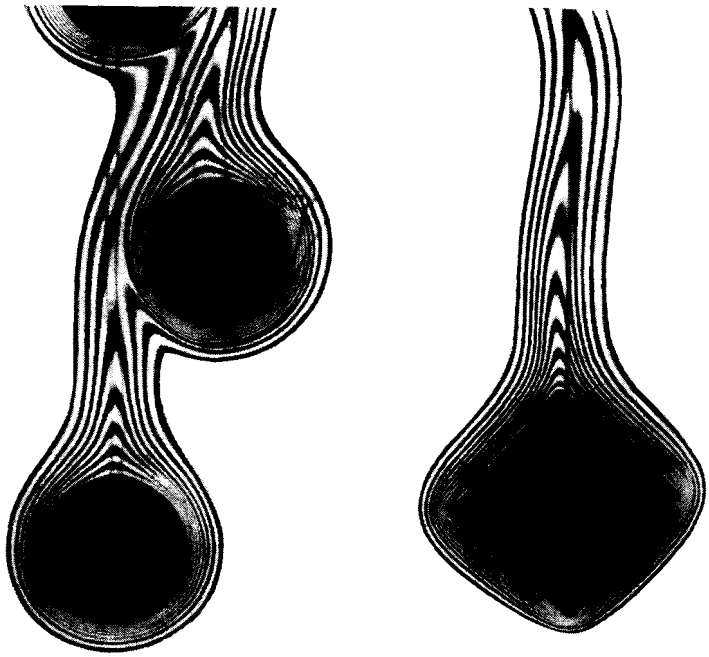
Bulletin of the

UNIVERSITY OF MINNESOTA



Institute of Technology 1957–1959

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 illustrated below.

Example		*Explanation*
10-11-12	(Hyphens)	Take the courses strictly in the order listed.
137*	(Asterisk)	Graduate students may prepare required Plan B papers.
10-11†-12	(Dagger)	Complete all courses preceding the dagger before getting any credit.
10-11-12‡	(Double dagger)	You may enter any quarter preceding the sign, e.g., 10, 11, or 12.
§7	(Section mark)	No credit given for the course described if you have credit for 7, an equivalent course.
¶8	(Paragraph sign)	You may enroll concurrently in both the course so marked and the course being described.
#	(Sharp)	Get the consent of the instructor before registering.
△	(Triangle)	Before registering, get consent at the office of the division, department, or school involved.
200 or above		Courses so numbered are for graduate students, and may be taken by fifth-year students only by specific permission of the dean of the Graduate School.
3rd yr		Class rank prerequisite for a course means that no one below that rank can register for the course without specific permission from the Scholastic Standards Committee.
prereq 89		A prerequisite course listed only by number is in the department offering the course being described.
prereq 6 cr		Prerequisite credits listed only by amount are those 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.

COVER PICTURE—The two photographs, taken with a Zehnder Mach interferometer, show two different tests to study heat transfer by free convection from heated horizontal tubes to the surrounding air. The dark circles and square represent the tubes and the lines surrounding them reveal the temperature and velocity field in the air.

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Institute of Technology

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College Offices

Office of the Dean, 107 Main Engineering
College of Engineering, 133 Main Engineering
School of Architecture, 310 Main Engineering
School of Chemistry, 139 Chemistry
School of Mines and Metallurgy, 103 Appleby Hall
School of Physics, 148 Physics

Volume LX Number 11 June 1, 1957

Entered at the post office in Minneapolis as semi-monthly second-class matter, Minneapolis, Minnesota. Accepted for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized July 12, 1918

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Gust Bitsianes, Ph.D.

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Iwao Iwasaki, Sc.D.

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Institute of Technology

I. GENERAL INFORMATION

General Objectives and Curriculums

Organization and Objectives—The Institute of Technology consolidates five related 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, in architecture, and in physics, and a 4-year curriculum in chemistry. 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

Certain departments provide that 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 manage-

ment, and operational research. Electrical and mechanical engineering are included in this combination.

