	.....
Geol 23-24, 25—Mineralogy; Rock Study	4	4	2
CE 18, 20—Surveying	3	.....	3
Hydr 103—Fluid Mechanics	.....	.....	5
Hydr 104—Fluid Mechanics Laboratory	.....	.....	1
MM 28—Rigid-Body Mechanics II	3	.....	.....
MM 40, 142—Deformable-Body Mechanics I; Experimental Mechanics	.....	3	2
IE 50—Elements of Industrial Engineering and Management	.....	3	.....
Total credits	16	16	19

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

Summer Field Trip

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

Fourth Year

	Credits—f, w, s		
MinE 16—Mine Maps	.....	.....	1
MinE 121, 122—Mine Plant Engineering; Mine and Petroleum Plant Engineering	.....	3	3
MetE 110, 111, 112—Mineral Dressing	4	4	4
Geol 110-111—Economic Geology	.....	3	3
Geol 125—Structural Geology	4	.....	.....
CE 37—Elementary Structural Engineering	3	.....	.....
EE 36, 40—Elements of Electrical Engineering; Electrical Engineering Survey	3	4	.....
ME 30—Thermodynamics (see statement below)	3	.....	.....
Technical elective (see statement below)	.....	.....	3
Nontech. Req. (see Index for "Nontechnical Required Courses")	.....	3	3
Total credits	17	17	17

Student has choice of either of the following as substitute for ME 30 and the technical elective (3 cr):

	Credits—f, w, s		
ME 30-31—Thermodynamics	3	3	.....
PCh 101-102—Physical Chemistry	4	4	.....

Summer Field Trip

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

Fifth Year

	Credits—f, w, s		
MinE 123—Mine Air Conditioning	3	.....	.....
MinE 131, 132—Rock Mechanics I and II	3	3	.....
MinE 141—Mineral Economics	3	.....	.....
MinE 142—Surface Mining Engineering	.....	3	.....
MinE 144-145—Advanced Mining Engineering	.....	2	4
Engl 85-86—Advanced Technical Communication	3	3	.....
GPhy 110—Introduction to Exploration Geophysics	.....	.....	3
MetE 12—Metallurgical Processes	3	.....	.....
MetE 121—Iron Ore Beneficiation	3	.....	.....
Technical electives	.....	.....	2
Nontechnical electives	.....	4	3
Total credits	18	15	12

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

IT: CE 19, 53, 147, 159; GE 101; GPhy 108; IE 153, 173, 180; ITM 90; ME 24, 32, 128, 198; MM 180; Met 56; PCh 101, 102

BA: Econ 1T-2T; BA 55A, 55B, 72

SLA: Geol 101, 106, 112; Ast 51

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

Third Year Summer Field Trip

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

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

Fourth Year

	Credits—f, w, s		
PetE 131—Reservoir Mechanics	....	....	3
PetE 134—Natural Gas Engineering	....	2	....
MinE 122—Mine and Petroleum Plant Engineering	....	....	3
Geol 101—Sedimentation	3	....	....
Geol 112—Petroleum Geology	3	....	....
Geol 125—Structural Geology	4	....	....
Geol 153—Subsurface Stratigraphy	....	....	2
EE 36, 40—Elements of Electrical Engineering; Electrical Engineering Survey	3	4	....
ME 30-31—Thermodynamics	....	3	3
PCh 101-102—Physical Chemistry	4	4	....
Technical electives	....	....	3
Nontechnical electives	....	3	3
Total credits	17	16	17

Spring Field Trip

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

Fifth Year

	Credits—f, w, s		
PetE 144-145—Advanced Petroleum Engineering	....	2	4
PetE 152-153-154—Petroleum Production Technology	3	3	3
MinE 131—Rock Mechanics I	3	....	....
MinE 141—Mineral Economics	3	....	....
CE 37—Elementary Structural Engineering	3	....	....
Engl 85-86—Advanced Technical Communication	3	3	....
GPhy 110—Introduction to Exploration Geophysics	....	....	3
ME 24—Elements of Machine Design	....	3	....
Met 56—Physical Metallurgy	....	....	3
Nontechnical electives	3	4	....
Total credits	18	15	13

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

IT: CE 19; GE 101; GPhy 108; IE 153, 173, 180; ITM 90; ME 32, 134, 150, 198; Phys 107-109-111, 114

BA: Econ 1T, 2T; BA 55A, 55B

SLA: Ast 51; Geol 106, 107, 131, 151

SCHOOL OF ARCHITECTURE

The School of Architecture offers three curriculums:

Five-Year Curriculum—Leads to the degree of bachelor of architecture, B.Arch. It normally requires 1 year of prearchitectural work followed by 4 years in the School of Architecture. It is intended for students who expect to enter the practice of architecture in any of its recognized phases. When supplemented by practical experience, it qualifies graduates for admission to registration examinations according to the laws of the various states.

Four-Year Curriculum—Leads to the degree of bachelor of arts, B.A., in the College of Science, Literature, and the Arts with a major in architecture. It normally requires 2 years of prerequisite work in the Lower Division. Two additional years in the Upper Division are normally required to complete the major sequence offered by the School of Architecture. It is intended for students who wish to combine some study of architecture with their general education. This curriculum does not in itself constitute terminal professional training. It does, however, provide an advantageous approach to professional training in specialized fields of architecture, city planning, landscape architecture, and decorative, industrial, or interior design. With appropriate modifications, it provides the first 4 years' work of the 6-year curriculum described below. For further details, see the *Bulletin of the College of Science, Literature, and the Arts.*

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

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

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

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

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

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

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

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

facilities of the School of Architecture. Prospective students are urged to consult advisers in the School of Architecture, 310 Main Engineering building.

FIVE-YEAR CURRICULUM

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

A certain amount of specialization in various phases of architectural design and practice may be accomplished by means of optional problems or course substitutions in Arch 121-122 and by choice of thesis subject in Arch 123.

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

In addition to the prescribed courses, sufficient approved electives must be taken to make a minimum total of 237 credits. The specific requirements are listed in the following program. This program is typical for students who have completed high school with acceptable credits in higher algebra, solid geometry, and preparatory English, and who maintain a normal rate of progress after admission to the University and the School of Architecture.

First Year

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

ITM 8, Solid Geometry, 0 credits, must be taken before EG 14 if solid geometry is not presented as an entrance unit.

ITM 9, Higher Algebra, 0 credits, or equivalent, must be taken before ITM 11 if higher algebra is not presented as an entrance unit.

English classification category 1 or 2 is prerequisite for Engl A-B-C and Engl 1A-2A-3A. A category of 1, 2, or 3 is prerequisite for Engl 1B-2B-3B. A student classified exempt from Freshman English by the Department of English will be required to complete a total of 12 credits in the field of language and/or literature.

The first year of prearchitectural work may also be taken in the College of Science, Literature, and the Arts. This work should include Freshman English, Math 10 (College Algebra), Math T (Trigonometry), Math C (Trigonometric Computation), Math 40 (Mathematical Analysis I) and Phys 1-2-3, 1A-2A-3A and should total a minimum of 45 credits. In choosing electives, preference should be given to history, economics, political science, sociology, and foreign language.

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

Second Year

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

Third Year

	Credits—f, w, s		
Arch 71-72-73—Building Technology	4	4	4
Arch 91-92-93—Architectural Design II	6	6	6
Art 60A-61A-62A—Drawing and Painting II	2	2	2
CE 38-39-41—Structural Design in Steel, Steel and Timber, Concrete	3	3	3
Approved electives	3	....	....
Total credits	18	15	15

Fourth Year

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

Fifth Year

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

FOUR-YEAR CURRICULUM

First and Second Years

The first- and second-year work is taken in the Lower Division of the College of Science, Literature, and the Arts as outlined in its bulletin. The following requirements must be included for admission to the major in architecture in the Upper Division: High school or college equivalents of higher algebra, solid geometry, Phys 1, 2, 3, 1A, 2A, 3A, Art 23A, 24A, 25A.

Third and Fourth Years

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

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

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

SIX-YEAR CURRICULUM

First and Second Years

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

architecture in the Upper Division and completion of the professional work in the last 2 years:

		Credits—f, w, s	
Math 10—College Algebra	5	.....	.....
Math T—Trigonometry	.....	3	.....
Math C—Trigonometric Computation	.....	2	.....
Math 40—Mathematical Analysis 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 Science, Literature, and the Arts as a major in architecture. The following courses should be included:

		Credits—f, w, s	
Arch 51-52-53—History of Architecture	4	4	4
Arch 81-82-83—Architectural Design I	6	6	6
Arch 91-92-93—Architectural Design II	6	6	6
Art 60A-61A-62A—Drawing and Painting II	2	2	2
Math 53—Mathematical Analysis II	5	.....	.....
MM 92, 93—Statics; Solid Mechanics for Architects	.....	4	4
Approved electives to make minimum 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 Science, Literature, and the 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 71-72-73—Building Technology	4	4	4
Arch 74-75-76—Building Technology	4	4	4
Arch 104—Planning	3	.....	.....
Arch 111-112-113—Architectural Design III	8	8	8
Arch 121-122—Architectural Design IV	9	9	.....
Arch 123—Thesis	.....	.....	12
Arch 126—Professional Relations	.....	3	.....
CE 38, 39, 41—Structural Design	3	3	3
Approved electives to make minimum total of 282 credits for the 2 degrees.			

SCHOOL OF CHEMISTRY

Three undergraduate curriculums are offered through the School of Chemistry: a 4-year program in chemistry, a 5-year program in chemical engineering, and a 5-year program in metallurgy. Each program is discussed separately below.

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 205 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	
InCh 24-25-26—Introduction to Chemical Principles	5	5	5
ITM 11, 12, 13A—College Algebra and Trigonometry I, II; Calculus I: Analytic Geometry and Calculus	5	5	5
Engl A-B-C—Freshman Literature and Composition	5	5	5
Electives		3	3
Total credits	15	18	18

ITM 9, Higher Algebra, 0 credits, to be taken before ITM 11 if higher algebra is not presented as an entrance unit.

ITM 8, Solid Geometry, 0 credits, to be taken before ITM 13A if solid geometry is not presented as an entrance unit.

Other Freshman English may be substituted at the discretion of the Department of English. If the total Freshman English taken is less than 15 credits, the difference should be added to the 32 credits of nonscientific electives specified below. Students who at any time are classified exempt from Freshman English by action of the Department of English will be required to complete an additional 15 credits of nonscientific electives.

Second Year

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

UPPER DIVISION

Third Year

	Credits—f, w, s		
AnCh 51-52—Quantitative Analysis	....	2	2
AnCh 53-54—Quantitative Analysis Laboratory	....	3	3
OrCh 102—Organic Qualitative Analysis	4	....	....
PCh 101, 102, 103—Physical Chemistry	4	4	4
Ger 50-51-52—Reading German	3	3	3
Electives	6	6	6
Total credits	17	18	18

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 127—Theoretical and Practical Fundamentals of Instrumental Methods	3	....	....
AnCh 132—Electrometric Measurements and Titrations	....	2	....
AnCh 141—Instrumental Methods in Analytical Chemistry	....	1	....
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	17	17

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

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

Of the 22 science elective credits, 6 must be in one of the sequences of Group I of the nontechnical requirements (see Index for "Nontechnical Required Courses"). Sixteen more credits may be chosen from the following list:

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

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

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

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, B.S., without professional designation, if they enter the Graduate School at the beginning of the fifth year.

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

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

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

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

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

LOWER DIVISION

First Year

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

Students will be placed in the proper English course after taking the English placement test. Students who do well will be exempted from Freshman English. 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 and/or literature.

Second Year

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

UPPER DIVISION

Third Year

		Credits—f, w, s		
ChEn 100—Chemical Engineering Stoichiometry	3	....	....	
ChEn 101-102-103—Principles of Chemical Engineering	5	5	3	
ChEn 119-120—Chemical Engineering Thermodynamics	....	3	3	
AnCh 51-52—Quantitative Analysis	....	2	2	
AnCh 58—Quantitative Analysis Laboratory	....	....	3	
PCh 101-102-103—Physical Chemistry	4	4	4	
Electives (consult adviser)	3	3	3	
Total credits	15	17	18	

Students who choose the Biochemical Engineering Option should take Bact 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	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	
Nontech. Req.—Group III (see Index for "Nontechnical Required Courses")	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 Bact 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	3
ChEn 171-172—Process Control	3	3	3	
EE 51—Electrical Engineering	5	....	....	
EE 52—Electrical Engineering Laboratory	1	....	....	
EE 52A—Electrical Engineering Problem Solving Laboratory	1	....	....	
EE 57-59—Engineering Electronics	....	3	3	
EE 58-60—Engineering Electronics Laboratory	....	1	1	
Engl 85-86—Advanced Technical Communication	....	3	3	
Met 60—Physical Metallurgy	....	....	3	
Met 161—Corrosion of Metals	....	....	2	
Electives	3	3	3	
Total credits	16	16	18	

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

Metallurgy

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

A total of 249 credits is required for graduation.

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

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

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

The recent technological advances in such fields as nuclear energy, jet propulsion, and rocketry have created demands for materials with properties heretofore not available. To meet this demand, metallurgists are constantly

engaged in research on the nature and properties of metals in order to develop suitable alloys.

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

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

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

LOWER DIVISION

First Year

See first-year curriculum for the College of Engineering.

Second Year

See second-year curriculum for the College of Engineering.

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

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

UPPER DIVISION

Before the beginning of the third year, it is recommended students obtain departmental approval of their complete elective program. Recommended technical electives are listed below. Others may be taken with department approval.

Third Year

		Credits—f, w, s	
PCh 101-102-103—Physical Chemistry	4	4	4
Met 53, 154, 155—Principles of Physical Metallurgy I, II, III	3	3	3
Met 53A, 154A, 155A—Laboratory in Physical Metallurgy	2	2	2
MM 27, 40, 28—Rigid-Body Mechanics I; Deformable-Body Mechanics I; Rigid-Body Mechanics II	3	3	3
MM 142—Experimental Mechanics	.....	.....	2
AnCh 57—Quantitative Analysis	4	.....	.....
Nontech. Req. (see Index for "Nontechnical Required Courses")	.....	3-4	3-4
Total credits	16	15-16	17-18

Fourth Year

		Credits—f, w, s	
Met 180-181-182—Thermodynamics of Alloys and Solid State Reactions	3	3	3
MetE 106, 107, 108—Principles of Process Metallurgy	3	3-4	3-4
Technical electives	6	6	6
Nontech. Req. (see Index for "Nontechnical Required Courses")	3	3	3
Total credits	15	15-16	15-16

Field Trip

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

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

Fifth Year

	Credits—f, w, s		
Met 173, 174, 175—Crystalline Properties of Metals; Modern Theory of Metals and Alloys; Imperfections in Metals	3	3	3
EE 36-37-38—Elements of Electrical Engineering	3	3	3
Engl 85-86—Advanced Technical Communication	3	3	....
Technical electives	6	6	6
Nontech. Req. (see Index for "Nontechnical Required Courses")	3	3	3
Total credits	18	18	15

Recommended technical electives:

ChEn 161-162-163; OrCh 16, 61-62, 63; PCh 104, 109, 116, 117, 118; GE 101, 103; EE 37A-38A; ITM 142-143; Met 57, 158, 161, 162, 165, 170-171-172; MetE 11, 134, 135, 136, 138, 141-142-143; Phys 107-109-111, 126-127-128.

SCHOOL OF PHYSICS

A 4-year curriculum is offered which leads to the degree bachelor of physics, B.Phys. The School of Physics reserves the right to limit the registration in the programs of its Lower and Upper Divisions to those students who give evidence of being able to profit from it.

The course sequences are intended to be sufficiently broad in scope to provide for the needs of those who desire to prepare for the industrial and governmental research fields as well as those intending to pursue their study of physics in graduate school. In addition to the following prescribed courses, sufficient approved electives must be taken to complete a total of 200 credits, including not less than 24 credits of the "Nontechnical Required Courses." The course outline which follows may be modified upon petition.

It is evident that a student having as an eventual objective a research career in the industrial or governmental laboratories or a teaching and/or research career in a university must attain an adequate background in mathematics. The program which follows is intended to be flexible enough to satisfy the special aptitudes and desires of the individual student while at the same time providing a strong background in fundamentals for everyone. A careful choice of the allowed electives and options should satisfy these special interests.

LOWER DIVISION

First Year

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

Electives may be selected from courses in the nontechnical group (see Index for "Nontechnical Required Courses"); or, EG 15, 16 may be substituted as technical electives. Students who are uncertain whether to major in physics or engineering should keep in mind that the College of Engineering requires EG 14-15-16.

A minimum of 12 credits in Freshman English is required. Students who at any time are classified exempt from any part of Freshman English by action of the Department of English will be required to complete a minimum of 12 credits in the area of language and/or literature.

Second Year

	Credits—f, w, s		
Phys 14, 50, 51—Intermediate General Physics	4	4	4
Phys 14A, 50A, 51A—Physics Laboratory	1	1	1
InCh 14-15—Inorganic Chemistry	4	4	....
OrCh 16—Carbon Compounds	....	....	4
ITM 24A, 25A, 26A—Calculus II, III: Analytic Geometry and Calculus; Calculus IV: Differential Equations and Calculus	5	5	5
Nontech. Req. (see Index for "Nontechnical Required Courses")	3-4	3-4	3-4
Total credits	17-18	17-18	17-18

For students who decide to transfer from the School of Chemistry to the College of Engineering or School of Physics, Phys 7-8-9 is considered the equivalent of Phys 11-12-13, 14 as prerequisites for more advanced courses.

UPPER DIVISION

Third Year

	Credits—f, w, s		
Phys 100-102-104—Mechanics and Electromagnetism	4	4	4
Phys 144—Electrical Measurements	4	....	....
Phys 146—Physics of Vacuum Tubes and Associated Circuits	....	4	....
Phys 148—Application of Electronic Circuits (or) Phys 133, 133A—Physical Optics and Physical Optics Laboratory	....	....	4
ITM 151A, 152, 153—Calculus V: Intermediate Calculus; Calculus VI, VII: Advanced Calculus	3	3	3
Technical electives (see statement below fourth-year program)	3-4	3-4	3-4
Nontech. Req. (see Index for "Nontechnical Required Courses")	3	3	3
Total credits	17-18	17-18	17-18

Fourth Year

	Credits—f, w, s		
Phys 107-109-111—Modern Physics (or) Phys 108-110-112—Principles of Atomic and Nuclear Physics	3	3	3
Phys 123-124-125—Thermodynamics, Statistical Mechanics, and Theories of the Structure of Matter	3	3	3
Advanced laboratory—Phys 120, plus other courses selected from Phys 121, 122, 134, 136 or technical electives (see statement below)	3	3	3
Ger 50-51-52—Reading German for Juniors and Seniors	3	3	3
Nontech. Req. (see Index for "Nontechnical Required Courses")	3-4	3-4	3-4
Total credits	15-16	15-16	15-16

Two quarters of advanced laboratory courses are required. Phys 120 is a required course; not more than 1 course in optics laboratory may be used to meet the requirement. For technical electives, see below. With the consent of the student's adviser, Ger 1-2-3 or Russ 1-2-3 may be substituted for Ger 50-51-52.

Technical Electives—The following courses may be used as technical electives in the third or fourth years:

PCh 101-102-103; EE 143-144-145, 153-154-155, 157-158-159, 164-165-166, 167-168-169, 187-188-189, 194-195-196 (any 9 credit hours); ITM 132, 133-134, 133B-134B, 142-143, 147, 148, 149, 155-156, 164-165-166, 169, 173, 174, 175 (any 9 credit hours); Math 121-122-123, 131A, 131B, 157-158-159, 170-171-172 (any 9 credit hours); Phys 126-127-128, 131, 191-192-193; ChEn 161-162-163

NONTECHNICAL REQUIRED COURSES**

(Social-Humanistic Area)

1. College of Engineering—School of Mines and Metallurgy—Metallurgy Department (Chemistry)—School of Physics

To complete the requirements in this area the student should elect credits as indicated in each of the 3 groups outlined below, plus enough credits from the recommended elective subjects to total 28 credit hours. These credits, in addition to the 18 credits of English (12 credits of Freshman English and the 6 credits of Engl 85, 86) comprise the group of nontechnical credits required for the Bachelor's degree (5-year program). For a 4-year curriculum, the student should elect credits as indicated below, plus enough credits from the elective subjects to total 25 credits in addition to the 12 credits of Freshman English. Students who are at any time exempt from any part of the 12-credit requirement in Freshman English must select additional courses in the area of language and/or literature to complete the 12 credits.