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, mathematics, metallurgical, and mining) with work in the School of Business Administration culminates in a degree in engineering and another in business administration. A 4-year combination of courses in the College of Engineering and the School of Business Administration leads to a degree in business administration.

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

Admission Requirements

High School Course Requirements—To be admitted to the Institute of Technology, a high school graduate must be in the top half of his class and meet the special mathematics requirement.

In addition to the admission requirements detailed in the *Bulletin of General Information,* all incoming freshmen must take a mathematics test as a condition for registration in the Institute of Technology. This examination will be administered during the registration program. *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 English by the English assignment card, they must complete this course during the quarter assigned. No credit is given for this course. Registration for Preparatory English is in the General Extension Division in Nicholson Hall; a fee of $18 is charged.

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 courses:

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

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

(c) Registering in ITM 10 (information available at the College of Engineering Office, 133 Main Engineering).

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 and the architectural or the physics curriculum 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), and those entering the School of Mines and Metallurgy in Appleby Hall (AH 103). 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 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 68 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.

Work-Study Program—A co-operative work-study curriculum in mechanical engineering combining practical work experience with regular academic work is available through co-operation with nearby industrial concerns. Students in the work-study program are on a 12-month basis and spend alternate quarters in industry, starting with the summer or fall quarter following their second year. While on work assignments, they are paid at regular rates by the companies. Application should be filed at the Mechanical Engineering office by February 1 of the student's second year. Selection will be based on scholastic ability, aptitude for industrial work, and financial need.

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.

In the Institute of Technology it is possible to complete the requirements for a commission and also for the Bachelor's degree in the normal time allotted for each engineering curriculum.

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 him to be present. A student who has been absent from an examination and who does not present to the instructor an acceptable excuse 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 receipt 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 except in the School of Chemistry.

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 within the first 30 calendar days of his next quarter in residence, except the Summer Session, or the I will change to an F.

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.

Honor Point Ratio—The quality of work is indicated by honor points. Each credit with the grade of A carries 3 honor points; each credit with the grade of B, 2 honor points; each credit with the grade of C, 1 honor point. The grades of D and F carry no honor points.

The honor point ratio for determining probationary status is defined as the total number of earned honor points divided by the total number of credits earned and failed. Only credits and honor points earned while registered in the Institute of Technology are used in calculating the honor point ratio. For example, assume that the following grades were received 1 quarter:

3 credits of A—3 × 3 = 9 honor points
3 credits of B—3 × 2 = 6 honor points
5 credits of C—5 × 1 = 5 honor points
2 credits of D—2 × 0 = 0 honor points
3 credits of F—3 × 0 = 0 honor points

16 credits 20 honor points

The honor point ratio would be: $\frac{20}{16} = 1.25$

When a course which was failed is repeated, the credit number for the course and for the repetition will both count in the honor point ratio. When a course which was passed with a grade of D is repeated, the first grade and credit are canceled and only the last grade and credit will count in the honor point ratio. In the School of Chemistry both grades will remain. The student must notify the college office of the second registration so that the honor point ratio can be corrected.

Requirements for Graduation—The Bachelor's degree with departmental designation will be recommended for those students with honor point ratios of 1.00 or better who have completed all of the required work and have the total number of credits specified in their curriculums. The honor point ratio 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 honor point ratio is below the specified 1.00 may attain needed honor point ratio by taking additional courses or repeating approved courses in residence. Approval must be given by the Scholastic Standards Committee. The student may not improve his honor point ratio by repeating courses in which he has already received a grade of C or better. If the deficiency in honor points is no greater than six, additional honor points may be earned in the Extension Division or Correspondence Study Department.

Students having an honor point ratio of 2.5 or better for their undergraduate work (excepting their last quarter's work) will be granted their degree "with high distinction."

Students having an honor point ratio between 2.0 and 2.49 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 1 year in residence before they will be recommended for graduation. If the term of residence is only 1 year, it must be the senior year. In any case such a student must spend 2 quarters of his senior year in residence.

The bachelor of science degree, undesignated, 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) Honor point ratio of 1.80 or better
(b) Completion of the first 4 years of the curriculum including the proportional part of the nontechnical required courses
(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—Since an honor point ratio of 1.00 is required for graduation, students with an accumulative ratio of less

than 1.00 are doing unsatisfactory work and will be placed on probation. While low grades are a primary factor in determining the probationary status, a record of numerous cancellations likewise indicates scholastic weakness and may lead to the student being placed on probation.

Those students who have raised their accumulative honor point ratio to 1.00 or better are automatically removed from probation.

Students in the College of Engineering who are on probation and whose accumulative honor point ratio is less than in the minimum schedule below, will be required to appear before the Scholastic Standards Committee and will be subject to exclusion from college. Experience has shown that a period spent away from college and in productive work permits some students to mature and to do satisfactory college work on re-entry at a later time.

Year	Completed Credits (Earned and Failed)	Minimum Accumulative Honor Point Ratio	Deficiency in Honor Points
1	33	.60	12
	49	.70	15
2	66	.80	13
	83	.82	15
	100	.84	16
3	117	.86	16
	134	.88	16
	150	.90	15
4	167	.92	13
	184	.94	11
	200	.96	8
5	217	.98	4
	234	1.00	0
	250	1.00	0

A list of the College of Engineering students who are due to be dropped 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 drop action, he should make an appointment to see his departmental Scholastic Committee and complete the "Drop 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 for cause at any time 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—A dropped 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 con-

sidered at least yearly. Usually, however, a student is dropped 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 dropped a second time if the quality of his work has not improved sufficiently.

If, while dropped 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—An honor point ratio of at least 1.00 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 at the time of registration in the Institute of Technology. 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 is assigned an adviser from the department in which he seeks his degree. 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 scholarships available to Minnesota high school graduates entering the University may be found in the *Bulletin of General Information.* Requests for information or applications should be addressed to the Bureau of Student Loans and Scholarships, 201 Eddy Hall.

For description of scholarships, 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 agricultural, chemical, civil, mechanical, or metallurgical engineering. Amount is $500.

Babcock and Wilcox Company Scholarships: For undergraduates in the Institute of Technology. Amount is $200-$300. Two awards annually.

Cities Service Oil Company Engineering Scholarship: For third-year students in mechanical, industrial, civil, electrical, chemical, petroleum, and geological engineering. Amount is $600.

Collins Radio Company Scholarships: For undergraduates in the Institute of Technology—preference to majors in electrical or mechanical engineering. Amount is $500. Three awards annually.

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

Victor L. Fixen Scholarship: For undergraduates in the Institute of Technology. Amount is $50.

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

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

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.

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-$1,500. 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 $500.

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

Western Electric Scholarship: For undergraduates in engineering. Award is for 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, or mining engineering. Amount is $500.

AERONAUTICAL ENGINEERING

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

Douglas Aircraft Scholarship: For senior or fifth-year student in aeronautical or mechanical engineering. Amount is $750.

AGRICULTURAL ENGINEERING

William Boss Agricultural Engineering Scholarship (Specialty Manufacturing Company of 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.

Minneapolis-Moline 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

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

C. H. Johnston Scholarship (C. H. Johnston, Architects and Engineers, of 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 $200.

Wisconsin Architects Foundation Scholarship (Milwaukee, Wisconsin): For residents of Wisconsin who are studying architecture at the University of Minnesota. Amount is $100-$200.

Thomas F. Ellerbe Prize or Scholarship (Co-operative Foundation): For excellence in study of buildings for co-operatives. Amount is $300.

Gargoyle Club Prize (Gargoyle Club, St. Paul, Minnesota): 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 $500.

Union Carbide and Carbon Corporation Scholarship (Linde Air Products Company, New York, New York): For seniors in chemical engineering and mechanical engineering in alternate years. Amount is $200 and full tuition.