Group I—Minimum of 6 credits from any one sequence

1. Bot 1-2-3
2. Psy 1-2, 155
3. Zool 1-2-3

Group II—Minimum of 6 credits from any one sequence

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

Group III—Minimum of 6 credits from any one sequence

1. Hum 51, 52, 53 or 21, 22, 23 or 71, 72, 73
2. Hist 20, 21, 22 or 79, 80, 81
3. Philosophy
4. Engl 37, 38, 39
5. Religion
6. Foreign language (see below)

The foreign language requirement cannot be satisfied by courses designed to meet technical needs of a particular scientific area; specifically, Ger 24-25-26 and 27-28-29 will not be accepted.

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

** Students who *complete* the program in NROTC may substitute 24 credits in naval science for an equivalent number of credits in the required nontechnical area. At least 6 credits must be taken within a sequence in 1 of the above 3 groups. The remainder of NROTC credits may be used as electives only if approved by the student's adviser and department head. Students who complete the program in Air ROTC or ROTC may substitute 15 credits in air or military science for an equivalent number of credits in the required nontechnical area. At least 15 credits in the required nontechnical area must be completed, including 6 credits or more within a sequence in 2 of the above 3 groups. The remainder of the ROTC credits may be used as electives only if approved by the student's adviser and department head. The ROTC program applies to all divisions of the Institute of Technology.

Section A. If the total number of credits completed from the 3 groups above is less than 28, sufficient credits must be taken to make up the balance from the following departments:

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

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

2. School of Architecture

See Architecture curriculum.

3. Chemical Engineering

See Chemical Engineering curriculum.

4. Chemistry

See Chemistry curriculum.

ADDITIONAL COURSE INFORMATION

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

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

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

1. 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.
2. Correspondence Study Courses:

   CE 146; EG 14, 15, 16; Engl 1B-2B-3B; GE 70; ITM 8, 9, 11, 12, 13A, 24A, 25A, 26A; MM 27, 28, 29, 40, 41, 127, 128; Nontechnical Required Courses (Social-Humanistic Area).

3. Evening Courses:

   InCh 4, 5, 11; AnCh 51, 52, 53, 54, 123; CE 18, 19, 20, 31, 32, 33, 130, 131, 132, 160; Hydr 103; EG 14, 15, 16; Engl 1B-2B-3B, 85-86; ITM 8, 9, 11, 12, 13A, 24A, 25A, 26A, 90; MM 27, 28, 29, 40, 41, 127, 128; Phys 11, 12, 13, 14; Nontechnical Required Courses (Social-Humanistic Area).

Engineering Aide—The Extension Division offers both Basic and Senior Engineering Aide Certificates. For description of these programs, see the *Bulletin of Evening Classes.*

III. COURSE DESCRIPTIONS

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

Aeronautical Engineering

Aeronautical Engineering (Aero)

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

20-21-22. Flying: Theory and Practice. Consists of 12 hours of ground instructions and 10 hours of flying. (2 cr per qtr; 1 lect hr and about 1 flying hr per wk; lab fee by ar) Staloch

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

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

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

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

103-104-105. Dynamic Stability and Control in Flight. Dynamics of rigid-body flight. Methods of solution. Longitudinal and lateral stability. Flap control. Measurements of aerodynamic derivatives. (3 cr per qtr; prereq 108 [or 102 in former curriculum]; 3 lect hrs per wk)

106A. Applied Aerodynamics I. Standard atmosphere and outer atmosphere. Aerodynamic characteristics of subsonic, transonic, supersonic, and hypersonic airfoils. Thin wing and body. Wing theory. Diffusers. Nozzles and jets. Interference effects of body, wing and tail planes. Subsonic and supersonic propellers. Nonsteady wing characteristics. (3 cr; prereq 102A; 3 rec hrs per wk)

107. Aerodynamics of Viscous Fluids. Viscosity effects in fluid flows. Navier-Stokes' equation. Laminar boundary layer theory. Application of boundary layer theory to aerodynamic design problems. (3 cr; prereq 102; 3 lect hrs per wk)

107A. Applied Aerodynamics II. Dynamic equations of aircraft and missiles. Power required and power available for different propulsion systems including effects of altitude and Mach numbers. Ceiling, climb, take-off, landing, range, and endurance. (3 cr; prereq 106A; 3 rec hrs per wk)

108. Applied Aerodynamics III. Static longitudinal stability and control. Maneuvering flight. Lateral and directional stability and control. Dihedral effect and power effects. Tail efficiency and aileron reversal. (3 cr; prereq 107A; 3 lect hrs per wk)

110. Compressible Viscous Flow. Navier-Stokes' equation of compressible viscous fluid. Energy equation. Dynamic and thermodynamic similarity. Thermal and velocity boundary layer equations. Karman-Tsien solution. Momentum and

energy integrals. Turbulent boundary layer. Shock wave boundary layer interaction. (3 cr; prereq 102A; 3 lect hrs per wk)

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

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

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

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

130A-131A-132A. Aero-Space System Design. Aerodynamics, performance, static stability and stress analysis related to a selected type of aero-space system. (4 cr per qtr; prereq ¶108 and ¶115A [in former curriculum fifth year status]; 2 lect and 4 lab hrs per wk)

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

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

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

150. Aeroelasticity I. 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. Flutter problems of rotary wing aircraft. (3 cr; prereq 107 or 102 and MM 193)

158. Physics of Atmosphere. Composition and thermal structure of the atmosphere, and physical processes involved in its determination. Relationship between the fields of pressure, temperature, and wind in the atmosphere. Composition and density of atmosphere at its outer boundaries. (3 cr; prereq ME 30 or Phys 51; 3 rec hrs per wk) Mantis

159. Aerodynamic Retardation. Aerodynamic, dynamic, and performance characteristics of principal retardation devices. Trajectory calculations. Interference effects. Similarity requirements. Retardation and recovery systems. (3 cr; prereq 107 or 102 or *)

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

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

173. Meteorology I. Survey of meteorological phenomena and physical principle. Thermo-dynamics. Equations for simple atmospheric motions. (3 cr; prereq 158; 3 rec hrs per wk) Mantis

174. Meteorology II. Weather analysis and interpreting of weather charts. (3 cr; prereq 173; 2 lect and 4 lab hrs per wk) Mantis

175. Meteorology III. Physical meteorology. Atmosphere stability. Heat balance. Equations of atmosphere hydrodynamics. Cyclones and anticyclones. (3 cr; prereq 173; 3 rec hrs per wk) Mantis

180. Flight Trajectory in Atmosphere and Space. Mechanical and aerodynamic forces on rocket. Dynamic equations of flight. Simplified vertical trajectory. Performance and trajectory of single- and multi-stage rocket. Optimization

in trajectory and orbit altitude. Trajectory of re-entering body into atmosphere. Satellite orbits. Lunar flight. Interplanetary operations. (3 cr; prereq 102A or ♯; 3 lect hrs per wk)

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

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

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

For Graduate Students Only

201-202-203. Aerodynamics of Compressible Fluid. Chang.

204. Supersonic Aerodynamics Laboratory

205-206-207. Boundary Layer Theory.

208. Aerodynamics of Compressible Viscous Fluid. Chang

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

220.* Introduction to Astronautics. Hermann

230. Aerodynamics of Supersonic Inlet Diffusers. Hermann

231-232.* Aerodynamics and Flight Performance of Supersonic Missiles. Hermann

238. Joint Seminar (AeroE, ITM)

240-241.* Dynamics of Aircraft Structures. Graves

272-273-274.* Research in Aeronautical Engineering

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; this course may be substituted for 92)

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

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

40. Deformable-Body Mechanics I. Stress and strain. Applications to tension and torsion members, beams, columns, and joints. Design considerations. Statically indeterminate members. (3 cr; prereq 27; 3 rec hrs per wk; this course may be substituted for 93)

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

92. Statics. (Architects and Combined Engineering-Business) Resolution of force systems. Equilibrium of rigid bodies and analysis of framed structures. Centroids and moments of inertia. (4 cr; prereq ITM 24A or 91; 4 rec hrs per wk; 27 may be substituted for 92)

93. Solid Mechanics for Architects. Introduction to static strength properties of structural materials. Stress and strain. Applications to tension and torsion members, beams, columns, and joints. Design considerations. Material testing. (4 cr; prereq 92; 3 rec and 2 lab hrs per wk; 40 may be substituted for 93)

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

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

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

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

180. Introduction to the Theory of Elasticity. General analysis of stress and strain in 2 and 3 dimensions. Interpretation of strain rosette measurements. Elasticity of metal crystals. Castigliano's theorems and Maxwell's reciprocal relationships. Energy methods in stress analysis. (3 cr; prereq 40 and ITM 149 or equiv)

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

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

193. Introduction to the Theory of Mechanical Vibrations. Dynamic response and natural frequencies of lumped-parameter systems. Transient and steady-state behavior of linear systems having single degree of freedom. Influence of damping. Vibration isolation. Lagrange's equations with application to forced and free vibrations of systems with several degrees of freedom. (3 cr; prereq 29, ITM 26 or 26A or 80)

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

199. Thermal Stresses. Analysis of thermal stresses in various types of structures such as aero-space components, pressure vessels, and nuclear reactors. Combined mechanical and thermal stress. Inelastic thermal stresses. (3 cr; prereq 180 and ME 133; 3 lect hr per wk)

For Graduate Students Only

202. Gyroscopic Instruments and Other Applications of Advanced Dynamics.

211*-212.* Theory of Vibrations I and II. Goodman, Sethna

221. Introduction to the Theory of Plasticity. Warner

222-223.* Theory of Plasticity. Warner

227. Introduction to Structural Instability. Mentel

235-236-237.* Theory of Mechanical Behavior of Solids with Application. Lazan

240-241-242.‡ Theory of Viscoelasticity. Hsiao

264-265-266.* Advanced Topics on Mechanics and Materials

290. Theory of Plates and Shells. Goodman

295-296.* Theory of Elasticity with Engineering Applications. Goodman, Warner, Robinson

297-298-299.* Mechanics and Materials Seminar

Agricultural Engineering (AgEn)

(College of Agriculture, Forestry, and Home Economics)

8. Laboratory. Engineering units and measurements. (1 cr; 2 lab hrs per wk)

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

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

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

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

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

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

125. Topics in Agricultural Physics. An advanced study of the essential physical principles involved in the utilization of electricity in agriculture. (3 cr; prereq 4th yr, EE 37 or integral calculus and 25 or equiv) Hustrulid

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

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

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

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

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

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

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

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

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

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

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

180. Agricultural Hydrology and Flood Control. Runoff measurements and estimation of runoff by statistical and analytical methods. Hydrograph analysis. Water storage, detention, and flood routing. Floods, flood damages, and flood control in agricultural areas. (3 cr; prereq 142 or ¶142; 3 lect hrs per wk; offered 1959-60 and alt yrs) 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. (4 cr; prereq 141, 142, 143 or ¶143; 2 lect and 6 lab hrs per wk; offered 1959-60 and alt yrs) 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. Survey of the adaptation, distribution, uses of major groups of economic plants and the factors and hazards of their production. (3 cr)

21. Grain and Oil Seed Crops. Production, improvement, and uses of corn, small grains, and oilseed crops. Lectures and laboratory. (4 cr; prereq 1; grad students may take 121)

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 aca-

demic 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.*

31-32-33. Air Science I: Foundations of Air Power. A general survey of air power designed to provide the student with an understanding of the elements and potentials of air power. Includes fundamentals of air power; military air powers of the world; military research and development; air vehicle industries; airlines and airways; aeronautical science; general aviation; elements of an aircraft; aerodynamics; guidance, control, and navigation and propulsion systems; space flight; military instruments of national security; and professional opportunities in the United States Air Force. (1 cr per qtr)

34-35-36. Air Science II: Foundations of Air Power. A survey of the development of aerial warfare with emphasis on principles of war; concepts of employment of forces; changing weapons systems; treatment of aerial warfare including targets, weapons, aircraft, and missiles; bases and facilities; and aerial operations. (1 cr per qtr; prereq 31-32-33)

131-132-133. Air Science III: Air Force Officer Development. Knowledge and skills required of a junior staff officer in the Air Force. Includes staff organization and functions; communicating; instructing; problem solving techniques as applied to Air Force staff and command problems; basic principles of leadership psychology; problems in leadership and management; application of the principles and theories of problem solving and leadership to simulated and real Air Force problems and the Military Justice System. (3 cr per qtr; prereq 34-35-36)

134. Air Science IV: Weather and Navigation. Weather and navigational aspects of airmanship, such as temperature, pressure, air masses, precipitation, weather charts, navigational charts and dead reckoning navigation; globes and maps in the air age world, and the geography of climate. Also includes military aspects of world political geography; factors of power; and geographic influences upon political problems with a geopolitical analysis of the strategic areas. (3 cr; prereq 133)

135-136. Air Science IV: International Relations and the Air Force Officer. Major factors underlying international tensions—nationalism, imperialism, and communism; the attempts to alleviate these tensions; balance of power concepts, the League of Nations, the United Nations and the regional security organizations; and the rise of the two super-powers—the United States and the USSR. Also, time is devoted to the study of material to help the cadet make a rapid effective adjustment to active duty as an officer in the United States Air Force. (3 cr per qtr; prereq 134)

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)

11-12-13. Architectural Drawing. Drafting techniques, orthographic, isometric, oblique and perspective projections; design sketching, architectural conventions, intersections, developments, shades and shadows, architectural lettering. (2 cr per qtr; 6 lect and lab hrs per wk)

51-52-53. History of Architecture. Significant architecture of the past, with particular reference to the geographic, social, and technical influences which produced it. (4 cr per qtr; prereq 2nd yr for IT students or 3rd yr for SLA students; 4 lect hrs per wk)

71-72-73. Building Technology. (Formerly Arch 57-58-59) Principles, techniques, materials, and equipment involved in building. (4 cr per qtr, §57-58-59; 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 71-72-73 or equiv; 4 lect hrs per wk)

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

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

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

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

105. Seminar in Planning. (3 cr; prereq 104; 3 seminar hrs per wk)

106. Planning. Technical phases of modern city planning with special reference to the architect's function therein. (3 cr; prereq 104 or Econ 110 or Pol 123 or Soc 106; 3 conf hrs per wk)

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

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

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

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

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

For Graduate Students Only

201.* Special Research in Architectural History

231-232-233.* Planning

251-252-253.* Architectural Design VI

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

Astronomy (Ast)

(College of Science, Literature, and the Arts)

20. Astronomy for Celestial Navigation. The principles and the practice of navigation of planes and ships by using the stars in the sky. Some dead-reckoning navigation is included. (5 cr) Luyten

51. General Astronomy. An outline of our knowledge of the planetary system and its motions, including those of the earth and the moon. (3 cr, §11; prereq Math T or ITM 12)

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

101. Celestial Mechanics. (3 cr; prereq Math 59 or ITM 25A; 3 rec hrs per wk) Danby

Bacteriology and Immunology (Bact)

(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 ♯) Johansson, Schmidt, McLaren, Crowell

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, ♯) Lichstein

122. Physiology of Bacteria Laboratory. Techniques employed in the study of bacterial physiology and metabolism. (3 cr; prereq 121, ♯) Lichstein

123. Bacterial Metabolism. Advanced treatment of metabolism; enzymes; biological energy; fermentation; respiration; nitrogen metabolism. (3 cr; prereq 121, 122 or equiv and introductory biochemistry, ♯; offered 1959-60 and alt yrs) Lichstein

Botany (Bot)

(College of Science, Literature, and the Arts)

1-2-3. General Botany. Survey lecture and laboratory course on the form, structure, and functions of plants; reproduction in plants and the principles of inheritance and variation; relation of plants to environment; the principal groups of plants; organic evolution. (10 cr) Hall, Norris

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) Ranz

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)

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

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

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, 6 class 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; prereq PCh 101; 2 lect and 2 rec hrs per wk) Madden

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

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

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

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

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

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

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

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

For Graduate Students Only

201-202-203.‡ Seminar

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

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

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. Amundson, Ceaglske, Isbin, Piret, Ranz, Madden, Preckshot, Tsuchiya, Aris, Dahler

Chemistry

Analytical Chemistry (AnCh)

51-52. Quantitative Analysis. Introductory lecture courses covering the general principles and theoretical foundations of quantitative analysis. 51: Gravimetric analysis. 52: Volumetric analysis. (2 cr per qtr; prereq InCh 26) Meehan

53-54. Quantitative Analysis Laboratory. Introductory courses covering the methods of quantitative analysis. 53: Gravimetric analysis. 54: Volumetric analysis. (3 cr per qtr; prereq 51 or ¶51 for 53, 52 or ¶52 for 54) Meehan

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; prereq InCh 11 or 26) Meehan, Herr

58. Quantitative Analysis. Laboratory course for chemical engineers. (3 cr; prereq 52 or ¶52)

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

101-102.‡ Quantitative Analysis. General principles, methods, and procedure of quantitative analysis, both gravimetric and volumetric. Typical problems are assigned and attention given to proper laboratory practice. (5 cr per qtr; prereq InCh 26; 1 lect, 1 rec, 1 quiz, and 9 lab hrs per wk) Meehan

103. Quantitative Inorganic Microanalysis. Representative methods of micro- and semi-microanalysis; gravimetric, volumetric, and colorimetric. (3 cr; limited to 16 students; prereq 51, 52, 53, 54; 1 lect and 6 lab hrs per wk) 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 51, 52, 53, 54; 1 lect and 6 lab hrs per wk) Sandell

105. Polarizing Microscope. Its use and application to chemistry. Identification of substances. (3 cr; limited to 16 students; prereq PCh 101; 1 lect hr and lab hrs ar per wk; this course may be substituted for AnCh 132) 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 51, 52, 53, 54; 1 lect hr and lab hrs ar per wk) Sandell

109. Rock Analysis. Laboratory course covering the technique of rock analysis. (3 cr; prereq 51, 52, 53, 54 and #) Goldich

122. Advanced Analytical Chemistry. Condensed review of modern fundamentals of gravimetric and volumetric analysis. (2 cr; prereq 51, 52, 53, 54; 2 lect hrs per wk) Meehan

123.* Advanced Analytical Chemistry. Analysis of complex materials by modern methods. (3 cr; prereq 51, 52, 53, 54 or #; 1 lect and 6 lab hrs per wk) Meehan

127-128.*‡ Theoretical and Practical Fundamentals of Instrumental Methods. (3 cr per qtr; prereq PCh 103; 3 lect hrs per wk) Meehan and staff

131. Applications of Indicators in Neutralization Reactions and pH Determinations. (2 cr without lab, 3 cr with lab; prereq 51, 52, 53, 54 and PCh 103; 2 lect and 3 lab hrs per wk) Bruckenstein

132. Electrometric Measurements and Titrations. Applications of potentiometric and conductometric methods in analytical work. (2 cr without lab, 3 cr with lab; prereq 51, 52, 53, 54 and PCh 103; 2 lect and 3 lab hrs per wk; 105 may be substituted for 132) Kolthoff, Bruckenstein

133.* Voltammetry and Amperometric Titrations. A lecture course. Use of the dropping mercury electrode (polarograph) and the platinum microelectrode in pure and applied chemistry. (2 cr; prereq 51, 52, 53, 54 and PCh 103; 2 lect hrs per wk) Kolthoff, Bruckenstein

134.* Voltammetry and Amperometric Titrations. A laboratory course. (2 cr; prereq 133 or ¶133; 6 lab hrs per wk) Bruckenstein

135-136-137.*‡ Seminar: Modern Problems in Analytical Chemistry. (1 cr per qtr; prereq 51, 52, 53, 54 and PCh 103; 1 lect hr per wk) Kolthoff

138. Advanced Volumetric Analysis. (3 cr; prereq 131; 2 lect hrs and lab hrs ar per wk) Kolthoff

140. Water Analysis. Analysis of potable water with interpretation of results. (2 cr; prereq 51, 52, 53, 54) Sandell

141. Instrumental Methods in Analytical Chemistry. Laboratory course. Quantitative applications of electrochemical, optical, and other instrumental techniques of analysis. (1-3 cr; prereq sr or grad, 127) Bruckenstein

For Graduate Students Only

201-202-203.*‡ Selected Topics in Analytical Chemistry. Kolthoff

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

262. General Survey of Analytical Chemistry. Kolthoff, Meehan, Sandell, Bruckenstein

301-302-303.*‡ Research in Quantitative Analysis. Kolthoff, Meehan, Sandell, Bruckenstein