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.

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.

CIVIL ENGINEERING

Associated General Contractors of Minnesota Scholarships: For undergraduates in civil engineering who have completed at least 2 years of engineering training. Candidates must have been residents of Minnesota prior to attending the University of Minnesota. Amount is $300. Ten awards annually.

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. Awards—Entering freshmen: $100, 1 in each of 18 districts in Minnesota. Advanced undergraduates: $200-$300, 3 or more awards annually. Graduate: $750-$1,000.

Socony Mobil Oil Company Scholarship: For fourth- or fifth-year students in the highway engineering area of civil engineering, particularly asphalt engineering. Amount is $500.

ELECTRICAL ENGINEERING

Louis Allis Company Engineering Scholarship: For students specializing in electrical engineering with special reference to machinery. Amount is $500.

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, Minnesota): For undergraduates in electrical engineering. Amount is $500. Two awards annually.

MECHANICAL ENGINEERING

American Iron and Supply Company Scholarships: See description under "School of Mines and Metallurgy" scholarships.

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

Ladish Company Scholarships in Metallurgical and Mechanical Engineering: See description under "School of Mines and Metallurgy" scholarships.

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 entering freshman from Minnesota high school or transfer from junior college in Minnesota for study in mechanical engineering. Amount is $400.

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

Union Carbide and Carbon Corporation Scholarship: See description under "Chemical Engineering and Chemistry" scholarships.

MINING, METALLURGICAL ENGINEERING, AND METALLURGY

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 Foundation for Education and Research Scholarship (Cambridge, Massachusetts): For students having 2 years of en-

gineering and acceptance for advanced work in metallurgical engineering. Amount is $400.

American Society for Metals, Minnesota Chapter, Scholarship: For undergraduate in metallurgical engineering. Amount is $250.

American Iron and Supply Company Scholarships: First 2 years: freshman entering department of metallurgical, mineral, and mechanical engineering; 1 from Hennepin County, 1 from Ramsey County. After 2 years: from any area. Amount is $500. Two awards annually.

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. 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, geological, and metallurgical engineering; 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 Company Scholarships in Metallurgical and Mechanical Engineering (Ladish Company, Cudahy, Wisconsin): For entering freshmen in metallurgical and mechanical engineering; renewable annually. Amount is $300, first 3 years; $350 for senior year. Two new awards annually.

Lake Superior Mining Institute Scholarships (Lake Superior Mining Institute, Negaunee, Michigan): For undergraduates in the School of Mines and Metallurgy. Amount is $100-$300.

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

Magnolia Petroleum Company Scholarship (Dallas, Texas): For undergraduates in geophysics, preferably seniors. Amount is tuition and fees plus $400.

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 mines and metallurgy, or high school graduates who wish to enroll in mines and metallurgy. Amount is up to $500.

Standard Oil Company of Texas Scholarship: For juniors or seniors in geophysics. Amount is $750.

Union Carbide and Carbon Corporation Scholarship (Electro-Metallurgical Company, Marietta, Ohio): For senior student in metallurgical engineering. Amount is tuition and fees plus $200.

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

PHYSICS

"S" Scholarship in Nuclear Science (anonymous sponsor): For junior students who show promise of future accomplishment in the peaceful use of nuclear science. Amount is $250.

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, 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 $1,200 to $2,100 and assistantships have stipends of $1,800 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, and (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 *communication*—oral, written, and graphical.

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.

Basic Curriculums 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		
Draw 14, 15, 16—Engineering Graphics	3	3	3
Engl 14, 15, 16—Written and Spoken Communication	3	3	3
GE 21—Orientation	1	....	....
ITM 11, 12, 13a—College Algebra and Trigonometry I; College Algebra and Trigonometry II; Calculus I: Analytic Geometry and Calculus	5	5	5
Phys 11, 12, 13—General Physics	5	5	5
Total credits	17	16	16

ITM 10, Solid Geometry, 0 credits, must be taken before Draw 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.

Second Year (for students who entered IT prior to fall 1957)

See departmental recommendation, when choice is required, before registering for any subject in the 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 24, 25—Calculus I: Differential; Calculus II: Integral	5	5	....
ITM 80—Elementary Differential Equations	....	....	3
MM 26—Engineering Statics (Engineering curriculum) MM 84—Principles of Statics and Dynamics (Mines curriculum)	....	....	5
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

Second Year (for students entering IT in fall 1957 or later)

	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 engineer-

ing 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. undesignated 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.

Degree Programs—Details of the upperclass 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
Engineering and Business Administration
Geological Engineering
Geophysics
Industrial Engineering
Mathematics, Applied
Mechanical Engineering
Metallurgical Engineering
Mining Engineering

Aeronautical Engineering

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

With the rapid development of aeronautics and astronautics in recent years, aeronautical engineering has assumed a prominent and important position among the engineering professions. The production, development, and use of equipment requires a thorough knowledge of the most recent developments in the aeronautical sciences, including high altitude and supersonic flight problems. Aeronautical engineers are required in all stages of the process, from the research work preliminary to improvements in design to the actual construction, testing, operation, and maintenance. Students trained in aerodynamics and the design of light structures have been in demand in recent years in many industries. Because of the extensive developmental work being done, new opportunities in the field of aeronautical engineering are continually being created.

It should be emphasized that mathematics plays an important part in aeronautical engineering and no student who feels poorly prepared in mathematics should enter this curriculum.

Aeronautical engineering is a professional engineering course and not a training course for airplane pilots. It deals with the preparation of students for research, design, construction, operation, management, and maintenance of aircraft from the standpoint of the engineer, scientist, or manager. However, students desiring practical flight training may take advantage of opportunities available through the University of Minnesota Flying Club, the U.S. Air Force, the National Guard, the Naval Reserve, or the division of Flight Activities of the University.

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

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 aeronautical engineering elect the following courses in the second year:

	Credits—f, w, s		
Aero 4, 5, 6—Laboratory	1	1	1
ITM 80—Elementary Differential Equations	....	....	3
Phys 51—Intermediate General Physics (or) OrCh 16—Carbon Compounds	....	....	4

Third Year

	Credits—f, w, s		
Aero 1—Aeronautics	3	....	....
Aero 140—Aeronautical Laboratory	....	....	4
Aero 158—Physics of the Atmosphere	....	2	....
Draw 28—Drafting	....	2	....
Hydr 101—Fluid Mechanics	3	....	....
ME 18—Materials and Processes	3	....	....
ME 21—Kinematics and Mechanisms	3	....	....
ME 130, 131, 132—Thermodynamics	3	3	3
MM 127—Engineering Dynamics	....	5	....
MM 128—Engineering Solid Mechanics	....	....	5
Electives (see statement following fifth-year curriculum)	....	3	3
Nontech. Req.—Group II or I (see Index for "Nontechnical Required Courses")	3	3	3
Total credits	18	18	18

Fourth Year

	Credits—f, w, s		
Aero 83—Stresses in Simple Structures	4	....	....
Aero 100, 101, 102—Aerodynamics	3	3	3
Aero 115—Airplane Stresses	....	3	....
Aero 141—Aerodynamics Laboratory	....	....	2
EE 36, 38—Electrical Engineering Survey	3	3	....
ITM 167A, 167B—Selected Topics in Mathematics for Aeronautical Engineers	3	3	....
ME 150—Internal Combustion Engines	....	3	....
ME 157—Gas Turbine and Jet Propulsion Power Plants	....	....	3
MM 193—Introduction to the Theory of Mechanical Vibrations	....	....	3
Electives (see statement following fifth-year curriculum)	....	....	3
Nontech. Req.—Group III (see Index for "Nontechnical Required Courses")	3	3	3
Total credits	16	18	17