Inorganic Chemistry (InCh)

4-5.† General Inorganic Chemistry. An introduction to chemistry from the standpoint of atomic structure; periodic properties of the elements and compounds derivable from structural considerations; a study of the laws governing the behavior of matter, theories of solutions, acids, bases, and equilibrium. (5 cr per qtr; prereq a first course in high school algebra; 3 lect, 1 quiz, 1 rec, and 3 lab hrs per wk) Brasted and staff

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

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

24-25†-26. Introduction to Chemical Principles. The lecture material deals primarily with the basic theories of chemistry: atomic structure, kinetic theory, chemical stoichiometry, the chemical bond, oxidation-reduction, solution theory, chemical equilibrium. Examples are drawn from all fields of chemistry. A considerable portion of the laboratory program involves qualitative analysis, including cation and anion analysis. (5 cr per qtr; no prereq; 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

50-51. Modern Chemistry. A nonmathematical study of modern chemistry. For juniors and seniors who have not had college chemistry. (3 cr per qtr; prereq jr or #; 3 lect hrs per wk) Bent and staff

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

103.* Atomic Structure and the Properties of the Elements Based Thereon. A systematic treatment of the 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) Hugus, Reynolds

104.* Chemistry of the More Representative Elements. A detailed discussion of the preparation, reactions, and chemical properties of the regular group elements and their compounds. (3 cr for undergrad, 4 cr for grad; prereq 103 or #; 3 lect hrs per wk) Brasted, Britton

105.* Co-ordination Compounds. A systematic study of the nature of complex ions, their preparation, bond structure, and isomerism (including kinetics and mechanisms of reaction). A brief consideration of compounds closely allied to the classical co-ordination compounds such as carbonyls, nitroso complexes, porphyrins, and metal-containing dyes. (3 cr; prereq 103 or #; 3 lect hrs per wk) Brasted

106.* Chemistry of the Less Familiar Elements. A detailed discussion of the preparation, reactions, and chemical properties of the elements and their compounds, not previously discussed in 104. Transition elements and inner transition elements are emphasized. (3 cr; prereq 104 or #; 3 lect hrs per wk; offered 1960-61 and alt yrs) Johnson

107.* Oxidation-Reduction Systematics. A discussion of the 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 1960-61 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 1959-60 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 1960-61 and alt yrs) O'Connor

113.* Mechanisms of Inorganic Reactions. A discussion of the prevalent ideas concerning the mechanisms of inorganic oxidation-reduction and substitution reactions. (3 cr; prereq PCh 103; 3 lect hrs per wk; offered 1959-60 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 51, 52, 53, 54 and PCh 103, 105) Hugus, Reynolds, Britton

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

For Graduate Students Only

203. Atomic Structure and the Chemical Bond. Hugus, Reynolds

204. The Chemistry of the Elements Based on Periodic Chart Relationships.

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

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

260. General Survey of Inorganic Chemistry

301-302-303.‡ Research in Inorganic Chemistry

Organic Chemistry (OrCh)

16. Carbon Compounds. (Engineers, except ChemE and MinE) A brief discussion of the carbon compounds, with special emphasis upon those useful as engineering materials, together with the processes by which such compounds are made. (4 cr; prereq InCh 15; 4 lect hrs per wk; this course cannot be substituted for OrCh 61 or 62) Leete

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

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

61-62.† Elementary Organic Chemistry. (Chem, ChemE, Premed, Predent, Pharm) Discussion of important classes of organic compounds, both aliphatic and aromatic together wtih some heterocyclic compounds. Laboratory work includes the preparation of typical substances. (4 cr per qtr; prereq 12-15 cr in chemistry; 3 lect, 1 lab conf, 1 quiz, and 4 lab hrs per wk) Koelsch, Kreevoy, Noland

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

64. Elementary Organic Chemistry Laboratory. (3 cr; prereq 63 or ¶63; 6 lab hrs and 1 conf hr per wk; this course is prerequisite to all advanced courses in organic chemistry) Leete

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

101. Intermediate Organic Chemistry. A survey course in which are considered important modern topics such as unusual types of aliphatic, aromatic, and heterocyclic compounds, natural products, and industrial processes. (3 cr; prereq 63 and 64 or equiv; 3 lect hrs per wk) Lauer

102. Organic Qualitative Analysis. Elementary course. Reactions of typical functional groups and an introduction to the methods of organic qualitative analysis. (4 cr; prereq 63 and 64 or equiv; 1 lect and 6 lab hrs per wk) Leete

106-107.* Advanced Organic Chemistry. Advanced descriptive course covering the field of organic chemistry, together with an introduction to the literature of organic chemistry. Lectures and outside reading. (3 cr per qtr; prereq 63 and 64; 3 lect hrs per wk; offered 1959-60 only) Smith

116.* Heterocyclic Compounds. Discussion of typical classes of heterocyclic compounds, their chemical and physical properties and uses, and the ring closures leading to heterocycles. (3 cr; prereq 63 and 64, 3 lect hrs per wk; offered 1960-61 and alt yrs) Leete

130. Organic Quantitative Analysis. Methods of proximate and ultimate analysis of organic compounds, with special attention to semimicro methods. (3 cr; limited to 15 students; prereq 63 and 64, AnCh 51, 52, 53, 54, and ♯; 1 lect and 6 lab hrs per wk) Lauer

139. Advanced Organic Chemistry Laboratory Work. Selected laboratory problems of an advanced nature, including some original work. Ability to read some German is assumed. (2-5 cr; limited to 20 students; prereq 63 and 64) Noland

140. Advanced Organic Chemistry. Functional group survey, synthesis using primarily aromatic systems; the theory of aromatic substitution. (3 cr; prereq 63 and 64; 3 lect hrs per wk) Fenton

141.* Reagents in Organic Chemistry. Discussion of typical reagents used in organic reactions; their limits of applicability, methods of use, and types of substances with which they react. (3 cr; prereq 63 and 64; 3 lect hrs per wk; offered 1960-61 and alt yrs) Koelsch

142.* The Chemistry of Natural Products. Discussion of the organic chemistry of important classes of natural products. (3 cr; prereq 63 and 64; 3 lect hrs per wk; offered 1959-60 and alt yrs) Leete

163. Intermediate Organic Chemistry. Intermediate course covering the field of organic chemistry. Theory and synthesis. Lectures and outside reading. (3 cr; not open to students who have had 63; prereq 42 or 62; 3 lect hrs per wk) Parham

164.* Advanced Organic Chemistry. Descriptive course covering the field of organic chemistry, together with an introduction to the literature of organic chemistry. Lectures and outside reading. (3 cr per qtr; prereq 163 or equiv; 3 lect hrs per wk; offered 1960-61) Parham

165. Mechanisms of Organic Reactions. A survey of currently accepted mechanisms of polar and free radical reactions, including methods used in the study of reaction mechanisms; introduction to the current electronic formulations of organic reactions. (3 cr; prereq 63 or 163, and either 106, 140 or 164; 3 lect hrs per wk) Noland

For Graduate Students Only

201-202-203.‡ Organic Chemistry Seminar

205.* Stereochemistry. Lauer

206.* Polymerization and High Polymers. Lauer

210. Organic Qualitative Analysis. Koelsch

215. Theoretical Organic Chemistry. Kreevoy

239. Organic Research Techniques. Parham and staff

261. General Survey of Organic Chemistry. Parham

301-302-303.‡ Research in Organic Chemistry

Physical Chemistry (PCh)

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

101-102-103.* Physical Chemistry. General survey of the subject. (4 cr per qtr; prereq 1 yr college chemistry, Phys 7, 8, 9 [or ¶Phys 7, 8, 9 with △], ITM 25A or Math 53; 3 lect and 1 rec hr per wk) Wertz, Livingston

104-105-106. Physical Chemistry Laboratory. (1 or 2 cr per qtr; prereq 101 or ¶101 for 104, 102 or ¶102 for 105, 103 or ¶103 for 106; 1 rec and 5 lab hrs per wk)

107-108.† Elementary Physical Chemistry. (Premed) (3 cr per qtr; prereq 1 yr college chemistry, 1 yr college physics, Math 40; 2 lect, 1 rec, and 3 lab hrs per wk)

109.* Physical Chemistry. Elementary atomic and molecular structure, wave mechanics, nuclear chemistry, photochemistry. (4 cr per qtr; prereq 103; 3 lect and 1 rec hr per wk)

110.* Experimental Research Techniques I. Physical manipulations, including the use of tools and machines as well as a course in glass blowing, with demonstrations and practice by the student. (2 or 3 cr; prereq 103 and ♯; offered 1960-61 and alt yrs) Wertz

111. Experimental Research Techniques II. Materials of research, high vacuum techniques, characteristics of thermionic tubes, rectifiers, amplifiers, oscillators, photocells. (2 or 3 cr; prereq 110; offered 1960-61 and alt yrs) Wertz

112. Advanced Physicochemical Experiments. Precise measurements in various fields such as thermochemistry, conductance, surface tension, magnetic susceptibility, dielectric constant, characteristics of the photographic plate, and ionization potentials of a gas. (2 or 3 cr; prereq 111; offered 1960-61 and alt yrs) Wertz

115. History of Chemistry. Development of the basic concepts of chemistry and the related sciences as they arose in the changing historical periods. (3 cr; prereq 3rd yr; 2 lect hrs per wk with addtl discussion periods) Reyerson

116. Thermodynamics and Chemistry. A detailed study of the principles of thermodynamics and their application to physical and chemical phenomena. (4 cr; prereq 103 and calculus; 3 lect hrs per wk) Mead

117. Fundamentals of Reaction Kinetics. Empirical analysis of rate measurements, collision theory, transition state theory, chain reactions. (3 cr; prereq 103; 3 lect hrs per wk) Crawford

118.* Advanced Physical Chemistry. Methods of determining molecular structure with simple applications. Chemical and physical properties in terms of the nature of chemical bonds. (3 cr; prereq 103; 3 lect hrs per wk)

128.* Colloid Chemistry. The fundamental principles of colloid chemistry, surface chemistry, electrokinetic phenomena, lyophobic and lyophilic colloids. (3 cr; prereq 103; 3 lect hrs per wk) Reyerson

129.* Adsorption and Catalysis. The fundamental principles of adsorption at the different interfaces and the application of these principles to heterogeneous catalysis. (3 cr; prereq 128; 3 lect hrs per wk) Reyerson

130.* Colloids in Industry. The important applications of colloid chemistry to many of the fields of chemical industry. (3 cr; prereq 128; 3 lect hrs per wk; offered 1960-61 and alt yrs) Reyerson

131.* Colloidal Processes. A survey of the important colloidal processes; coagulation, sol-gel transformation, thixotropy, and dilatancy. (3 cr; prereq 128; 3 lect hrs per wk; offered 1959-60 and alt yrs) Reyerson

132-133-134.‡ Colloid Chemistry Laboratory. (1 or 2 cr per qtr; prereq 128 or ¶128) Reyerson

175.* Photochemistry. General survey, including a discussion of spectroscopy, with particular reference to the visible and ultraviolet absorption spectra of molecular gases. (3 cr, §120; prereq 103 and Phys 9; 3 lect hrs per wk; offered 1960-61 and alt yrs) Livingston

For Graduate Students Only

204-205-206. Atomistics. Prager

214. Kinetics and Mechanism of Enzymic Reactions. Lumry

217-218. Thermodynamics and Chemistry. Mead

221-222-223.‡ Colloid Seminar. Reyerson

250-251-252.‡ Physical Chemistry Seminar. Crawford

253-254-255.‡ Seminar in Molecular Spectroscopy. Crawford

259-260-261.‡ Seminar in Chemical Kinetics. Livingston

263. General Survey of Physical Chemistry

265-266-267.‡ Seminar in Magnetochemistry. Wertz

268-269-270.‡ Seminar in Physical Chemistry of Polymers. Prager

271-272-273.‡ Seminar in Physical Chemistry of Biological Systems. Lumry

274-275-276.‡ Seminar in Quantum Mechanics. Mead

290-291-292.‡ Selected Topics in Physical Chemistry. Livingston, Crawford, Lumry, Mead, Prager, Reyerson, Wertz

301-302-303.‡ Research in Physical Chemistry. Livingston, Crawford, Kolthoff, Reyerson, O'Connor, Lumry, Prager, Wertz

Civil Engineering (CE)

General: CE 1, 2, 3, 124, 169, 280-281-282.

Highway Engineering and Soil Mechanics: CE 51-52, 53, 146, 148, 151, 152, 153, 156, 158, 159, 251-252.

Hydraulic Engineering: CE 160, 161, 164, 166, 263.

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

Structural Engineering: CE 31, 32, 33, 34, 37, 38, 39, 41, 130, 131, 132, 136, 137, 140, 141, 142, 143, 144, 147, 233, 234-235, 236, 240-241-242, 243-244, 247-248-249.

Surveying: CE 17, 18, 19, 20, 23, 109, 111, 112.

1-2-3. Civil Engineering Laboratory. Fundamentals of civil engineering practice in the laboratory and field, presented by lectures, laboratory tests, demonstrations, and inspection trips. Problems and reports. (1 cr per qtr; 3 lab hrs per wk; recommended in 2nd yr)

17. 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. Adjustment of traverses, triangulation and level circuits. (3 cr; open to students other than IT; prereq ITM 12 or equiv; 2 lect and 4 lab hrs per wk)

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 12, EG 14; 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 14, 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 40; 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. (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 timber frame buildings. (3 cr; prereq 38; 3 lect hrs per wk)

41. Elementary Structural Design (Concrete). (Arch) Elementary structural analysis and design of reinforced concrete for buildings and foundations. (3 cr; prereq 39; 3 lect hrs per wk)

51-52. Highways and Pavements. Elements of highway planning, economics, location, design, construction, and maintenance. Field trips and laboratory testing of materials. (3 cr per qtr; prereq ¶MM 40; 2 lect and 3 lab hrs per wk) Thomas

53. Elements of Soil Mechanics. Physical properties of soils; soil profiles; stress distribution; shearing strength. Laboratory identification and compaction tests. (3 cr; prereq 52 [no prereq for Min and GeolEng]; 2 lect and 3 lab hrs per wk) Kersten

109. Geodetic Surveying. First-order triangulation, traverse, and level nets. Least squares adjustments of survey nets. Computations and use of state-wide coordinate grids. Geodetic astronomy. (3 cr; prereq 23 or #; 2 lect and 3 lab hrs per wk) Fant

111. Land Surveying. Study of Minnesota Public Land Survey and proper methods of resurveys. Subdivision design and computations. Preparation of standard plats and descriptions. (3 cr; prereq 23 or #; 2 lect and 3 lab hrs per wk) Fant

112. Aerial Surveying and Photogrammetry. Theory and methods of making planimetric and topographic maps from aerial and terrestrial photographs. (3 cr; prereq 23 or #; 2 lect and 3 lab hrs per wk) Fant

124. Railway Engineering. Design, construction, and maintenance of railway roadbed, track, and structures. Economic principles of railway transportation. (3 cr; prereq 23 or #; 2 lect and 3 lab hrs per wk)

130. Statically Indeterminate Structures. Method of moment area. Williot diagram. Slope-deflection method. (3 cr; prereq 33; 2 lect and 2 lab hrs per wk) Andersen

131. Structural Analysis. Moment distribution method. (2 cr; prereq 130; 1 lect and 3 lab hrs per wk) Andersen

132. Structural Design. Continuous structures of steel and concrete. (2 cr; prereq 131; 1 lect and 3 lab hrs per wk) Andersen

136. Advanced Structural Analysis. Wind bracing for buildings. Space structures. Secondary stresses. (3 cr; prereq 132; 3 lect hrs per wk) Graves

137. Structural Laboratory. Theoretical and experimental study of structural members, structural models, and strain gauges. Lectures and demonstrations on photoelasticity and dynamic strain measurements. (3 cr; prereq 141 and ¶131; 2 lect and 3 lab hrs per wk) Graves

140. Advanced Structural Laboratory. Continuation of CE 137. Calculated and experimental influence lines for framed structures including gabled bents. Secondary stresses in trusses. (3 cr; prereq 137; 2 lect and 3 lab hrs per wk)

141. Reinforced Concrete. Principles of reinforced concrete. Design of beams, slabs, columns, and footings. Analysis of continuous beams and rigid frames by moment distribution. (3 cr; prereq 33; 2 lect and 3 lab hrs per wk)

142. Reinforced Concrete Design. Continuation of CE 141. Application of principles of design of complete building frames, footings, and retaining walls. (3 cr; prereq 130, 141; 2 lect and 2 lab hrs per wk)

143. Arch Analysis and Design. Analysis and design of steel and reinforced concrete arches. (3 cr; prereq #; 3 lect hrs per wk) Andersen

144. Prestressed Reinforced Concrete. Principles of design and analysis for pretensioned and posttensioned construction. Methods of prestressing and fabrication. Design of buildings and bridges using prestressed reinforced concrete. (3 cr; prereq 142; 3 lect hrs per wk)

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. Study of the basis for design, design of intersections, street grades, pavement design, plans, and specifications. (3 cr; prereq 52; 2 lect and 3 lab 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

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. Traffic administration. (3 cr; prereq 52; 2 lect and 3 lab hrs per wk) Thomas

158. Airport Design. Field layout, capacity, drainage, lighting, and studies of subbases, 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. Centrifugal pumps, analysis, and problems. Characteristic curves, pump constants, selection, and economic factors. Open channel flow design, hydraulic elements, varied flow computations, losses, irrigation, and drainage problems. (3 cr; prereq Hydr 103 and 104; 2 lect and 3 lab hrs per wk)

161. Hydrology. Sources of basic data, common curves. Precipitation, types, variations, rainfall depth computations, storm rainfall, intensity-duration-frequency. Losses. Groundwater and infiltration. Run-off, characteristics, components, variations, estimating supply, storage. Flood flows, unit graph analysis, flood control. Erosion, transportation, silting. Water use and rights. (3 cr; prereq Hydr 101 or 103; 2 lect and 3 lab hrs per wk)

164. Water Conservation. Weather variations and cycles, variable stream flow and water levels with respect to control in problems of public water supply, sewage disposal, water power, navigation, floods, and low water. National and state water conservation policies with discussion of typical problems. (3 cr; prereq 161 or #)

166. Water Power. Stream flow and water power estimates. Storage problems. Analysis, design, and selection of water power structures and equipment. Types and purposes of dams. Turbine analysis. Transmission lines. Cost and value of water power. Typical problems, inspection trips. (3 cr; recommended for srs in sanitary engineering; prereq 161; 2 lect and 4 lab hrs per wk)

169. Public Works Engineering. An introduction to the engineering phases and relationships of public works. Historical survey. Federal, state, and local administration problems. Present trends and practices. The need for adequate public planning design and construction. 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 Sewage Treatment. Sources and quantities of sewage; sanitary, storm, and combined sewer systems; materials and methods of construction, physical, chemical, and biological characteristics of sewage. 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, sewage, air, coagulant chemicals, disinfectants, sewage sludge, etc. (3 cr; prereq 5th yr or grad; 8 lab hrs per wk) Johnson

173.* Sanitary Engineering Problems (Water). Investigations of problems in water supply. Supplements CE 170. Collection, distribution, and purification. Economic studies. (3 cr; prereq 170; 3 lect hrs per wk) Schroepfer

174.* Sanitary Engineering Problems (Sewage and Industrial Wastes). Investigations of problems in sewage treatment and industrial waste disposal. Supplements CE 171. 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. (Required of grad and 5th yr students in sanitary option) Reports and discussions on assigned topics in the field of sanitary engineering with occasional talks by practicing sanitary engineers. (1 cr per qtr; prereq 5th yr or grad; 1 rec hr per wk) Schroepfer

179. Public Health Engineering. Public health problems associated with the location, construction, and operation of water supplies, purification works, and distribution systems, with the treatment and disposal of sewage, excreta, and waste, and with the production, pasteurization, and distribution of milk. (3 cr) Schroepfer

For Graduate Students Only

233.* Advanced Structural Design. Andersen

234-235.*‡ Advanced Theory of Structures. Andersen, Graves

236.* Advanced Structural Problems. Graves

240-241-242. Advanced Structural Laboratory

243.* Dynamics of Structures

244.* Dynamics of Structures Laboratory

247-248-249.* Seminar in Structures

251-252.* Advanced Soil Mechanics Laboratory. Kersten

261.* Water Plant Design. Schroepfer

262.* Sewage Plant Design. Schroepfer

263. Advanced Hydraulic Engineering Problems. Straub

264. Sanitary Engineering Unit Operations. Schroepfer

276.* Advanced Sanitary Engineering (Water). Schroepfer

277.* Advanced Sanitary Engineering (Sewage and Industrial Waste). Schroepfer

280-281-282.* Civil Engineering Research

Economics and Business Administration

(School of Business Administration)

NOTE—A major revision in course numbering in the School of Business Administration was made in 1958. In the following courses, the *old* course number appears in a separate set of parentheses at the end of each course description.