Fifth Year

	Credits—f, w, s		
Aero 106—Compressible Flow	....	3	....
Aero 107—Aerodynamics of Viscous Fluids	3	....	....
Aero 120, 121, 122—Airplane Design	2	2	2
Aero 130—Aerodynamic Design Laboratory	2	....	....
Aero 131, 132—Airplane Design Laboratory	....	2	2
Aero 135—Airplane Static Testing	....	....	2
Aero 190, 191—Seminar	....	1	1
Engl 85, 86—Advanced Technical Communication	3	3	....
GE 103—Professional Problems	....	1	....
ME 151—Advanced Internal Combustion Engines	3	....	....
ME 158—Aircraft Power Plant Laboratory	....	....	2
Electives (see statement following fifth-year curriculum)	3	3	3
Nontech. Req. (see Index for "Nontechnical Required Courses")	....	....	3
Total credits	16	15	15

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

Agricultural Engineering

A 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 in agricultural engineering is designed to prepare the student for professional attainment in dealing with problems of agriculture. Agricultural engineering includes the application of power to farm uses; 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. A study of such principles requires 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. This combined course and the conditions of eligibility are described under the engineering and business administration curriculums.

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	....
MM 26—Engineering Statics	....	....	5
Phys 51—Intermediate General Physics	....	....	4

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

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 8, 9—General Economics	....	3	3
Hydr 103—Fluid Mechanics	....	5	....
Hydr 104—Fluid Mechanics Laboratory	....	1	....
ME 18—Materials and Processes	....	3	....
ME 21—Kinematics and Mechanisms	....	3	....
ME 24—Elements of Machine Design	....	....	3
MM 127—Engineering Dynamics	....	....	5
MM 128—Engineering Solid Mechanics	5	....	....
ME 142—Experimental Mechanics	2	....	....
Soil 1—Soils and Soil Management	5	....	....
Total credits	18	18	17

Fourth Year

	Credits—f, w, s		
AgEn 141—Agricultural Drainage	3	....	....
AgEn 142—Erosion Control	....	3	....
AgEn 143—Irrigation	....	....	3
AgEn 147—Design and Management of Farm Machinery	....	3	....
CE 37—Elementary Structural Engineering	3	....	....
EE 36, 37, 38—Electrical Engineering Survey	3	3	3
ME 121—Machine Design	3	....	....
ME 130, 131—Thermodynamics	3	3	....
ME 133—Heat Transmission	....	....	3
Rhet 22—Public Speaking	....	....	3
Technical elective (a minimum of 6 cr selected from AgEn 167, 171, 172, 176, 180, 181)	....	3	....
Nontech. Req. (see Index for "Nontechnical Required Courses")	3	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	....
Engl 85, 86—Advanced Technical Communications	....	3	3
GE 101—Contracts and Specifications	....	....	3
GE 103—Professional Problems	1	....	....
ME 150—Internal Combustion Engines	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	3
Electives (sufficient to complete a total of at least 250 credits)	....	....	4
Nontech. Req. (see Index for "Nontechnical Required Courses")	3	....	....
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 undesignated 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 an honor point ratio of 1.50 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.

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
MM 26—Engineering Statics	....	....	5

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	....	....	3
Geol 5, 6—Engineering Geology	3	3	....
Hydr 103—Fluid Mechanics	....	5	....
Hydr 104—Fluid Mechanics Laboratory	....	1	....
MM 127—Engineering Dynamics	....	....	5
MM 128—Engineering Solid Mechanics	5	....	....
MM 142—Experimental Mechanics	2	....	....
Nontech. Req.—Group II or I (see Index for "Nontechnical Required Courses")	3	3	3
Total credits	19	18	17