Economics (Econ)

Econ 1T-2T. Principles of Economics. (Open to IT students). The principles underlying economic activity and the way these principles work out through our economic institutions. 1: Demand and supply, competition and monopoly, and the distribution of income. 2: National income, money and banking, business cycles, and international trade. Econ 1-2 or equivalent are prerequisite for most advanced courses in business administration and economics. (3 cr each qtr, §1-2, C, 50A-50B; prereq 3rd qtr fr for 1, 1 for 2) (Econ 8-9)

Econ 1-2. Principles of Economics. Same as Econ 1T-2T (Econ 6-7)

Econ 65. Intermediate Economic Analysis: The Firm. Examination of the behavior of firms under competitive and monopolistic conditions, with particular attention to factors influencing the firm's decisions regarding production, output, and prices. (3 cr, §165; prereq 2 or equiv) (Econ 81)

Econ 66. Intermediate Economic Analysis: Income and Employment. Determinants of national income, employment, and price level, with particular attention to aggregate consumption and investment. (3 cr, §166; prereq 2 or equiv or ♯) (Econ 80)

Econ 67. Money and Banking. Historical development, present pattern, and economic role of financial institutions, with special emphasis on commercial banks, the money supply, and the Federal Reserve System. (3 cr, §old 3, 57; prereq 2 or equiv) (Econ 57)

Econ 68. Elements of Public Finance. Survey of government expenditures, budgeting, fiscal policy, debts, and taxes in terms of fiscal institutions, impact on business and the economy, and policy issues. Condensed course given especially for School of Business Administration students. (3 cr, §168, 178A-178B; prereq 2 or equiv) (BA 58)

Econ 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; and purposes and effect of antitrust laws and laws relating to "unfair business practices." (3 cr, §169; prereq 65 or 165 for business or economics majors, suitable background in law or political science for others or ♯) (Econ 85)

Econ 172. Public Policy: Labor Relations. Employer-employee-union relationships and their social control; legislative, executive, and judicial attempts to deal with these issues; economics and social implications. (3 cr; prereq BA 52 or 152) (Econ 164)

Business Administration (BA)

BA 1. Business and the American Economy. Descriptive survey of the American economy with emphasis on the business segment. Includes some attention to functions to be performed by any economic system and within typical businesses; kinds of decisions to be made and examples of information needed for making selected decisions. (3 cr; prereq fr or soph with no previous BA, or social studies majors in education with no previous BA) (Econ A)

BA 5. Elements of Statistics. Elementary concepts in statistical methods. Sources and collection of data; tabular and graphic presentation; frequency distributions; probability; sampling; introduction to statistical estimation and decision-making. (4 cr, §151, Soc 45; prereq Math 10 or equiv) (Econ 5A, 5B)

BA 50. Production Management. Introduction to the management of the production function. The techniques, the managerial problems, and the decision-making processes in planning and controlling the production activity. Emphasis is on 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; prereq Econ 2 or equiv) (BA 89)

BA 51. Business Statistics. Basic concepts of regression and correlation; statistical estimation and decision-making, with applications to such fields as survey sampling, acceptance sampling and statistical quality control; introduction to time series analysis and index numbers. (3 cr, §161; prereq soph with ♯, 5 or equiv) (BA 74)

BA 52. Modern Industrial Relations: Labor Marketing. An introduction to current employment relationships, emphasizing an economic approach and analysis. Fundamentals of the application and conservation of human resources in employment with consideration of 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) (Econ 73)

BA 53. Insurance Principles. Risk and its adverse economic effects; methods of handling risk; theory of insurance and insurable risks; insurable personal, property, and liability risks; risk management; personal, property, and liability insurance contracts; types of insurers; production, underwriting, actuarial, finance, and claims functions of insurers; industry and government regulation; social insurance. (3 cr, §153; prereq Econ 2 or equiv) (Econ 50)

BA 54. Transportation I: Principles. Introduction to the roles, interests, and relationships of users of the service, carriers, and regulatory agencies in the transportation field, emphasizing the 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 and evaluation of national transportation policy. (3 cr, §154; prereq Econ 2 or equiv) (BA 71)

BA 55A-55B. Elementary Accounting. The equivalent of BA 24-25-26 (Principles of Accounting) for School of Business Administration students and for 5-year combined engineering and business students. (8 cr, §24-25-26; counts as Lower Division course when transferred to College of SLA) (BA 54-55)

BA 55C. Managerial Costs. General survey of cost accounting from point of the executive who must use cost information in conduct of his business. (3 cr, §115A, 115B, 265A; prereq 26 or equiv) (BA 66)

BA 56. Corporation Finance. The corporation in comparison with other types of business units. Organization and capital structure, raising fixed and circulating capital, treatment of corporate earnings, incentives to and forms of combination, trusteeship, and reorganization. (3 cr, §156; prereq 1) (Econ 75)

BA 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) (BA 77)

BA 58. Business Law: Contracts. Law of contracts. Case method used in BA 58, 78, 88, 98. (3 cr, §158; prereq Econ 2 or equiv) (BA 51)

BA 60. Business Policy and Management Control. An evaluation of the areas of managerial authority and responsibilities, organizational relationships, and effective executive action. Presents managerial problems of policy formulation involving decisions based upon a knowledge of all the major functions in the firm. (3 cr, §160; prereq 3rd qtr sr) (BA 182G)

Electrical Engineering (EE)

12-14-16. Elements of Electrical Engineering Laboratory. Principles, materials, instruments, elementary circuit calculations, laboratory techniques, safety, orientation. (1 cr per qtr; prereq ITM 13A; 2 lab hrs per wk)

36-37-38. Elements of Electrical Engineering. (Aero, AgEn, ME) Basic concepts of direct-current and alternating-current circuits, electric and magnetic fields. Analysis of electron devices and their associated circuitry, semiconductors. Electromechanical energy conversion. Regulating systems, instrumentation. (3 cr per qtr; prereq ITM 26A or 80; 3 lect and 2 prob session hrs per wk for 36, 3 lect hrs per wk for 37 and 38)

37A-38A. Electrical Engineering Laboratory. Supporting laboratory for EE 37-38. Experimental study of electric circuits and devices with emphasis on instrumentation and measurement techniques. (1 cr per qtr; prereq ¶37-38; 2 lab hrs per wk)

40. Electrical Engineering Survey. (CE, MinE) Principles of operation of electric machines. Type study of transformers, motors, generators, and their application in electrical systems. (4 cr; prereq 36; 3 lect hrs and 2 lab hrs per wk)

51-53-55. Electrical Engineering. Analysis of lumped and distributed direct-current and alternating-current circuits in the steady state with an introduction to the transient state. Single-phase and polyphase circuits with sinusoidal and nonsinusoidal excitation. Static and quasi-static electric and magnetic field theory. (5 cr per qtr; prereq ITM 26A or 80, Phys 50; 5 lect hrs per wk)

52-54-56. Electrical Engineering Laboratory. Experimental study of electric circuits. (1 cr per qtr; prereq ¶51-53-55; 2 lab hrs per wk)

52A-54A-56A. Electrical Engineering Problem Solving Laboratory. Supervised problem sessions. (1 cr per qtr; prereq ¶51-53-55; 2 lab hrs per wk)

57-59. Engineering Electronics. Analytical and graphical analyses of electron devices and their associated circuitry: vacuum and gas tubes, photoelectric cells, semiconductors and transistors. (3 cr per qtr; prereq 51; 3 lect hrs per wk)

58-60. Engineering Electronics Laboratory. Vacuum tube characteristics and coefficients, voltage and power amplifiers, glow tubes, thyratrons, relaxation oscillators, control circuits, transistor characteristics and circuits. (1 cr per qtr; prereq ¶57-59; 2 lab hrs per wk)

81. Electrical Engineering Measurements. Instruments, construction, limitations, sources of error, calibration. Precision measurement of voltage, current, power, energy, resistance, inductance, mutual inductance, capacitance. (3 cr; prereq 55; 2 lect and 2 lab hrs per wk)

98. Seminar. Weekly discussion of current engineering periodicals, reports on assigned topics. (1 cr; prereq #)

101-102-103. Summer Engineering Employment. Summer work in an engineering field of not less than 360 hours per summer. Requires a written term report. (1-3 cr per qtr; prereq completion of 2nd-, 3rd-, or 4th-yr work and approval of instructor prior to regis) Riaz

109. Electromagnetic Fields. A theoretical study of electricity and electromagnetism leading to the development and simple applications of Maxwell's equations. Vector notation is employed. (3 cr; prereq 55, 56; 3 lect hrs per wk)

109A. Electromagnetic Fields Laboratory. An experimental study of electromagnetic phenomena. (1 cr; prereq ¶109; 2 lab hrs per wk)

121-123-125. Analysis of Electromagnetic Devices. Fundamental principles including equivalent circuits and methods of nonlinear circuit analysis. Theory of coupled circuits including transformers for impedance matching, power transfer, signaling, magnetic amplifiers. Theory of force, torque, and voltage production in electromechanical energy-conversion devices. Generalized treatment of synchronous, asynchronous, and commutator type machines. (3 cr per qtr; prereq 55, 56; 3 lect hrs per wk)

122-124-126. Experimental Study of Electromagnetic Devices. Transducers, including direct-current machines, transformers, magnetic amplifiers, induction and synchronous machines, commutator type machines including metadynes. (1 cr per qtr; prereq ¶121-123-125; 2 lab hrs per wk)

131-133-135. Electronic Circuit Design. Analysis and design of vacuum-tube and transistor circuits, rectifiers, amplifiers, oscillators, etc. Laboratory construction and check of designs. (3 cr per qtr; prereq 163; 2 lect and 2 lab hrs per wk)

132-134-136. Study of Electric Machines. Broadly applicable principles with special emphasis on design. Prediction of performance, steady and transient behavior, direct-current generators and motors, alternating-current transformers, generators, and synchronous motors. (3 cr per qtr; prereq 125; 2 lect and 2 lab hrs per wk)

138-139-140. Electric Power Control. Analysis of power circuits using symmetrical components, circuit protection. Control of motors, generators, metadynes, applications of magnetic amplifiers. Power system stability. (3 cr per qtr; prereq 109, 125, 161; 2 lect and 2 lab hrs per wk)

141. Electrical Engineering Materials. Dielectric, magnetic, and conductive properties of materials used in electrical engineering including methods of measurement and examples of application. (3 cr; prereq 109; 3 lect hrs per wk)

141A. Electrical Engineering Materials Laboratory. Laboratory study of properties of materials used in electrical engineering. Methods of measurement. (1 cr; prereq ¶141; 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 53, ITM 26A or 80, MM 29 or equiv) Lambert or Lyon

150. Dynamical Methods in Electrical Engineering. Lagrangian and Hamiltonian formulations of dynamics, with applications to electromagnetic systems. Lagrange's equations; gyroscopic systems; dissipative forces; normal coordinates and small oscillations; Hamilton's equations; variational principles for discrete and continuous systems; energy theorems. (3 cr; prereq MM 29 or equiv, ITM 153 and ♯; 3 lect hrs per wk)

151. Thermodynamic Methods in Electrical Engineering. Basic thermodynamic concepts and laws, with special application to electromagnetic systems. Energy, entropy, and thermodynamic potentials; application to electrically and magnetically polarizable materials, rigid or elastic; piezoelectricity, magnetostriction, thermoelectricity, reciprocal relations in reversible and irreversible processes. (3 cr; prereq ITM 153, Phys 51 or ME 30, and ♯; 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. Fluctuations, stochastic processes, nonequilibrium problems. Relations to information theory. (3 cr; prereq 150, 151, Phys 109, and ♯ [students not meeting these specific course requirements should consult instructor]; 3 lect hrs per wk)

153-154-155. Introduction to the Properties of Solids. Classical statistical theory of matter, thermal properties of solids, crystal structure, ionic crystals, dielectrics, wave mechanics and its application to atomic and molecular structure, the electron theory of metals, band theory of solids, imperfections in crystals. (3 cr per qtr; prereq Phys 125 or Phys 101-103-105, ♯; 3 lect hrs per wk) Dekker

157-158-159. Electronic Control. Analysis and applications of difference amplifiers, regulators, phase-sensitive demodulators, inverters, and timing circuits. Linear servomechanisms and associated stability analysis using Nyquist and Bode techniques. Analog computers and system error analysis. (3 cr per qtr; prereq 125, 163; 2 lect and 2 lab hrs per wk)

161-162-163. Electrical Engineering Networks. Theoretical studies of lumped linear networks in the transient and steady state. Application of Laplace Transforms in transient analysis. General lumped constant network analysis; two terminal pair networks, filter theory, linear amplifier networks, and analysis of feedback amplifiers. (3 cr per qtr; prereq 53, 54, 59, 60; 3 lect hrs per wk)

161A-162A-163A. Networks Laboratory. General laboratory study of lumped electrical networks under transient and steady state operation. Studies of transmission characteristics of active and passive networks. (1 cr per qtr; prereq ¶161-162-163; 2 lab hrs per wk)

164-165-166. Communication Circuits. Theoretical and laboratory study of selected topics in electric communication. Spectral analysis; modulation theory, including amplitude, frequency, and pulse modulation; noise; elements of information theory; system analysis. (3 cr per qtr; prereq 163; 2 lect and 2 lab hrs per wk)

167-168-169. Electromagnetic Theory and Application. Electromagnetic theory, Maxwell's equations, boundary value problems. Propagation of waves in space, on lines, and in waveguides. Cavities, antennas, and radiation. Introduction to microwave tubes. (3 cr per qtr; prereq 109, ♯; 2 lect and 2 lab hrs per wk)

171-172. Undergraduate Thesis. Investigation of approved problems in electrical engineering. (3-6 cr per qtr; prereq approval of faculty sponsor)

173-174-175. Physical Electronics. Electron devices used in electrical engineering; thermionic, photo, secondary emission, semiconducting, and photo-conducting devices. Devices based upon the electric and magnetic properties of matter. (3 cr per qtr; prereq 141 or equiv; 3 lect hrs per wk for 173, 2 lect hrs and 2 lab hrs per wk for 174 and 175) van der Ziel

176. Analog Computer, Engineering Problems. Theory, operation, and applications of differential analyzers; nonlinear elements, transient and steady state response, stability. (3 cr; prereq 161 and ITM 26A or 80)

177. Analog Computing Laboratory. (1-3 cr; prereq 161, ITM 26A or 80)

178-179-180. Nonlinear Active Circuits. Wave-shaping circuits, multivibrators, switching circuits, time-base and pulse generators, digital computer circuits. (3 cr per qtr; prereq 163; 3 lect hrs per wk)

183-184-185.‡ Special Electrical Laboratory. Special problems in electrical engineering. (1-3 cr per qtr; prereq approval of faculty sponsor)

187-188-189. Problems in Electrical Engineering. Nonlinear network analysis applied to electrical problems involving power amplification, amplitude modulation and demodulation, and oscillations. Special emphasis on methods of analysis in which nonlinear characteristics are approximated by broken segments, i.e., piecewise linear methods. Electrical circuits with time varying parameters and special applications. Problems involving distributed constant networks with special application to transmission of electrical signals. (3 cr per qtr; prereq 109, 125, 163; 3 lect hrs per wk)

191-192-193. Active Network Theory. Response of amplifiers to arbitrary excitation, selected topics in feedback amplifiers, negative impedance networks, active filters, high-precision and high-frequency amplifiers, frequency and amplitude stability of oscillators, high-frequency oscillators. (3 cr per qtr; prereq 163, ITM 153, or equiv, ‡) Anderson

194-195-196. Servomechanisms. Theoretical and laboratory study of feedback control systems, with application to autopilots and to process-control, fire-control, and missile systems. Frequency response, root locus, and application of analog computers in the simulation of control systems. (3 cr per qtr; prereq 125, 163, ‡; 3 lect hrs per wk)

197-198-199. Electrical Design of Machines I. Methods and procedures for the design of standard equipment for specific performance characteristics and for the design of special apparatus. Special problems in rotating machinery design, study of harmonics in air-gap flux waves, effect upon performance. Transformers for control and electronic applications. (3 cr per qtr; prereq 125 and ‡) Kuhlmann

For Graduate Students Only

204-205-206. Metadyne Statics and Linear Dynamics. Cartwright

207-208-209. Metadyne Nonlinear Dynamics. Riaz

211-212-213. Network Analysis and Synthesis. Lambert

221-222-223. Electric Power Seminar

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

233-234-235. Fluctuation Phenomena. van der Ziel

236-237-238. Solid State Theory. Dekker and staff

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

261-263-265. Problems in Electromagnetism. Shepherd

262-264-266. Communication Seminar. Staff

267-268-269. Theory of Communication. Staff

272-273-274. Fundamentals of Acoustics. Lambert or Lyon

275-276-277. Electrical Design of Machines II. Kuhlmann

287-288-289. Electron Tube Analysis. Staff

291-292-293. Electronics Seminar. Staff

294-295-296. Advanced Control Theory. Staff

English (Engl)

A-B-C. Freshman Literature and Composition. A combined course in composition (6 cr) and literature (9 cr) identical with Engl 1A-2A-3A, except that it puts even greater emphasis upon literature. It satisfies the Group A requirement for graduation in the College of Science, Literature, and the Arts. (5 cr per qtr; prereq assignment to Category 1, 1A, or 2; students absent on first day will lose their place in this class)

1A-2A-3A. Freshman English. A combined course in composition (6 cr) and literature (6 cr) identical with Engl 1B-2B-3B, except that it puts greater emphasis upon literature. It satisfies the Group A requirement for graduation in the College of Science, Literature, and the Arts. (4 cr per qtr; prereq assignment to Category 1, 1A, or 2; students absent on first day will lose their place in this class)

1B-2B-3B. Freshman English. A combined course in composition (9 cr) and literature (3 cr). It concentrates upon developing the student's skill in writing exposition, with an introduction to literary types as the chief means of providing subject matter for the writing. The literature read consists of novels, short stories, plays, and poems, both English and American. It satisfies the Group A requirement for graduation in the College of Science, Literature, and the Arts. (4 cr per qtr; prereq assignment to Category 1, 1A, 2, or 3; students absent on first 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 or A-B-C or 1A-2A-3A or 1B-2B-3B or Comm 1-2-3 or exemption from requirement; 3 rec hrs per wk) Foster, Myers

85-86. Advanced Technical Communication. Theory and practice in professional uses of language. 85: Reports and talks. 86: Letters, articles, conferences. (3 cr per qtr; prereq C or 3A or 3B or 16; 3 rec hrs per wk) Guthrie, Haga

General Engineering (GE)

21. Orientation. Series of lectures designed to orient the student who has just begun his university course. (1 cr; 1 lect hr per wk)

70. The Slide Rule. Computation practice and theory. Design of special scales. (1 cr; prereq ITM 11 or ¶11; 1 rec hr per wk)

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

103. Professional Problems. Lectures covering some of the problems the engineer will meet upon entering his professional career. (1 cr; 1 lect hr per wk)

105. Engineering Library Techniques. Lectures designed to instruct the student in the use of libraries and bibliographic tools in technical fields. (1 cr; 1 hr per wk)

Geology and Mineralogy (Geol)

(College of Science, Literature, and the Arts)

1-2. General Geology (Physical and Historical). A study of geologic processes and of the materials on which they operate. A résumé of the history of the earth and its inhabitants as recorded in the rocks. (3 cr per qtr; no prereq for 1; 1 or 8 or 51 for 2; 3 lect hrs per wk)

A-B. General Geology Laboratory (Physical and Historical). The physical properties of common minerals and rocks; interpretation of topographic maps. Identification of fossils; interpretation of geologic maps. (2 cr per qtr; prereq 1 or 8 or 51 or ¶1 or 8 or 51 for A; A, 2 or ¶2 for B; 4 lab hrs per wk)

5-6. Geology for Engineers. Materials of the earth and geologic processes. Applications of geology to engineering problems. Brief survey of occurrence, properties, production, and use of building stones, cements, clays, fuels, and road material. (3 cr per qtr; prereq InCh 15; 3 lect hrs per wk) Schwartz

8. Earth Features and Their Meaning. Introductory course. A general education elective. Explanation of the natural landscape as produced by such agents as the atmosphere, water, glaciers, volcanoes, and mountain-building forces acting on the materials of the earth. (5 cr; 5 lect hrs per wk) Thiel

23-24. Mineralogy. Crystal systems; morphological, physical, and chemical characters of minerals; classification and description of common minerals. Determinative work in laboratory, blowpipe analysis, sight identification. (4 cr per qtr; prereq 1 term college chemistry; 3 lect and 4 lab hrs per wk) Zoltai

25. Rock Study. The occurrence and origin of rocks; their mineral and chemical composition and classification. (2 cr; prereq 24; 1 lect, 1 rec, and 2 lab hrs per wk) Phinney

51. Principles of Physical Geology. Geologic processes and materials; relations of geology to man. Comparable to Geol 1 in subject matter, but with broader scope and wider readings. Suitable for nonscience majors. (3 cr, §1, §5, §8, or §NSci 6; prereq 15 cr in college natural science or math) Wright

100. Field Work in Northern Minnesota. Geologic field methods and study of selected areas on the iron ranges and other parts of northern Minnesota. A comprehensive report is required for Graduate School credit. (3 cr; prereq 25)

101. Sedimentation. Origin of sedimentary rocks and their primary structures; lithologic associations. (3 cr; prereq 24; 3 lect hrs per wk) Thiel

102.* Methods of Study of Sediments. Sedimentary rocks. Textural and mineralogical analyses of clastic and nonclastic materials. (3 cr; prereq 101, 106; 1 lect and 4 lab hrs per wk) Thiel

103.* Micropaleontology. Classification of Foraminifera, Ostracoda, and other small fossils, their use in stratigraphy. (3 cr; prereq 107) Swain

104. Micropaleontology. Advanced study of selected groups of microfossils. (2 cr; prereq 103; offered 1959-60 and alt yrs) Swain

106. Petrography. Optical methods for identification of minerals in thin sections and immersion media; microscopic work on rocks. (3 cr; prereq 25; 1 lect, 1 rec, and 4 lab hrs per wk) Phinney

107. Invertebrate Paleontology. Morphology and classification of important fossil groups. Principles of paleontology. (3 cr; prereq B or △; 2 lect and 3 lab hrs per wk) Sloan

108.* Stratigraphic Paleontology. Uses of fossils in stratigraphy; environmental analysis; detailed study of a selected fauna. (3 cr; prereq 107; 1 lect and 4 lab hrs per wk) Sloan

109. Advanced Invertebrate Paleontology. Procedures in taxonomy; preparation of a paleontologic report. (3 cr; prereq 108) Sloan

110-111.* Economic Geology. The nature, genesis, and distribution of mineral deposits; relation of mineral deposits to structure and surficial alteration. (3 cr per qtr; prereq 125; 3 lect hrs per wk) Schwartz

112.* Petroleum Geology. Composition and origin of petroleum, methods of exploration and the geology of the important oil producing regions. (3 cr; prereq 125; 3 lect hrs per wk) Swain

114.* Geology of Minnesota and Adjoining Areas. Structure, stratigraphy, lithology and their associated mineral resources, with emphasis on the Pre-Cambrian. (3 cr; prereq 25; 3 lect hrs per wk) Thiel

115. Field Work in Southeastern Minnesota. July 15 to 30, approximately. Stratigraphic methods and principles as illustrated by study of Cambrian and Ordovician rocks. (3 cr; prereq 25) Sloan

118. Geomorphology. Origin and evolution of landforms in temperate, arctic, desert, and tropical regions in different geologic settings. Effects of structural history and climatic change on landform development. Relations of geomorphic processes to soil formation and engineering problems. Field trips; term paper or field project. (3 cr; prereq B; 3 lect hrs per wk) Wright

119A.* Geomorphology of Eastern United States. General geology of the physiographic provinces east of the Great Plains; landforms and Cenozoic history.

Map study. (3 cr; prereq 118 or 125; 2 lect hrs per wk, lab ar; offered 1960-61 and alt yrs) Wright

119B.* Geomorphology of Western United States. General geology of the physiographic provinces from the Great Plains westward; landforms and Cenozoic history. Complementary to 119A. Map study. (3 cr; prereq 118 or 125; offered 1959-60 and alt yrs) Wright

120.* Glacial Geology. Modern glaciers. Erosion and deposition. Chronology of Pleistocene climatic changes in glaciated and nonglaciated areas. (3 cr; prereq B; 3 lect hrs per wk) Wright

121.* Crystallography. Symmetry relations in the 32 crystal classes and 230 space groups. Drawings and measurements, projections, and mathematical calculations. (3 cr; prereq trigonometry and 1 yr college chemistry) Zoltai

125. Structural Geology. Primary and secondary structures of rocks, mechanics and modes of deformation, and structural techniques. Laboratory exercises in three-dimensional representation and solution of selected structural problems. (4 cr; prereq 25 or ♯) Craddock

126. Advanced Structural Geology. Fundamental problems and genesis of secondary structural features with emphasis on detailed analysis of typical examples. Comprehensive term paper required for graduate credit. (3 cr; prereq 125) Craddock

131-132. Petrology. Petrographic description, classification, and origin of rocks. Sedimentary rocks principally in 131, igneous and metamorphic rocks in 132. (4 cr per qtr; prereq 106; 2 lect, 1 rec, and 4 lab hrs per wk) Phinney

140.* Applied Petrography. Problems in mining and petroleum geology. (3 cr; prereq 131) Phinney

145.* Aerial Photographs. Elements of photogrammetry, construction of mosaics and of planimetric and topographic maps, stereovision, geologic and geomorphic interpretation, field use. (3 cr; prereq 118 or 125 or ♯; 6 lab hrs per wk) Wright

146-147.* Soil Mineralogy. Crystal systems; morphological, physical, and chemical characters of minerals; classification and description. Blowpipe analysis, sight identification. (3 cr per qtr; for students in soil science, civil engineering, and other nonmajors; prereq 1 term college chemistry) Zoltai

150. Field Geology. (June 15-July 15) Detailed systematic field work in stratigraphy, structural geology and economic geology; preparation of geologic maps and other illustrations. Normally to be followed by Geol 171. Field, Black Hills, S. D. (6 cr; prereq 125)

151. Stratigraphy I. Principles of stratigraphic classification and correlation; biostratigraphic zones, sedimentary facies and cycles. Typical pre-Mesozoic sequences. (3 cr; prereq 25, 107; 3 lect hrs per wk) Swain

152.* Stratigraphy II. Typical Mesozoic and Cenozoic sequences; methods of presentation of stratigraphic data. (3 cr; prereq 151; 3 lect hrs per wk) Swain

153.* Subsurface Stratigraphy. Application of sample logs, electrical logs, and other methods to the detailed stratigraphy of the subsurface in selected areas. (2 cr; prereq 151; 4 lab hrs per wk) Swain

154.* Geological Oceanography and Limnology. Sedimentary and biological processes in modern oceans and lakes and their application to geology and paleontology. (2 cr; prereq 101 and 118 or ♯; offered 1959-60 and alt yrs) Swain

155.* Vertebrate Paleontology. Stratigraphic and morphologic aspects of fossil vertebrates. (3 cr; prereq 107 or Zool 22 or ♯) Sloan

161.* Advanced Mineralogy. Systematic study of mineral groups. Laboratory study of specimens. Physical and chemical tests. (3 cr; prereq 24) Zoltai

166-167.* Mineralography. Opaque minerals; applications to problems in ore genesis and history. (3 cr per qtr; prereq 111, 131) Schwartz

170.* Geologic Problems. Individual research in laboratory, or field problems. (1-3; prereq consent of major adviser)

171.* Preparation of Geologic Report. Supervised preparation of a geologic report, with maps and other illustrations, on an acceptable area or subject. Preliminary manuscript due at midquarter. (1 cr; prereq 4th yr, 150 or △)

175.* Field Work in Glacial Geology and Geomorphology. Mapping of surficial deposits and landforms of a selected area in Minnesota. One day in field each week. (3 cr; prereq 118, 120) Wright

176. Pleistocene Geology. Glaciated and unglaciated areas, particularly in North America, Europe, and the Mediterranean region. Relation of Pleistocene climatic changes to soils, biogeography, and archaeology. (3 cr; prereq 120; offered 1959-60 and alt yrs) Wright

177. Advanced Geomorphology. Selected topics in river morphology, slope analysis, arctic and desert landforms. Methods of study. (3 cr; prereq 118; offered 1960-61 and alt yrs) Wright

178. Advanced Principles of Economic Geology. Fundamental principles involved in the origin of ore deposits. (3 cr; prereq 111) Schwartz

179. Mining Geology. Economic geology applied to problems in mining. (3 cr; prereq 111; offered 1959-60 and alt yrs) Schwartz

181. Principles of Geochemistry. Chemical structure and composition of the earth. Distribution of the elements within the lithosphere, hydrosphere, atmosphere, and biosphere. (3 cr; prereq 25 and 1 yr college chemistry) Gast

182. Isotopic and Nuclear Processes in Geology. Measurement of geologic time using natural radioactivity. Variations in isotopic compositions due to radioactivity and to natural isotope fractionation processes. (3 cr; prereq 25 and physical chemistry or ‡) Gast

183. Advanced Geochemistry. Chemical evolution and heat balance of the earth, phase equilibria at high temperatures and pressures, and other selected topics. (3 cr; prereq 182, differential equations or ‡; offered 1959-60 and alt yrs) Gast

Geophysics (GPhy)

90-91-92. Industrial Employment. (2 cr per qtr; prereq △)

108. Introduction to General Geophysics. Physics of the earth; evidence and data on age, shape, internal constitution, gravity and magnetic fields. (3 cr; prereq Phys 9 or 14, Geol 2...Geol 125 recommended) Mooney

109. Elementary Seismology. Physics and geology of earthquakes; causes, effects, distribution. Seismic waves. (3 cr; prereq Phys 9 or 14, Geol 125) Mooney

110. Introduction to Exploration Geophysics. Principles of exploration by gravity, magnetic, seismic, and electrical measurements. (3 cr; prereq Phys 9 or 14, Geol 2...Geol 125 recommended) Mooney

125. Principles of Gravity and Magnetic Exploration. Techniques of interpretation; use in geologic and mining problems. (2 cr; prereq Phys 14, Geol 125, ITM 25A) Mooney

126. Principles of Seismic Exploration. Reflection and refraction seismology; interpretation of data. (2 cr; prereq Phys 14, Geol 125, ITM 25A) Mooney

127. Principles of Electrical Exploration. Methods, theory, interpretation, and instruments. (2 cr; prereq Phys 14, Geol 125, ITM 25A) Mooney

131-132-133. Selected Topics in Theoretical Seismology. (Cr ar; prereq ‡; offered when feasible) Mooney

135-136-137.*‡ Special Problems in Geophysics. (Cr ar; prereq #) Mooney

German (Ger)

(College of Science, Literature, and the Arts)

1A-2A-3A. Beginning German: Conversational Section. Five class meetings a week. Provides basic experience in speaking and understanding the German language through the use of texts dealing with real-life situations; provides a reading knowledge that is adequate for this level; provides necessary insight into the structure of the language of analysis of texts already learned. (5 cr per qtr) Menze

1B-2B-3B. Beginning German: Language and Culture. Five class meetings a week. Provides, without emphasis on formal grammar, foundation of a reading knowledge adequate for cultural or professional purposes; gives an introduction to German culture and its contributions to Western Civilization; encourages an understanding of the nature of language by systematic compari-

son between German and English. Stresses direct experience with a variety of reading material in German and English. (5 cr per qtr) Ramras

1C-2C-3C. Beginning German. Five class meetings a week. Gives a knowledge of the elements of grammar and the facility to read and write easy German. (5 cr per qtr; students submitting 1 yr high school German for entrance take Ger 2; those offering 2 yrs high school German take Ger 3)

50-51-52. Reading German: A Beginning Course for Juniors and Seniors. Develops reading proficiency by concentrating from the outset on vocabulary building and reading techniques and reduces presentation of formal grammar to a minimum. Intensive study of a variety of texts in class; individual projects in extensive reading. (3 cr per qtr)

History (Hist)

(College of Science, Literature, and the Arts)

20-21-22.‡ American History. A survey of the political, economic, and social history of the United States, with emphasis on the forces that resulted in the emergence of modern America. 20: Colonial and early national period. 21: Sectionalism and national development. 22: Modern America. (3 cr per qtr; prereq soph) Beatty, Chambers, Murphy, Noble

79-80-81.‡ The United States in the 20th Century. Political, economic, diplomatic, and social history of the United States from the Spanish-American War to the present. 79: 1898-1916. 80: 1916-1932. 81: 1932 to present. (3 cr per qtr) Chambers

89. Economic History of Modern War. Economic aspects of the French Revolution and Napoleonic Wars, and of World War I and World War II. (3 cr; offered when feasible) Bowditch

112-113-114.‡ Economic History of Europe. 112: Economic life in ancient and medieval times. 113: Economic developments in the early modern world. 114: Economic developments since 1750. (3 cr per qtr) Bamford

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

146-147-148.‡ American Economic and Social History. 146: Colonial life. 147: From the Revolution to 1860. 148: Developments since 1860. (3 cr per qtr) Loehr

Humanities (Hum)

(College of Science, Literature, and the Arts)

21. American Life I. Individualism as a concept in American life and thought. (3 cr) Kwiat, Noble, Turpie, Weber

22. American Life II. The role of religious and philosophic attitudes in formation of American beliefs. (3 cr) Kwiat, Noble, Turpie, Weber

23. American Life III. The rise of American intellectual and cultural nationalism and its place in the modern world. (3 cr) Kwiat, Noble, Turpie, Weber

51-52-53.‡ Humanities in the Modern World. Similar to Hum 1-2-3 except that it is confined to juniors and seniors. (5 cr per qtr, § corresponding qtrs of 1-2-3) Amberg, Blum, Kwiat

71-72-73.‡ Humanities in the United States. Introduction to American cultural history. Each quarter is organized around topics which disclose a major conflict of ideals—for example, liberty and property in the early Republic, individualism and majority rule in the pre-Civil War era, materialism and idealism in the present industrial age. Such figures as Jefferson, Hamilton, Thoreau, Mark Twain, Frank Lloyd Wright, and William Faulkner are studied. (3 cr per qtr) Levenson

A student may take any combination of 21, 22, 23, 71, 72, 73 up to a maximum of 9 credits.

Hydromechanics (Hydr)

(Civil Engineering Department)

101. Fluid Mechanics. (AeroE and EE) Hydrostatics, Bernoulli's theorem, pressure-momentum relationships, compressible and incompressible flow. (3 cr; prereq MM 27; 3 rec hrs per wk; 103 may be substituted for 101) Straub and staff

103. Fluid Mechanics. Physical fluid properties, fluid statics, energy principle for compressible and incompressible fluids, pressure-momentum principles, elementary principles of turbines and pumps, dimensional analysis, introduction to advanced principles of flow phenomena. (5 cr; prereq MM 27; 5 rec hrs per wk; this course 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 in open channels, with practical applications to the design of hydraulic structures, computations of drawdown curves, backwater curves, hydraulic jump, measuring flumes, submerged weirs, etc. (3 cr; prereq 101 or 103 and 104; 3 rec hrs per wk) Anderson or Straub

184-185-186. Advanced Hydraulic Problems. Problems in hydraulic design. (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. Study of 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 concerning the characteristics of turbines, pumps, etc. Hydraulic models. (2 cr per qtr; prereq 101 or 103 and 104; 6 lab hrs per wk; offered when demand warrants) Straub and staff

For Graduate Students Only

287. Fluid Turbulence. Straub, Silberman

290-291-292. Advanced Fluid Mechanics. Straub

293. Hydrodynamics. Silberman

294. Hydrodynamics. Silberman

295. Hydrodynamics. Silberman

296-297-298. Hydrodynamics. Silberman

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. (No cr; 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. (No cr; prereq elementary algebra; 5 rec hrs per wk)

11. College Algebra and Trigonometry I. Trigonometric functions, right triangles, slide rule, oblique triangles, vectors, radian measure. Factoring, fractions, functions and graphs, linear equations and determinants, exponents and radicals, quadratic equations, inequalities, systems of quadratic equations, proportion and variation, mathematical induction, binomial theorem. (5 cr; prereq 9 or equiv; 5 rec hrs per wk)

12. College Algebra and Trigonometry II. Progressions, logarithms. Trigonometric formulas and identities, trigonometric curves, inverse trigonometric functions, trigonometric equations, complex numbers. Theory of equations, permutations, combinations, probability, partial fractions, hyperbolic functions. (5 cr; prereq 11; 5 rec hrs per wk)

13A. Calculus I: Analytic Geometry and Calculus. Rectangular co-ordinates, locus and equation, straight line, conic sections. Limit, derivative, rules of differentiation, rates, curve tracing, maxima and minima. (5 cr; prereq 8, 11, 12 or equiv; 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. Mean value theorem, definite integral. Differentiation and integration of transcendental functions. Polar co-ordinates. Methods of integration. Applications of integration: areas, volumes, moments, centroids, moments of inertia, hydrostatic pressure, work. (5 cr; prereq 13A; 5 rec hrs per wk)

25A. Calculus III: Analytic Geometry and Calculus. Vector and parametric equations. Solid analytic geometry treated by vector methods. Partial differentiation, geometry of surfaces, differentials, directional derivative, maxima and minima. Multiple integrals, volume, surface area, physical applications. (5 cr; prereq 24A; 5 rec hrs per wk)

26A. Calculus IV: Differential Equations and Calculus. Infinite series; convergence tests, Taylor's formula and expansion of functions. Differential equations; equations of first order; standard methods of solutions; linear equations with constant coefficients, applications; simultaneous equations, integration by series, numerical methods. (5 cr, §80; prereq 25A; 5 rec hrs per wk)

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

99. Mathematical Problem Seminar. Problems ranging from elementary algebra and geometry through undergraduate mathematics will be assigned and discussed weekly. (3 cr; prereq 25 or 25A; 3 rec hrs per wk)

104. Variational Problems in Engineering. Euler-Lagrange equations, isoperimetric problems, geodesics, Fermat's and Hamilton's principle, vibration and stresses in elastic bodies, methods of Rayleigh-Ritz, Galerkin, Kantorovich, etc., eigenvalues and eigenfunctions. (3 cr; prereq 153 or 148 or 150A or ♯; 3 rec hrs per wk)

105A-105B. Summer Employment. (2 cr per qtr; prereq completion of 3rd yr work and △)

132.* Introduction to Statistics and Probability. Descriptive statistics, correlation, permutations and combinations, probability distributions, elementary limit theorems. (3 cr; prereq 25 or 25A; 3 rec hrs per wk)

133-134.* Statistics with Engineering Applications. Random samples, estimation, confidence intervals, testing hypotheses, small sample distributions, quality control, acceptance sampling, regression, analysis of variance, elementary design of experiments, distribution-free methods. (3 cr per qtr; prereq 132; 3 rec hrs per wk)

133A-134A.* Mathematical Methods in Operations Analysis. Game theory, linear programming, Markoff processes, decision functions, Monte Carlo methods, with applications to waiting lines, traffic, scheduling, allocation, inventory,

search, learning, reliability. Emphasis is put on the necessary mathematical tools. (3 cr per qtr; prereq 90 or 132 or #; 3 rec hrs per wk)

133B-134B.* Probability with Engineering Applications. Recurrent events, random walk, diffusion, Markoff chains, Poisson processes, general random processes, random noise, stationary processes, spectral densities and autocorrelation functions, linear and nonlinear transformations, prediction, and smoothing. (3 cr per qtr; prereq 132, 153...or 132, 148, 149...or #; 3 rec hrs per wk)

142-143.* Vector and Matrix Theory with Applications. Systems of linear equations, determinants, finite dimensional vector spaces, matrices, characteristic values and their numerical estimation, reduction to canonical forms, quadratic and bilinear forms. Application to engineering problems. (3 cr per qtr, §149; prereq 25 or 25A; 3 rec hrs per wk)

147.* Vector Analysis. (Formerly ITM 154) Scalar and vector products, derivatives, geometry of space curves, del operator, line and surface integrals, divergence and Stokes' theorem, transformation of co-ordinates, dyadics, applications. (3 cr, §152, 154; prereq 25 or 25A; 3 rec hrs per wk)