Summer Camp

CE 23—Surveying Camp	9 credits

Fourth Year

	Credits—f, w, s		
CE 24—Railway Engineering (or) CE 146—Concrete and Concrete Materials	3	....	....
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
CE 146—Concrete and Concrete Materials (or) CE 24—Railway Engineering	....	....	3
CE 160—Applied Hydraulics	3	....	....
CE 161—Hydrology	....	3	....
CE 170, 171—Water Supply; Sewerage and Sewage Treatment	....	3	3
EE 36, 37—Electrical Engineering Survey	....	3	3
ME 42—Heat Engines	4	....	....
Nontech. Req.—Group III (see Index for "Nontechnical Required Courses")	3	3	3
Total credits	19	17	17

Fifth Year

	Credits—f, w, s		
CE 141, 142—Reinforced Concrete; Reinforced Concrete Design	3	3	....
CE 147—Foundations	....	....	3
Engl 85, 86—Advanced Technical Communication	3	3	....
GE 101—Contracts and Specifications	3	....	....
GE 103—Professional Problems	....	1	....
Technical electives (taken in the Institute of Technology, or others by departmental approval)	6	3	3
Nontech. Req. (see Index for "Nontechnical Required Courses")	....	....	3
Total credits	15	10	9

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 100 and 102 in the list of fifth-year courses in sanitary engineering may be substituted, upon approval, for any of the following: CE 24, 34, 52, 146. This will enable students under the sanitary engineering option to graduate with 250 credits instead of the 254 credits that would be required for those electing the option in the fifth year. This selection would also 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	....
GE 103—Professional Problems	....	1	....

PubH 100—Elements of Preventive Medicine and Public Health	3	...	...
PubH 102—Environmental Sanitation	3	...	...
Total credits	16	16	7

CE 172, Bact 53, PubH 100 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 undesignated. 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 127, 128, 142; Hydr 103, 104; Econ 8, 9; Pol A, B.

Fourth Year

CE 130, 141, 146, 147, 161, 170, 171; GE 103; EE 36, 37; 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 the specialized fields of communications, electronics, power, and industrial engineering.

A student may be granted a B.S. degree undesignated 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 (HPR = 1.80 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.

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

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—Electrical Engineering Problem Solving Laboratory	1	1	....
EE 57, 59—Engineering Electronics	....	3	3
EE 58, 60—Engineering Electronics Laboratory	....	1	1
Hydr 101—Fluid Mechanics	....	....	3
MM 85—Principles of Solid Mechanics	....	3	....
MM 127—Engineering Dynamics	5	....	....
Nontech. Req.—Group I or II (see Index for "Nontechnical Required Courses")	4-3	4-3	4-3
Total credits	16-15	18-17	17-16

Fourth Year

	Credits—f, w, s		
EE 121, 123, 125—Analysis of Electromagnetic Devices	3	3	3
EE 122, 124, 126—Experimental Study of Electromagnetic Devices	2	2	2
EE 129—Electrical Transients	....	....	3
EE 141—Electrical Engineering Materials	3	....	....
EE 161, 162, 163—Electrical Engineering Networks	3	3	3
EE 161A, 162A, 163A—Networks Laboratory	1	1	1
ME 40—Heat Engines	....	3	....
Electives	3	3	3
Nontech. Req.—Group III (see Index for "Nontechnical Required Courses")	3	3	3
Total credits	18	18	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	4	3
Total credits	15	16	15

Electrical Engineering Electives—Two elective sequences must be completed from the following 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—Industrial Electronics	3	3	3
EE 164, 165, 166—Communication Circuits	3	3	3
EE 167, 168, 169—Electromagnetic Theory and Application	3	3	3
EE 173, 174, 175—Physical Electronics	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 8, 9, 73 for the nontechnical requirements in Group II.