148.* Differential Equations. Linear differential and difference equations with constant coefficients, isoclines, phase plane, reduction in order, numerical solutions, series solutions, Bessel functions, Legendre polynomials, introduction to boundary value problems. (3 cr, §150A; prereq 80 or 26 or 26A; 3 rec hrs per wk)

149.* Determinants and Matrices. Determinants, matrices, linear equations, vector spaces, quadratic and bilinear forms, characteristic roots, applications to systems of ordinary differential equations. (3 cr, §142; prereq 25 or 25A; 3 rec hrs per wk)

150A.* Ordinary Differential Equations. Linear equations of second order, successive approximations. Existence theorems, systems of ordinary differential equations. Numerical integration and solution by series. (3 cr, §148; prereq 26 or 26A or 80; 3 rec hrs per wk)

151A. Calculus V: Intermediate Calculus. Limit concept, derivative, Reimann integral, numerical integration, partial differentiation, multiple integrals. (3 cr; prereq 26 or 26A or 80; 3 rec hrs per wk)

152.* Calculus VI: Advanced Calculus. Maxima and minima in several variables, vector algebra and calculus, Green's and Stokes' theorems, integrals depending upon a parameter. (3 cr, §147; prereq 151A; 3 rec hrs per wk)

153.* Calculus VII: Advanced Calculus. Infinite series, computation with series, series with variable terms, uniform convergence, power series. Fourier series and orthogonal functions, special functions. (3 cr; prereq 151A; 3 rec hrs per wk)

155-156.* Tensor Analysis with Applications. (3 cr per qtr; prereq 147, 149 or 142, 152 or #; 3 rec hrs per wk)

161-162-163.* Analytical Dynamics. Newton's laws, energy, momentum, and angular momentum principles for inertial reference frames, modifications for noninertial reference frames. Lagrange's equations. Motion of particles, rigid bodies, e.g., planets, tops, gyroscopes. Stability, small oscillations. Hamilton's principle, motion of elastic bodies. Hamilton's equations, transformation theory. (3 cr per qtr; prereq MM 127 or MM 28, 29 or #; 3 rec hrs per wk) Koehler

164-165-166.* Theory and Programming of Modern Digital Computers. Modular arithmetic. Design of binary arithmetic units. Decimal coding and decimal arithmetic units. Storage devices and control. Input-output media. Coding and machine operation. Applications to mathematical and physical problems. Subroutine libraries, regional and abstract assembly programs, interpretive systems, compilers. (3 cr per qtr, §165A; prereq 26 or 26A or 80; 3 rec hrs per wk) Stein

165A. Introduction to Programming Modern Digital Calculators. Organization of a modern digital calculator. Binary number system. Instruction code, elementary coding, flow charts, techniques for avoiding errors, code checking, scaling, subroutines, assembly techniques, interpretive programs. (3 cr, §165; prereq 25 or 25A; 3 rec hrs per wk) Stein

167A-167B. Selected Topics in Mathematics for Aeronautical Engineers. (3 cr per qtr; prereq 26 or 26A or 80; 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 168A or 174 or ‡; 3 rec hrs per wk)

169.* Mathematical Theory of Fluid Flow. The general equations of fluid mechanics. Concepts from thermodynamics. The classical constitutive equations. Specialization to various subfields of fluid mechanics, including hydrostatics, barotropic perfect fluids, gas dynamics, and viscous flow theory. Examples of exact solutions. (3 cr; prereq 152, 168A or 152, 174 or 147, 168A or 147, 174 or ‡; 3 rec hrs per wk)

173.* Elementary Partial Differential Equations. Partial differentiation, Fourier series, proof of convergence, orthogonal systems, Sturm-Liouville systems, solution of partial differential equations by separation of variables, applications. (3 cr; prereq 148 or 153; 3 rec hrs per wk)

174.* Elementary Theory of Complex Variables. Complex numbers, derivatives and integrals of analytic functions, elementary functions and their geometry, Cauchy's integral theorem and formula, Laurent expansions, evaluation of contour integrals by residues. (3 cr; prereq 26 or 26A; 3 rec hrs per wk)

175.* Integral Transforms. Laplace transforms, inversion formula and method of residues, applications to systems of ordinary and partial differential equations, problems in heat conduction and mechanical vibrations, Fourier transforms, three-dimensional wave equation. (3 cr; prereq 168A or 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 ‡)

184. Elementary Numerical Analysis in Engineering. Finite differences, interpolation, summation of series, numerical integration, Euler-McLaurin formula and asymptotic expansions. Numerical solutions of systems of algebraic and transcendental equations, Newton's and Graeffe's method. (3 cr; prereq 26 or 26A or 80; 3 rec hrs per wk) Koehler or Munro

185-186.* Numerical Analysis in Engineering. Approximation of functions and least squares. Approximate solution of ordinary and partial differential equations, Moulton's, Runge's relaxation and iteration methods. Calculation of eigenvalues of matrices and differential problems, Rayleigh-Ritz method. Integral equations. Programming of computers. (3 cr per qtr; prereq 147, 148, 149, 184...or 152, 153, 184 or ‡; 3 rec hrs per wk) Koehler or Munro

190A-190B-190C.* Combinatorial Topology. Linear complexes, chains, boundary, coboundary operations; application to electrical circuits. Homology and cohomology classes. Betti numbers and Euler's theorem. Interpretation of Kirchhoff's laws. Two-dimensional complexes; characterization of surfaces. Jordan curve theorem. Orientability. Representation of surfaces by canonical cycles. Generalization to 3-dimensional manifolds. Subdivision of a complex. Cell complexes and the Poincaré duality theorem. (3 cr per qtr; prereq 142 or ¶142 or ‡; 3 rec hrs per wk) Calabi

191A.* Normal Multivariate Analysis I. (3 cr; prereq 134, 142, 152 or ‡; 3 rec hrs per wk)

191B.* Normal Analysis of Variance and Covariance. (3 cr; prereq 134, 142, 152 or ‡; 3 rec hrs per wk)

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 ‡)

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 168A or 174 or ‡; 3 rec hrs per wk) Fulks

199A-199B-199C.*‡ 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 ‡)

For Graduate Students Only

201. Normal Multivariate Analysis II

202. Statistical Analysis of Categorical Data and Generalizations

217-218-219.* Riemannian Geometry. Milgram

224-225-226.* Lie Groups and Lie Algebras. Yamabe

227-228-229.* Mathematics of Computers and Control Devices. Munro

232-233-234.* Mathematical Theory of Fluid Dynamics. Serrin

235-236-237.* Topological Groups. Yamabe

238.* Joint Seminar. (AeroE, ITM)

240A-240B-240C.* Asymptotic Methods in Linear Analysis. Reich

248-249-250.*‡ Reading and Research

261-262-263.* Functions of a Complex Variable. Warschawski

264-265-266.* Conformal Mapping. Warschawski

267-268-269.* Selected Topics in the Theory of Analytic Functions. Warschawski

270A.* Advanced Numerical Analysis of Partial Differential Equations

270B.* Advanced Numerical Analysis of Linear Systems

274-275-276.* Partial Differential and Integral Equations of Applied Mathematics. Rosenbloom

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

280A.* Galois Theory. Milgram

280B.* Rings and Ideals. Milgram

280C.* Algebraic Numbers. Milgram

281-282-283.* Potential Theory. Serrin

284-285-286.* Nonlinear Ordinary Differential Equations. Turrittin

287-288-289.* Hilbert Space and Functional Analysis. Milgram

301-302-303.* Topics in Advanced Differential Geometry. Milgram

304-305-306.* Advanced Topics in Differential and Difference Equations. Markus

307-308-309.* Mathematical Problems of Theoretical Physics. Rosenbloom

Mechanical Engineering

Engineering Graphics (EG)

14. Engineering Graphics. Engineering representation and analysis including systems of projection, co-ordinate systems, and solution of space problems with mathematical correlation. Engineering geometry, shape, description, sketching, and pictorial illustration. (3 cr; prereq solid geometry; 2 lect and 4 lab hrs per wk)

15. Engineering Graphics. Engineering representation and analysis. Continuation of graphic solution of space problems. Intersections, developments, size description, common devices and application of theory and standard practices to graphic communication. (3 cr; prereq 14; 2 lect and 4 lab hrs per wk)

16. Engineering Graphics. Graphical computation of engineering problems involving graphic algebra, calculus, and statics. Functional scales, nomography, representation and analysis of empirical data. (3 cr; prereq 15; 2 lect and 4 lab hrs per wk)

17. Technical Sketching. Applications of orthographic projection as developed through sketching. Principles of pictorial representation, shading. Basic prin-

ciples of dimensioning, sectioning. Pipe and flow diagrams. (1 cr; prereq 14; 2 lab hrs per wk)

50. Diagrams and Charts. Elementary course dealing with the construction of simple diagrams and charts. (2 cr; prereq 14; 2 lect and rec hrs per wk)

51. Graphic Representation and Computation. Types of charts and applications to the solution of problems and equations. (3 cr; prereq 15, ITM 11; 3 lect and rec hrs per wk)

52. Alignment Charts. Functional scales. Application of geometry to the development of straight-line alignment charts for equations of three or more variables. (3 cr; prereq 15, ITM 12; 3 lect and rec hrs per wk)

55. Production Illustration. Detail and assembly drawing by use of isometric, oblique, axonometric freehand, and mechanical perspective. Shaded drawings suitable for reproduction. (2 cr; prereq 16; 6 lect and lab hrs per wk)

111-112-113. Advanced Descriptive Geometry. Parallel and central projections. Curves and surfaces. Intersections and tangencies. Shades and shadows. Warped surfaces. The figured plan. (3 cr per qtr; prereq 16, ITM 25A; 3 lect and rec hrs per wk)

118. Curve Fitting. Derivation of formulas to fit experimental data. Combination of graphic and algebraic methods. (3 cr; prereq 16, ITM 25A, or ‡; 3 lect and rec hrs per wk)

152-153-154. Nomography. Application of geometry to the development of alignment charts involving curved and straight line scales. Networks, combination of networks, and alignment charts. Line co-ordinates. Use of determinants for the construction of alignment charts. Special rules. (3 cr per qtr; prereq 52, ITM 25A or ‡; 3 lect and rec hrs per wk)

157-158-159. Graphical Mathematics. Correlation of descriptive and algebraic geometry. Geometrography. Graphical calculus. Gradation of experimental data. Interpolation. (2 cr per qtr; prereq 16, ITM 25A; 2 lect and rec hrs per wk)

Industrial Engineering (IE)

50. Elements of Industrial Engineering and Management. A survey of industrial plant operation, production management, and industrial engineering functions. (3 cr; prereq 3rd yr; 3 rec hrs per wk)

153. Methods Engineering and Work Measurement. Development of methods and processes for economical production; motion study, time study. (3 cr; prereq 50 or ¶50; 2 rec and 3 lab hrs per wk)

154. Advanced Methods Engineering and Work Measurement. Multiple operation analysis, advanced work measurement techniques, incentives. (3 cr; prereq 153; 2 rec and 3 lab hrs per wk)

155. Industrial Wage Administration. Job evaluation, wage surveys, wage policies, establishment and administration of incentive wage plans. (3 cr; prereq 153; 3 lect hrs per wk)

163. Process Planning and Development. Planning of manufacturing operations to meet quantity, quality, and cost requirements of the product. (3 cr; prereq 50, ME 15, 16; 2 rec and 3 lab hrs per wk)

165. Industrial Plants. Analysis of materials flow; layout of production and service departments; plant buildings, service facilities, and handling equipment. (3 cr; prereq 153; 2 rec and 3 lab hrs per wk)

167. Materials Handling and Packaging. Development of materials handling systems and selection of equipment; industrial packaging techniques. (3 cr; prereq 153; 3 rec hrs per wk)

170. Production Planning and Control. Planning of production requirements; routing, scheduling, and co-ordination of production; inventory policies and control. (3 cr; prereq 50; 3 rec hrs per wk)

171. Quality Control. Quality standards, application of statistical methods and sampling theory; interpretation of results and corrective action. (3 cr; prereq ITM 90 or 132 or ‡; 3 rec hrs per wk)

173. Engineering Economic Analysis. Analysis of capital expenditures and annual operating costs as the basis for management policies and decisions. (3 cr; prereq 50)

174. Analysis for Production Management. Analytical methods associated with decisions involving probability analysis; prediction and control; applications of mathematical models and optimal solution. (3 cr; prereq 50 and 171 or ‡; 3 rec hrs per wk)

180. Elements of Supervision. Supervisory functions and relations with employees, other supervisors, staff departments, and management. (3 cr; prereq 50; 3 rec hrs per wk)

182. Industrial Safety. Safety requirements for production processes, equipment, and plants; organization and administration of safety programs. (3 cr; prereq 50; 3 rec hrs per wk)

190. Industrial Engineering Seminar. Current developments in industrial engineering and management; assigned articles and classroom discussion. (1 cr; prereq 12 cr in industrial engineering; 2 rec hrs per wk)

194-195-196.‡ Applied Industrial Engineering. Industrial engineering surveys and programs; case problems; studies in local plants. (3 cr per qtr; prereq 15 cr in industrial engineering; 3 lect hrs per wk for 194, hrs ar for 195 and 196)

197. Industrial Sampling Techniques. Selection and operation of attributes sampling plans; operating characteristic curves; sampling techniques for continuous production; variables sampling plans; administrative and economic comparisons. (3 cr; prereq 171 or ITM 132 or ‡; 3 lect hrs per wk)

198. Sequential Analysis of Industrial Data. Sequential vs. "classical" methods; operating characteristic functions for attributes and variables sequential plans; the average sample number function; economic considerations; applications in research and production. (3 cr; prereq ITM 133 or ‡; 3 lect hrs per wk)

199. Design of Industrial Experiments. Designs involving crossed, nested, and mixed classifications; mathematical models for the analysis of variance; estimation and comparison of effects; factorial experiments; confounding; balanced incomplete block designs; applications in research and production. (3 cr; prereq ITM 133 or ‡; 3 lect hrs per wk)

For Graduate Students Only

251-252-253.‡ Advanced Industrial Engineering

261-262-263.‡ Production Engineering Problems

271-272-273.‡ Industrial Engineering Research

Mechanical Engineering (ME)

15. Casting, Working, and Welding of Engineering Materials. Identification and classification of metals. Fundamentals of patterns. Sand molding, core making and shell molding. Machine molding and melting. Mechanical working of metals and alloys. Welding techniques, e.g., gas, arc. Properties of molding sands. Precision casting. Inspection testing, e.g., magnaflux, X-ray. Plastic materials and fabrication. (3 cr; prereq IE 50, Met 56, and MM 142; 2 lect and 3 lab hrs per wk)

16. Cold Processing of Materials. Machine shop practice, theory of metal cutting, product inspection including measurement of dimensions, surface roughness and hardness. (3 cr; prereq IE 50, Met 56, and MM 142; 2 lect and 3 lab hrs per wk)

21. Kinematics and Mechanisms. Displacement, velocity, and acceleration analysis of basic mechanisms. Analysis and design of cams and gears. (3 cr; prereq EG 16, ITM 26A or ¶ITM 26A; 2 lect and 2 lab hrs per wk)

22. Mechanisms of Automatic Machines. Analysis of various mechanisms, automatic transmissions, vending machines, feeding devices, packaging machinery. (3 cr; prereq 21; 2 lect and 3 lab hrs per wk)

23. Dynamics of Machinery. Study of combined static and inertia forces in machinery. Analysis of energy cycle diagrams. (3 cr; prereq 22, MM 29; 2 lect and 3 lab hrs per wk)

24. Elements of Machine Design. Applications of the fundamentals of stress analysis in the design of machines. Analysis of machine elements. (3 cr; prereq MM 41; 2 lect and 3 lab hrs per wk)

30-31-32. Thermodynamics. Properties and processes for working fluids in engineering devices. Application of the fundamental laws correlating energy with heat and work. (3 cr per qtr; prereq ITM 26A or ¶ITM 26A, Phys 14; 3 rec hrs per wk)

33. Mechanical Engineering Laboratory I. Principles of industrial measuring instruments. Humidity, pressure, vacuum, level, area, and temperature measuring systems. Telemetering and calibration procedures. (2 cr; prereq 30 or ¶30; 1 lect and 3 lab hrs per wk)

34. Mechanical Engineering Laboratory II. Dynamic response of instrument measurements, measuring systems for flow, viscosity, specific gravity, speed, and power. Gas analysis, calorimetry and other instrumentation procedures. (2 cr; prereq 33; 1 lect and 3 lab hrs per wk)

90-91-92-93.† Industrial Assignment. Co-operative work-study curriculum, industry laboratory quarters (work periods). Grades are based on a formal written report by the student, covering his work during the industrial assignment. (4 cr per qtr; prereq regis in co-operative work-study program)

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

110. Control of Metal Working Processes. Inspection by X-ray, gamma-ray, magnetic particle, metallographic, and chemical methods. (3 cr; prereq 15, 16; 1 lect and 6 lab hrs per wk)

111. Advanced Casting Processes. Advanced techniques and new developments in molding and casting; foundry control procedures. (3 cr; prereq 110; 2 lect and 3 lab hrs per wk)

112. Properties and Fabrication of Plastics. Materials, equipment, and processes for fabrication of plastics. Plastic product and mold design. (3 cr; prereq 15, 16 or ♯; 2 lect and 3 lab hrs per wk)

113. Advanced Metal Cutting. Advanced machine tool operation. Selection, tooling, and set-up of machine tools for production. (3 cr; prereq 15, 16; 1 lect and 6 lab hrs per wk)

114. Advanced Welding. Theory and applications of welding processes; factors affecting weldability; considerations in the design of weldments. (3 cr; prereq 15, 16; 2 lect and 3 lab hrs per wk)

115. Control of Manufacturing Standards. Precision measuring instruments and gauges for dimensional control in interchangeable manufacture. (3 cr; prereq 15, 16; 1 lect and 6 lab hrs per wk)

119. Design for Casting, Forming, and Welding. Basic factors in the design of parts and structures for most efficient processing and fabrications and maximum performance. (3 cr; prereq 15, 16; 1 lect and 6 lab hrs per wk)

121. Machine Design. Advanced machine elements. Design practice and machine layout. Analysis of complete machines. (3 cr; prereq 24; 2 lect and 3 lab hrs per wk)

122. Mechanical Engineering Design. Advanced statics, dynamics, and stress analysis applied to machines. Special design problems. (3 cr; prereq 121; 1 lect and 6 lab hrs per wk)

123. Creative Engineering. Application of fundamentals of engineering design with emphasis on creative aspects. (3 cr; prereq 4th-yr engr; 1 lect and 6 lab hrs per wk)

124. Experimental Stress Analysis. Experimental application and theoretical evaluation of the methods of stress analysis. Strain gauges, surface coatings, photoelasticity, dynamic stress measurements, penetration methods, and fracture methods. (3 cr; prereq MM 41; 2 lect and 3 lab hrs per wk)

125. Machine Design Laboratory. Use of vibration instruments, stroboscopes, sound meters and analyzers, photoelastic, polariscope, electronic measuring devices and testing machines. (2 cr; prereq 24; 1 lect and 3 lab hrs per wk)

127. Lubrication. Hydrodynamic theory of lubrication. Bearing design and construction, laboratory tests on 8-inch journal bearings. (3 cr; prereq 121; 3 lect hrs per wk)

128. Photoelastic Stress Analysis. Fundamentals of advanced stress analysis. Theory of photoelasticity and operation of polariscopes. Applications to solutions of special design problems. (3 cr; prereq MM 41; 2 lect and 3 lab hrs per wk)

129. Vibration Engineering. Advanced vibration theory with application to vibration absorption and isolation. (3 cr; prereq MM 193; 3 lect hrs per wk)

133. Heat Transmission. Introduction to conduction, convection, and radiation of heat and their utilization in engineering applications. Discussions of heat exchangers. (3 cr; prereq 32 and Hydr 101 or 103 or ¶Hydr 101 or 103...or Hydr 101 or 103 and ‡; 3 lect or rec hrs per wk)

134. Thermodynamics of Fluid Flow. Thermodynamic analysis of internal flow of viscous and compressible fluids. Applications to various flow processes and components in engineering systems. (3 cr; prereq 32, Hydr 103; 3 rec hrs per wk)

136. Reactor Heat Transfer. Heat conduction with internal heat generation, thermal stresses, liquid metal heat transfer, forced convection in noncircular ducts, boiling and two-phase flow. (3 cr; prereq 133 or equiv; 3 rec hrs per wk)

141. Heat Power Engineering. Application and control of fuels and combustion and applications of thermodynamics and heat transmission to steam power and process engineering. (3 cr; prereq 32; 3 rec hrs per wk)

142. Advanced Heat Power Engineering. Exploration of potentially fruitful areas of power plant progress; performance limiting elements in a power system that control its competitive position in present and future power plants. (3 cr; prereq 141; 3 rec hrs per wk)

143. Turbomachinery. Theoretical analysis of energy transfer between fluid and rotor, principles of axial, mixed, and radial flow compressors and turbines. Applications to gas turbines, fluid transmissions and power plants. (3 cr; prereq 134 or ¶134; 3 rec hrs per wk)

146. An Introduction to Combustion. Flame propagation, quenching and ignition in a homogeneous gaseous mixture; combustion of solid and liquid particles, packed beds, and gaseous jets. (3 cr; prereq 133 or ¶133; 3 rec hrs per wk)

147. Heat Power Design. Design methods for internal combustion engines, steam power plants, and other power generation systems. Detail design and layout of specific devices. (3 cr; prereq 143, 146; 1 lect and 6 lab hrs per wk)

150. Internal Combustion Engines. Principles of spark ignition engine, fuel-air cycle analysis, combustion flames, knock phenomena, air flow and volumetric efficiency, mixture requirements, ignition requirements and performance. (3 cr; prereq 32; 3 rec hrs per wk)

151. Advanced Internal Combustion Engines. Principles of supercharging, turbocharging and compounding, heat transfer in air and liquid cooled cylinders, chemistry of fuels, knock sensitivity, deposits and preignition, engine lubrication, wear and contaminant control. (3 cr; prereq 150; 3 rec hrs per wk)

152. Diesel and Free Piston Engines. Principles of the Diesel engine and free piston gasifier, combustion of stratified charge, theory of fuel spray formation and vaporization, hydraulic phenomena in fuel injection systems, air flow, scavenging processes, and performance. (3 cr; prereq 150; 3 rec hrs per wk)

154. Design of Internal Combustion Engines. Principal components, piston, rod, crankshaft, and valve mechanism, or compressor and turbine for compounded engine. (3 cr; prereq 121 and 150; 3 rec hrs per wk)

155. Rocket Propulsion. Mode of operation and performance limitations of: chemical rockets with liquid, solid and free radical propellants, nuclear and solar rockets with thermal and electromagnetic propellant acceleration. (3 cr; prereq 134 and 146...or 146 and Aero 102A; 3 rec hrs per wk)

157. Gas Turbine and Jet Propulsion Power Plants. Gas turbine and ramjet cycles and principles; characteristics of compressors and turbines; power and efficiency calculations. (3 cr; prereq 143; 3 rec hrs per wk)

158. Aircraft Power Plant Laboratory. Laboratory performance of piston engine and jet engine components, heat balance analysis, characteristics of compres-

sor, turbine, and combustion chambers, fuels and lubricant properties. (2 cr; prereq 143, 146; 1 lect and 3 lab hrs per wk)

159. Heat Power Laboratory. Laboratory performance of gasoline and Diesel engines, steam turbines and engines, also characteristics of nozzles and ejectors. Analysis of indicator diagrams. Correlation of test data with theory and practice. (2 cr; prereq 143, 146; 1 lect and 3 lab hrs per wk)

160. Psychrometrics and Air Conditioning. Atmospheric environmental control and relation to human comfort. Psychrometers, air distribution, air cleaning. Heat transmission in building materials. (3 cr; prereq 133 or ¶133; 3 lect hrs per wk)

161. Heating and Air Conditioning Design. Application of the fundamentals to the design of year around heating and air conditioning systems; heating and cooling loads, fluid flow in systems, warm air, hot water, steam heating, and heat transfer components. (3 cr; prereq 160 and 180; 1 lect and 6 lab hrs per wk)

163. Principles of Particle Technology. Definition, theory, and measurement of particle properties, particle dynamics, size distributions, and characteristics of powders encountered in particle transport, gas cleaning, and particle processing. (3 cr; prereq 32 or ♯; 3 lect hrs per wk)

166. Industrial Ventilation and Exhaust System. Contaminants, dispersion mechanisms, fans, injectors, natural drafts, and control velocities as applied to manufacturing and processing systems. (3 cr; prereq 160; 3 lect hrs per wk)

169. Air Conditioning and Refrigeration Laboratory. Experimental studies of heating, air conditioning, and refrigeration equipment. Correlation of test data with theory. (2 cr; prereq 34, 160 and 180; 1 lect and 3 lab hrs per wk)

170. Tool Design. Design of jigs, fixtures, and dies for machining, forming, welding, and assembly operations. (3 cr; prereq 15, 16; 1 lect and 6 lab hrs per wk)

180. Mechanical Refrigeration. Applied thermodynamic studies of single-stage and two-stage vapor cycles, air cycle, steam jet, and absorption systems. Refrigerants, refrigeration equipment. (3 cr; prereq 32; 3 lect hrs per wk)

181. Advanced Mechanical Refrigeration. Low temperature refrigeration methods including multi-stage and other vapor cycle systems; production of dry ice; liquefaction of gases. The heat pump and other special topics. (3 cr; prereq 180; 3 lect hrs per wk)

194. Advanced Engineering Problems. Work pertaining to special investigations in the various fields of mechanical engineering. (2-4 cr; open only to 5th-yr ME with a minimum 2.5 grade point average; prereq consent of chief of division concerned)

198. Industrial Instrumentation and Automatic Control. Theory and operation of instruments and automatic controls. Domestic and industrial control mechanisms. On-off, proportional, floating, and rate response in control instruments. (3 cr; prereq EE 38 or ¶EE 38; 2 lect and 3 lab hrs per wk)

199. Servomechanisms. Study of basic servomechanisms. Mechanical and electrical error indicators. Analysis of various types of damping. (3 cr; prereq EE 37, ITM 26A; 2 lect and 3 lab hrs per wk)

For Graduate Students Only

224-225-226. Advanced Applied Dynamics. Ryan

228. Photoelasticity. Ryan

229. Advanced Vibration Engineering. Ryan

230. Advanced Thermodynamics. Ibele

231. Statistical and Nonequilibrium Thermodynamics. Ibele

232. Advanced Thermodynamics of Fluid Flow. Ibele

233. Conduction. Eckert

234. Convection. Eckert

235. Radiation. Eckert

242. Advanced Power Plants. Lee

246. Flames in Homogeneous Mixtures. Blackshear

247. Diffusion Flames. Blackshear

248. Atomization Vaporization and Mixing. Blackshear
250. Dynamics of High Speed Engines. Murphy
253. Advanced Gas Turbines and Jet Propulsion. Murphy
255. Advanced Rocket Propulsion. Blackshear
265. Advanced Psychrometric Theory and Atmospheric Environmental Control. Threlkeld
266. Advanced Psychrometric Processing. Threlkeld
267. Advanced Air Conditioning. Threlkeld
280. Theoretical Refrigeration. Jordan
282. Reverse Applications of Refrigeration—Heat Pump. Jordan
290-291-292. Mechanical Engineering Research
293. Graduate Seminar
296-297. Advanced Servomechanisms. Ogata
298. Advanced Instrumentation and Automatic Control. LaJoy

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 in inorganic chemistry) Joseph
12. Metallurgical Processes. Introduction to the principles of process metallurgy. Survey of iron and steel processes and important nonferrous processes. (3 cr; prereq 8 cr in inorganic chemistry) Bitsianes
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 in inorganic chemistry) Bitsianes
107. Principles of Process Metallurgy. Phases in pyrometallurgical systems. Process classification: roasting, agglomeration, matte and reduction smelting. (3-4 cr depending on lab; prereq 106) Bitsianes
108. Principles of Process Metallurgy. Converting, metal refining, retorting, hydrometallurgical processes, electrolytic methods. (3-4 cr depending on lab; prereq 107) Bitsianes
110. Mineral Dressing. Theory and practice of comminution. Volumetric and gravimetric sizing. Principles of the movement of solids in fluids. Laboratory investigation of crushing, grinding, size analysis, and size of liberation of ores. (4 cr) Cooke
111. Mineral Dressing. Principles of ore beneficiation by gravity, magnetic, and electrostatic processes. Material balances. Laboratory examination and concentration of ores. (4 cr; prereq 110) Cooke
112. Mineral Dressing. Principles of flotation in ore concentration. Theory of frothing, collecting, depression, activation, conditioning. Integration of processes into flowsheets. (4 cr; prereq 111) Cooke
118-119-120.‡ Metallurgical Engineering Practice. Report writing on current problems in mineral dressing and in ferrous and nonferrous metallurgical practice. (Cr ar; prereq ‡) Staff

121. Iron Ore Beneficiation. Principles and methods. Metallurgical and economic factors in the concentration of iron ores. (3 cr; prereq 111; 2 lect and 3 lab hrs per wk) Wade

122. Advanced Mineral Dressing. Advanced flotation theory and special research techniques. (3 cr; prereq 112) Cooke

123. Advanced Mineral Dressing. Determination of methods for economic extraction of minerals from ores. (3 cr; prereq 122) Cooke

124-125-126.*‡ Special Problems in Mineral Dressing. (Cr and hrs ar; prereq 112) Cooke

134.* Metallurgical Unit Processes. Physico-chemical principles as applied to the unit processes. Slag-metal equilibria, kinetics of metallurgical reactions, slag constitution. (3 cr; prereq 108) Bitsianes

135.* Metallurgical Unit Processes. Gas-solid processes. Blast furnace smelting, control of slag-metal and gas-solid reactions. Oxygen-enriched blast and high top pressure. (3 cr; prereq 11) Joseph

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

138. Advanced Process Metallurgy. Application of physical chemistry to some advanced problems in process metallurgy. Heterogeneous chemical reactions. (2 cr; prereq 134) Bitsianes

141-142-143.‡ Special Problems in Process Metallurgy. Laboratory investigation of problems involved in metallurgical unit processes. (Cr and hrs ar; prereq 108) Joseph, Bitsianes

144. Metallurgical Unit Operations. Preparation, handling, and control of particulate solids and of their fluid suspensions. (2 cr; prereq 111 or ‡) Schulz

For Graduate Students Only

201-202-203.*‡ Research in Process Metallurgy. Bitsianes, Joseph

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

210-211-212.*‡ Seminar in Metallurgical Engineering. Staff

220. Flotation Theory. Cooke

Metallurgy (Met)

(Department of Metallurgy, School of Chemistry)

1. Metallurgy Laboratory. The field of metallurgy, what a metallurgist does, experiments demonstrating the behavior of metals and alloys. (1 cr; 1 hr per wk) Staff

53. Principles of Physical Metallurgy I. Atomic structure, crystal structure of metals, Hume-Rothery rules, elements of phase diagrams. (3 cr; prereq 3rd yr) Nicholson

53A. Laboratory in Physical Metallurgy. (2 cr; prereq ¶53) Nicholson

56. Physical Metallurgy. (MechE, MinE, PetE, IndAdm) Introductions 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, Sivertsen, Swalin

57. Physical Metallurgy of Industrial Alloys. Alloy steels, stainless steels, high temperature alloys, alloys of aluminum, copper, and nickel. (2 or 3 cr depending on lab; prereq 53 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

154.* Principles of Physical Metallurgy II. Transformations in solids, precipitation hardening, order-disorder, the iron-carbon diagram, heat treatment. (3 cr; prereq 53 or ‡) Jerabek

154A. Laboratory in Physical Metallurgy. (2 cr; prereq ¶154) Jerabek

155.* Principles of Physical Metallurgy III. Plastic deformation of metals, dislocation theory, structure of cold worked metal, recovery and recrystallization, preferred orientation. X-ray metallography. (3 cr; prereq 154 or ♯) Sivertsen

155A. Laboratory in Physical Metallurgy. (2 cr; prereq 154 or ¶155) Sivertsen

158. Principles of Metal Fabrication. General principles of fabrication from a 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) 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 PCh 101) Nicholson

162. Nuclear Metallurgy. Nature of radiation damage and effects of neutron irradiation on the properties of crystalline materials. (1 cr; prereq 56 or equiv or ♯; 1 lect hr per wk) Swalin

165.* Engineering Physical Metallurgy. Corrosion, protective coatings, surface hardening, casting, forming, welding, powder metallurgy. (3 cr; prereq 56 or 60 or 154) Jerabek

170-171-172.‡ Special Problems in Physical Metallurgy. Laboratory investigation. (1, 2, or 3 cr per qtr) Nicholson, Jerabek, Swalin

173. Crystalline Properties of Metals. An introduction to the geometry and properties of metal crystals. Topics to be discussed are X-ray diffraction, electrical and thermal conductivity, Hall effect, optical properties, and elastic and plastic behavior of metals. (3 cr; prereq 155) Sivertsen

174.* Modern Theory of Metals and Alloys. Free electron theory of metals and application. Imperfection in crystals. (3 cr; prereq Phys 51 or ♯) Sivertsen

175. Imperfections in Metals. Theory of imperfections and their effects on properties of metals. (3 cr; prereq 174 or ♯) Sivertsen

180-181-182. Thermodynamics of Alloys and Solid State Reaction. Theory of liquids, heterogeneous equilibria, free energy-composition diagrams and reaction kinetics. (3 cr per qtr; prereq PCh 103 or ♯) Swalin

For Graduate Students Only

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

213-214-215.‡ Seminar in Physical Metallurgy. Staff

250.* Thermodynamics of Alloys. Swalin

251-252. Kinetics of Solid State Reactions. Swalin

260-261.* Dislocation Theory of Crystals. Nicholson, Johnston

263. Advanced X-ray Diffraction of Metals. Nicholson, Sivertsen

Military Science (Mil)

(Department of Military Science and Tactics)

1-2-3. Military Science I. (First Year Basic) Organization of the Army and ROTC; individual weapons and marksmanship; American military history; school of the soldier and exercise of command. (1 cr per qtr; 3 hrs per wk)

4-5-6. Military Science II. (Second Year Basic) Map and aerial photograph reading; crew-served weapons and gunnery; school of the soldier and exercise of command. (1 cr per qtr; prereq 1-2-3 or 6 months of military service; 3 hrs per wk)

151-152-153. Military Science III. (First Year Advanced) Leadership; military teaching methods and rifle marksmanship; organization, function, and missions of the branches of the army; small unit tactics and communications;

school of the soldier and exercise of command. (3 cr per qtr; prereq 4-5-6 or 1 yr military service; 5 hrs per wk)

154-155-156. Military Science IV. (Second Year Advanced) Operations, logistics, military administration and personnel management, service orientation, school of the soldier, and exercise of command. (3 cr per qtr; prereq 151-152-153; 5 hrs per wk)

Mining Engineering (MinE)

1. Mineral Engineering Laboratory. The fields of geophysics and of mining, geological, petroleum, and metallurgical engineering described in lectures, laboratories, and field trips. (1 cr; 1 hr per wk) Staff

13. Mine Surveying. Mining claims, bore holes, shaft plumbing, underground traversing, and leveling. (3 cr per qtr; prereq CE 18 or ‡; 3 lect and 1 quiz hr per wk) Yardley

14. Surveying Field Work. General work with mine surveying equipment in preparation for MinE 15, underground surveying in Iron Ranges. (Cr ar; prereq ¶13; offered when feasible)

15A. Mine Surveying Field Work. Surveying of an underground mine located on Iron Range, including shaft plumbing. Survey of an open-pit mine, including an estimate of surface stripping. Solar and stellar observations. Study of mining operations and plants for 1 week. (6 cr; prereq 13; 4 wks beginning about June 15) Yardley, Lacabanne

15B. Mine Surveying Field Work. Same as 15A, but without 1 week study of mining operations. (5 cr; prereq 13; 3 wks beginning about June 15) Yardley, Lacabanne

16. Mine Maps. Various methods of mine mapping; preparation of map from mine survey notes taken in MinE 15A or 15B. Ore estimates. (1-2 cr; prereq 15A or 15B; 3 lab hrs per wk)

70. Principles of Mining. Nongeologic factors as determinants of ore. Weighting and combining of samples, reliability of ore estimates. Principles and techniques of development and mining systems. Designed to provide general knowledge of mining. (3 cr; prereq ‡) Yardley

90-91-92. Industrial Employment. Summer work in the mineral industries for a period of 2 or more months. Character of work to be approved by the department. Satisfactory record of employment and an acceptable report required. (2 cr per course; prereq ‡)

111. Exploration of Mineral Deposits. Principles and techniques of prospecting and exploration. Factors in evaluating mineral deposits. Theory of combining core and sludge analyses. (3 cr; prereq 3rd yr or ‡; 4 lect hrs per wk) Yardley

112. Development of Mineral Deposits. Blast hole drilling, selection and use of explosives, haulage, development of underground deposits, timber treatment. (3 cr; prereq 111 or ‡; 4 lect hrs per wk) Yardley

113. Exploitation of Mineral Deposits. Rock stresses and failure. Shafts, hoisting, mine drainage. Support of excavations and underground mining methods. (3 cr; 112 or ‡; 4 lect hrs per wk) Pfleider

121. Mine Plant Engineering. Basic engineering principles in design and selection of mine plant equipment. Calculations involving power transmission and drilling, transporting, and hoisting of materials. (3 cr; prereq 113, MM 28, or ‡; 2 lect and 4 lab hrs per wk) Roberts, Fairhurst

122. Mine and Petroleum Plant Engineering. Basic engineering principles in design and selection of mine and petroleum plant equipment. Calculations involving compressed air, pumping, transmission of gases and fluids, electrical equipment, and power systems. (3 cr; prereq Hydr 103, ME 30 or ‡, EE 37; 3 lect and 3 lab hrs per wk) Roberts, Fairhurst

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 113, Hydr 103; 3 lect and 3 lab hrs per wk) Roberts, Fairhurst

131. Rock Mechanics I. Stress and strain in 2 and 3 dimensions. Theoretical solutions for stress around mine openings. Physical properties and behavior of

rocks under stress. Rock support and failure in mines. (3 cr; prereq MM 142 or #; 3 lect hrs per wk) Fairhurst

132. Rock Mechanics II. Design of mine openings. Measurement of stresses around mine openings. Determination of physical properties of rock. Model investigations using strain gauge and photoelastic methods. Elastic wave propagation in blasting. Hydrodynamic theory of explosive detonation. (3 cr; prereq 131; 2 lect and 3 lab hrs per wk) Fairhurst

133. Advanced Rock Mechanics. Current theories of rock failure. Rock bursts, subsidence phenomena. Influence of geology on mine layout. Seismic and photographic studies of rock failure by blasting and high earth pressure. Mechanics of drilling, blasting, crushing operations. (3 cr; prereq 132 or #; 3 lect hrs per wk) Fairhurst

139. Inspection Trip. Study of mining operations, mine plant, and metallurgical plants in several mining camps. Engineering report. (3 cr; prereq #; 2 wks beginning about September 15)

141. Mineral Economics. Forecasted demands, resources, and conservation of minerals. Mine and oil field examinations and valuation. Costs, taxation, depletion. Organization and administration. (3 cr; prereq 113 or PetE 112 or #; 4 lect hrs per wk) Pfleider

142. Surface Mining Engineering. Development, engineering, planning, and operation of open-cut properties. Drilling, blasting, excavation, and transportation. Quarries methods, equipment, field for product. Placers dredging, hydraulicking. (3 cr; prereq 112 or #; 4 lect hrs per wk) Pfleider

143. Coal Mining Engineering. Economics and technology of coal. Production and preparation, including mining methods and mechanization. Time-study applications. Mine gases; safety work and organization. (3 cr; prereq 113; 4 lect hrs per wk) Yardley

144-145. Advanced Mining Engineering. Preparation of a report on a mining property or some phase of the mineral industry. (2 cr for 144, 4 cr for 145; prereq 141; 6 lab hrs per wk for 144, 10 lab hrs per wk for 145) Pfleider and staff

151-152-153.*‡ Special Mining Engineering Problems. Literature survey or research work on mining problems. (Cr and hrs ar; prereq 113)

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

180.* Geochemical Exploration. Application of geochemical techniques and principles to the search for orebodies. Laboratory work on geochemical methods for the determination of total and specific heavy metal content of rocks, soil, water, and plants. (3 cr; prereq #; 2 lect and 2 lab hrs per wk) Yardley

For Graduate Students Only

201-202-203.*‡ Mineral Engineering Seminar. Pfleider and staff

210.* Engineering Report. Pfleider

212-213-214.*‡ Mining Research Problems. Pfleider and staff

220. Advanced Mine Air Conditioning

230.* Advanced Geochemical Exploration. Yardley

240.* Advanced Concepts in Drilling of Rocks. Pfleider

Naval Science (Nav)

(Department of Naval Science)

LOWER DIVISION

11. Naval Orientation. Organization, functions, and mission of the Navy and the Department of Defense; duties and responsibilities of a naval officer; types and characteristics of ships. (3 cr)

12. **Sea Power.** Naval history and sea power; fundamental concepts of sea power; the principles of naval warfare; global geography and the evolution of sea power. (3 cr)
13. **Sea Power.** Naval history and sea power; history of the United States Navy; the evolution of sea power; seamanship. (3 cr)
22. **Naval Weapons.** (3 cr)
23. **Naval Weapons.** (3 cr)

UPPER DIVISION

I. Line Sequence

51. **Naval Engineering.** (3 cr)
52. **Naval Engineering.** Introduction to celestial navigation. (3 cr)
53. **Celestial Navigation.** (3 cr)
61. **Naval Operations.** (3 cr)
62. **Naval Operations, Leadership.** (3 cr)
63. **Leadership.** (3 cr)

II. Supply Corps Sequence

57. **Organization and Logistics; Naval Finance.** (3 cr)
58. **Naval Accounting; Basic Supply Afloat.** (3 cr)
59. **Advanced Supply Afloat.** (3 cr)
67. **Ships Store Afloat; Clothing and Small Stores.** (3 cr)
68. **Commissary.** (3 cr)
63. **Leadership.** (3 cr)

III. Marine Corps Sequence

54. **Evolution of the Art of War I.** (3 cr)
55. **Evolution of the Art of War II.** (3 cr)
56. **Modern Basic Strategy and Tactics.** (3 cr)
64. **Amphibious Warfare I.** (3 cr)
65. **Amphibious Warfare II.** (3 cr)
66. **Leadership.** (3 cr)

Petroleum Engineering (PetE)

90-91-92. **Industrial Employment.** Summer work in the petroleum industry or an allied field for a period of 2 or more months. Character of work to be approved by the department. Satisfactory record of employment and an acceptable report are required. (2 cr per course; prereq ♯)
111. **Oil Field Development.** Drilling and completion of oil wells, methods and equipment involved. Problems and protection of completed well; directional drilling, well surveying; electrical and mechanical logging and other methods of securing underground information; well records. (3 cr; prereq Geol 25 or ♯; 4 lect hrs per wk) Lacabanne
112. **Oil Field Production.** Principles and methods. Petrophysics of oil reservoirs, oil and gas phase relations under reservoir conditions; condensate fields; sand drainage; oil reservoir performance; lifting oil; secondary methods of recovery; gas wells. (3 cr; prereq 111 or ♯; 4 lect hrs per wk) Lacabanne
131. **Reservoir Mechanics.** Reservoir rocks, fluids, forces, and classification of energies. Rock-fluid systems and equations of flow for principal reservoir drives. (3 cr; prereq 134, Hydr 103 or ♯)
134. **Natural Gas Engineering.** Properties of natural gas, gravities. etc. Critical condition of gases, deviations, compressibility factor, reduced and pseudo

states; retrograde condensation. Estimation of gas reserves. Orifice meters, measurement of gas flow. Gas well capacities by back pressure. Gas hydrates. (2 cr; prereq 112 or #; 2 lect hrs per wk) Lacabanne

135. Engineering Study Through Field Trip of Several Oil Fields. Oil well drilling, production methods, refining practices, reservoir features, etc. (3 cr; prereq #; 2-wk field trip ar) Lacabanne

144-145. Advanced Petroleum Engineering. Preparation of report on the exploration and development of an oil property or some phase of the industry. (2 cr for 144, 4 cr for 145; prereq MinE 141; 6 lab hrs per wk for 144, 10 lab hrs per wk for 145) Pfleider

152-153-154. Petroleum Production Technology. Problems in oil and gas production. Mud fluids, core analysis, permeability and porosity, electrical and mechanical coring and other logging methods, oil well cements, oil flow and drainage through porous formations, water analysis, problems. (3 cr per qtr; prereq 112 or #; 1 lect and 6 lab hrs per wk) Lacabanne

155-156-157.*‡ Special Problems in Petroleum Engineering. Seminar in petroleum problems. (Cr and hrs ar; prereq ¶144 or ¶145 or #) Lacabanne

For Graduate Students Only

201-202-203. Petroleum and Natural Gas Engineering Seminar. Lacabanne

206.* Engineering Study of an Oil Field. Lacabanne, Pfleider

207-208-209.*‡ Research Problems in Petroleum Engineering. Lacabanne, Pfleider

Philosophy (Phil)

(College of Science, Literature, and the Arts)

1. Problems of Philosophy. Introduction; main fields of investigation; permanent problems; principal methods and schools of philosophy; historical and contemporary views. (5 cr; prereq 3rd qtr fr)

2. Logic. Difference between logical and fallacious reasoning; the functions and uses of language; rules of good definition and sound argument. (5 cr) Staff

3. Ethics. Examination of the problems which arise when human beings attempt to think systematically about conduct and values (are there absolute standards?), the problem of free will, and a survey of historical views about the right and the good. (5 cr; prereq 3rd qtr fr)

10. Science and Religion. Inquiry into nature of science and religion as currently interpreted, with an attempt to find grounds of conflict and/or reconciliation. (2 cr; prereq soph)

40. Logic of Scientific Reasoning. Introduction to the principles of scientific method; definition and classification; observation, measurement, experiment; elementary statistical concepts; hypotheses, theories, evidence, and confirmation; nature and limits of the scientific enterprise. (3 cr; prereq 2; offered when feasible)

Physics (Phys)

1-2-3. Introduction to Physical Science. Demonstration lectures on the principles of physics and physical phenomena underlying these principles. (3 cr per qtr; prereq high school algebra and plane geometry for 1, 1 for 2 and 3; 3 lect hrs per wk)

1A-2A-3A. Introduction to Physical Science Laboratory. Laboratory course given in conjunction with Phys 1-2-3. (1 cr per qtr; prereq 1-2-3 or ¶1-2-3; combination of 1-2-3 with 1A-2A-3A may be used to fulfill the laboratory-science group requirement)

4-5-6. General Physics. (Primarily for Premed) 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)

7-8-9. General Physics. Mechanics, heat, electricity, sound, and light. Laboratory work an integral part of course. (5 cr per qtr; prereq ¶ITM 13A or Math 40 for 7...¶ITM 24A or Math 53 for 8...¶ITM 25A or Math 54 for 9; 4 lect, 1 quiz, and 2 lab hrs per wk; courses must be taken in order)

11-12-13. General Physics. Mechanics, heat, electricity, sound, and light. (5 cr per qtr; prereq ¶ITM 11 or ¶Math T for 11...¶ITM 12 or ¶Math 10 for 12...¶ITM 13A or ¶Math 40 for 13; 4 lect, 1 quiz, 2 rec, and 2 lab hrs per wk for 11...4 lect, 1 quiz, and 2 lab hrs per wk for 12 and 13; courses must be taken in order)

14. Intermediate General Physics. Selected topics in mechanics, thermodynamics, and electromagnetism. (4 cr; prereq 11-12-13, and ¶ITM 24A or Math 53; 4 lect and 1 quiz hrs per wk)

14A. Physics Laboratory. Parallel to Phys 14. (1 cr; prereq ¶14; 2 lab hrs per wk; optional course)

50. Intermediate General Physics. Introductory course in atomic physics, including elements of kinetic theory and atomicity of matter. (4 cr; prereq 6, 9 or 14, ¶ITM 25A or Math 54; 4 lect and 1 quiz hrs per wk)

50A. Physics Laboratory. Parallel to Phys 50. (1 cr; prereq ¶50; 2 lab hrs per wk; optional course)

51. Intermediate General Physics. Selected topics in wave motion and nuclear physics. (4 cr; prereq 50 and ITM 25A or Math 54; 4 lect and 1 quiz hrs per wk)

51A. Physics Laboratory. Parallel to Phys 51. (1 cr; prereq ¶51; 2 lab hrs per wk; optional course)

70. Industrial Summer Employment. Employment with an industrial firm in a professional or semiprofessional capacity doing work in the field of physics. Applications must be approved by the department prior to employment. Ten weeks of summer employment with a written report on this work approved by both employer and the department. (1 cr; prereq 3 yrs academic work plus △ during previous spring qtr)

100-102-104. Mechanics and Electromagnetism. Theoretical course in mechanics, electricity, and electromagnetism designed to prepare students for advanced work. (4 cr per qtr, §MM 29 and Phys 100; prereq 3rd yr, 9 or 14, ITM 26 or 26A or Math 55 for 100...100 or MM29 for 102...102 for 104)

101-103-105.‡ Theoretical Physics. Fundamental principles of mechanics, thermodynamics, kinetic theory of gases, electricity, and magnetism. Supplements the general course and prepares students for more specialized graduate courses. (3 cr per qtr; prereq 4th yr, 9 or 14, ¶differential equations or ♯; 3 lect hrs per wk)

107-109-111. Modern Physics. Emphasis on an interpretation of experimental phenomena. Topics include: atomicity of matter, special relativity, the nuclear atom, atomic and molecular structure and spectra, quanta and atoms, wave mechanics, nuclear physics, modern developments in classical physics, astrophysics, particle physics. (3 cr per qtr; prereq ITM 26 or 26A or Math 55, ♯ if taken out of sequence; 3 lect hrs per wk)

108-110-112. Principles of Atomic and Nuclear Physics. Analytical course, combining elementary quantum mechanics with its historical background and applications to atomic and nuclear physics. Topics include: special relativity, origin of quantum theory, electrons and quanta, atomic structure, particles and waves, the theory of quantum mechanics, one-electron atoms, exclusion principle, multi-electron atoms, X rays, scattering, and nuclear physics. (3 cr per qtr; prereq 50, ITM 153 or Math 108, △)

114-116-118.‡ Elementary Physical Investigation. Problems, either experimental or theoretical, in which student may have some special interest. Written report required. (3 cr per qtr; prereq 3rd yr or above and △)

120. Atomic Physics. Laboratory course to introduce techniques and methods used in physics research laboratories. Vacuum gauges and systems, properties of charged particles, X-ray diffraction, ionization of gases, mass spectroscopy, photoelectricity, secondary electron emission. (3 cr; prereq 50 or ¶107; 8 hrs per wk)

121. Experimental Nuclear Physics I. Laboratory course not requiring extensive knowledge of electronic circuits. Natural radioactivity, cloud chambers, ionization chambers, properties of nuclear radiations, alpha, beta, and gamma

rays, neutrons; shielding artificial radioactivity, photographic techniques, health protection. (3 cr; prereq 50, 107; 8 hrs per wk)

122. Experimental Nuclear Physics II. Laboratory course in techniques in nuclear physics requiring knowledge of electronic circuits. Geiger, proportional, scintillation, and coincidence counters. Cosmic rays. Nuclear resonance phenomena. Health monitoring instruments. (3 cr; prereq 50, 107 or ♯; 8 hrs per wk)

123-124-125. Thermodynamics, Statistical Mechanics, and Theories of the Structure of Matter. Analytical course in the principles of thermodynamics and introductory statistical mechanics, with applications drawn from atomic and molecular physics and the physics of the liquid and solid states. Laws of thermodynamics, thermodynamic potential functions, equations of state, phase transitions; transport phenomena, ensembles of identical systems, classical and quantum statistics; thermal, electrical, and magnetic properties of matter. (3 cr per qtr; prereq 4th yr, 50, and ¶differential equations for 123...123 and ¶109 for 124...124 for 125)

126-127-128. Solid State Physics. Introduction to the physics of bulk matter. Structure and types of solids; ionic, molecular, and metallic solids; thermal, electrical, and magnetic behavior of matter; theory of conduction in metals and semiconductors; crystal imperfections and their effects. (3 cr per qtr; prereq 50 and ¶differential equations)

131. Geometrical Optics. Fundamentals of ray optics and a study of its applications to optical instruments and their components. (3 cr; prereq 3rd yr, 15 cr in physics, ITM 25A or Math 54; 3 lect hrs per wk)

133. Physical Optics. Wave theory of interference, diffraction, polarization, and double refraction, with a study of their applications. (3 cr; prereq 3rd yr, 15 cr in physics, ITM 25A or Math 54; 3 lect hrs per wk)

133A. Physical Optics Laboratory. Parallel to Phys 133. (1 cr; prereq ¶133; 3 lab hrs per wk; optional course)

134. Experimental Optics. Laboratory work in spectrometry, optics of compound lenses, photometry, absorption, interferometry, and polarized light. (3 cr; prereq 3rd yr, 15 cr in physics, ITM 25A or Math 54; 1 lect and 5 lab hrs per wk)

135. Spectroscopy. Light sources, instruments, and methods used in spectroscopy of the X-ray, ultraviolet, visible, and infrared regions of the spectrum. (3 cr; prereq 3rd yr, 15 cr in physics, ITM 25A or Math 54; offered when demand warrants)

136. Spectrum Analysis. Laboratory work dealing with the measurement of wave lengths, intensities, and absorption coefficients in the infrared, visible, and ultraviolet regions of the spectrum. (3 cr; prereq 3rd yr, 15 cr in physics, ITM 25A or Math 54; 1 lect and 5 lab hrs per wk)

144. Electrical Measurements. An experimental course covering ballistic and current galvanometers, magnetic flux measurements, potentiometer methods, D.C. bridges, and audiofrequency A.C. bridges. (4 cr; prereq 9 or 14 and ITM 25A or Math 54; 3 lect and 3 lab hrs per wk)

146. Physics of Vacuum Tubes and Associated Circuits. Thermionics and vacuum tube circuits, with emphasis on applications to physics research. (4 cr; prereq 144 or ♯; 3 lect and 3 lab hrs per wk)

148. Application of Electronic Circuits. Lecture and laboratory work on amplifiers, computing circuits, servomechanisms, regulating circuits, and other devices employed in physics research. (4 cr; prereq 146 or ♯; 3 lect and 3 lab hrs per wk)

181-183-185. Atomistics and Elementary Quantum Mechanics. An introduction to wave mechanics, atomic structure, and nuclear physics. (3 cr per qtr; prereq 101-103-105 or equiv or ♯)

191-192-193.‡ Intoduction to Mathematical Physics. Intensive treatment of the equations of mathematical physics using material drawn from the fields of mechanics, small vibrations of continuous media, acoustics, electromagnetic theory, and heat conduction. (3 cr per qtr; prereq 101-103-105 or equiv; differential equations and advanced calculus)

For Graduate Students Only

Prerequisites for the following courses are Phys 191-192-193 or consent. Additional prerequisites are noted for certain courses. A reading knowledge of German will be presumed in certain phases of the work.

201-202-203. Dynamics of Fluid Motion
204-205-206. Statistical Thermodynamics
207-208-209. Electrodynamics, Theoretical Optics, and the Theory of Relativity
210-211-212. Quantum Mechanics
213-214-215. Seminar in Contemporary Experimental Physics
216-217-218. Seminar in Contemporary Theoretical Physics
225-226-227. Advanced Quantum Theory. (Prereq 210-211-212)
228-229-230. Nuclear Physics. (Prereq 210-211-212 or 231-232-233)
231-232-233. Theory of Atomic and Molecular Structure
237-238-239. Seminar in Radiofrequency Spectroscopy
246-247-248. Cosmic Rays
249-250-251. Theory of the Solid State of Matter
252-253-254. Seminar in Nuclear Physics
255-256-257. Seminar in Mass Spectroscopy
258-259-260. Seminar in Cosmic Rays
264-265-266. Elementary Particle Physics
267-268-269. Atmospheric Physics
270-271-272. Special Topics in Nuclear Physics. (Prereq 228-229-230)
301-302-303. Research in Physics

The following courses will be offered when demand warrants:

234-235-236. Advanced Theory of Optics and Optical Instruments
261-262-263. Mathematical Foundations of Quantum Mechanics

Political Science (Pol)

(College of Science, Literature, and the Arts)

1-2.† American Government and Politics. Analysis of principles, organization, procedures, and functions of government in the United States—national, state, and local. Attention will be given throughout to current issues. (3 cr per qtr) Christensen, Flom

A-B.† The State in the Modern World. Examination of principles, structure, and operation of the modern state. Emphasis on nation state; historical development; democratic government: United States, Great Britain; totalitarian government: Nazi Germany, Soviet Russia; conflict between states. (3 cr per qtr) Lippincott, Holt

5. American Government and Politics. Covers most of Pol 1-2. (5 cr, §1-2)

25. World Politics. Introduction to contemporary international relations; the policies of the great powers; nationalism; imperialism; internationalism. (3 cr) Mills

Psychology (Psy)

(College of Science, Literature, and the Arts)

1-2.† General Psychology. General introduction to the study of human behavior. Prerequisite to all advanced courses in psychology. (3 cr per qtr; prereq 2nd

yr or 3rd qtr fr with B avg) Clark, Heron, Jenkins, LaBerge, Lofquist, MacCorquodale, and Senders

155. Industrial Psychology. Psychological problems in industrial production; biomechanics (the adaptation of the machine to the capacities and limitations of the operator), work and effort, and the role of communication in an industrial organization. (3 cr; prereq 1-2 and Math 10 or equiv, or 10 cr in statistics) Dunnette

Public Health (PubH)

(College of Medical Sciences)

2. Personal and Public Health. Individual and community activities for the promotion of health and safety. (2 cr, §3 or 3A or 3B or GC 10C)

3. Personal Health. Normal body function; causes and prevention of disease. (2 cr, §2 or 3A or 3B or 50 or GC 10C)

50. Personal and Community Health. Fundamental principles of health conservation and disease prevention. (3 cr, §3, 3A, 3B, 4, 51, 52, 100, or GC 10C)

75. Introduction to Environmental Sanitation. Principles of urban and rural sanitation relating to water, food, wastes, housing, air, insects, rodents. (3 cr; prereq 3 cr in public health or 50)

100A. Elements of Public Health. Occurrence and prevention of communicable, degenerative, and industrial diseases. Protection of food, water, and milk; maternal and child health. (3 cr; prereq 3 or 50, and course in bacteriology)

102. Environmental Sanitation I. Methods for promoting man's health and comfort by controlling environment. (3 cr; prereq 50 or ¶50, or 51 or ¶51, or 100A or ¶100A)

Rhetoric (Rhet)

(College of Agriculture, Forestry, and Home Economics)

22. Public Speaking. A practical course in the fundamentals of speechmaking. Emphasis upon organizing the speech and projecting it to the audience. (3 cr; prereq rhetoric communication requirement or equiv)

Social Science (SSci)

(College of Science, Literature, and the Arts)

1-2-3. Introduction to Social Science. An integrated study of the factors—historical, political, economic, social, psychological, and cultural—that influence and are influenced by man's conduct. The course is organized around three basic themes: (a) development of personality, (b) work as a central aspect of modern life, and (c) the quest for community. (4 cr per qtr) Blum, Cooperman, Sibley, and staff

Sociology (Soc)

(College of Science, Literature, and the Arts)

1. Man in Modern Society. Characteristics of human group life. Analysis of the factors associated with development of human group life and man's social environment; structure of the social environment and its influence upon individual's behavior. (3 cr) Sirjamaki

2. The American Community. Sociological analysis of modern American society. Topics emphasized include the distribution of population, urban-rural differences, social factors in the business systems, occupational groups, the determination of social status, and minority group adjustment. Attempts to familiarize student with current research methods. (3 cr; prereq 1 or 1A or 3) Martindale

14. Rural Sociology. Presentation of factual data necessary to an understanding of the problems of rural social life. (3 cr) Taylor

Soils (Soil)

(College of Agriculture, Forestry, and Home Economics)

19. Intermediate Soils. Basic physical, chemical, and microbiological properties of soils. Soil genesis, classification, and principles of soil fertility. Lectures, laboratory. (4 cr; prereq InCh 5)

20. Interpretation of Soil Information. Use and interpretation of soil surveys, land use capabilities, and physical properties. Soil tests and fertilizer recommendations. Use of soil research data. Lecture and laboratory. (3 cr; prereq 1 or 3 or 19)

123. Fertilizers. History of the fertilizer industry; manufacture, characteristics and use of the important fertilizer nutrients. (3 cr; prereq 3 or 19 or 119 or #)

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)

Zoology (Zool)

(College of Science, Literature, and the Arts)

1-2-3.† General Zoology. Structure, physiology, embryology, classification, and evolution of animals. (10 cr) Olson, Stephens, Kerr

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