Fourth Year

		Credits—f, w, s	
EE 121, 123, 125—Analysis of Electromagnetic Devices	3	3	3
EE 122, 124, 126—Experimental Study of Electromagnetic Devices	2	2	2
EE 129—Electrical Transients	....	....	3
EE 141—Electrical Engineering Materials	3	....	....
EE 161, 162, 163—Electrical Engineering Networks	3	3	3
EE 161A, 162A, 163A—Networks Laboratory	1	1	1
IE 150—Elements of Industrial Engineering and Management	3	....	....
IE 153—Methods Engineering and Work Measurement	....	3	....
IE 170—Production Planning and Control	....	....	3
Engineering accounting (consult head of Industrial Engineering Division)	3	3	....
Nontech. Req. (see Index for "Nontechnical Required Courses")	....	3	3
Total credits	18	18	18

Fifth Year

		Credits—f, w, s	
Engl 85, 86—Advanced Technical Communication	3	3	....
IE 171—Quality Control	....	3	....
IE 173—Engineering Economic Analysis	3	....	....
IE 180—Elements of Supervision	....	....	3
IE 190—Industrial Engineering Seminar	....	....	1
IE 194—Applied Industrial Engineering	....	....	3
ME 40—Heat Engines	....	3	....
Industrial engineering electives	3	3	3
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 74 credits of business subjects listed on the following page as satisfying the requirements for the degree of bachelor of business administration. Required courses have been waived in both colleges with the understanding that the courses in the two colleges will be carried simultaneously and supplement each other. The work is to be completed as a unit and both degrees obtained at the same commencement period.

Application for admission to this program may be made by filing a petition with the Scholastic Standards Committee for the combined engineering and business curriculums, located in 133 Main Engineering building. An honor

point ratio of 1.50 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:

	Credits—f, w, s		
Econ 8, 9—General Economics	3	3	....
Econ 28—Business Law	....	....	3

These courses are in lieu of nontechnical requirements.

Third Year

	Credits—f, w, s		
BA 54, 55—Elementary Accounting, Combined Course	4	4	....
BA 77—Survey in Marketing	....	....	3

Econ 185 may be substituted for BA 77.

Fourth Year

	Credits—f, w, s		
BA 66—Managerial Costs	....	....	3
BA 71—Transportation: Services and Charges I	....	....	3
BA 74—Business Statistics A	....	3	....
BA 89—Production Management	....	....	3
BA 167—Introduction to Industrial Relations	....	3	....
Econ 5B—Elements of Statistics	3	....	....
Econ 73—Manpower Economics and Labor Problems	3	....	....
Econ 80, 81—Intermediate Economic Analysis: Income and Employment, Firms and Households	3	3	....

Fifth Year

	Credits—f, w, s		
BA 58—Elements of Public Finance	....	3	....
BA 180G, 181G, 182G—Senior Topics: Production Management	3	3	3
Econ 50—Insurance Principles	3	....	....
Econ 75—Corporation Finance	3	....	....
Econ 85—Government Regulation of Business	....	....	3
Plus 2 of the following:			
BA 111—Purchasing	....	3	....
BA 113—Sales Management	3	....	....
BA 133—Standard Costs	....	....	3

BA 146—Investments		3	
BA 156—Finance Management	3		
BA 168—Advanced Personnel Administration			3
BA 170—Methods Analysis and Work Measurement		3	
BA 173—Market Analysis and Research		3	
Psy 130—Vocational and Occupational Psychology		3	
Psy 160—Psychology in Personnel Work			3
Total credits for 2nd to 5th years		74	

Credits for the program in business and economics must total 74.

Substitutions: Econ 185 for BA 77; ITM 90 for Econ 5B; IE 153 for BA 170; IE 150 for BA 89. 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 74 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.

Candidates will be expected to take, either as undergraduates, or as graduate students, at least one course in several subject areas. Some of these will not carry graduate credit even though taken while a graduate student. Specific course requirements in general will be met by the following courses or their equivalents (due attention being given to their prerequisites): BA 51, 130 or 139, 156, 167, 184, 187; Econ 5B, 142, 143-144, 175, 185, 189.

Additional courses in business administration are required to total 45 graduate credits.

The above program may be completed satisfactorily in about 1 year provided the student has taken the following courses as an undergraduate: BA 54-55; Econ 8-9, 57, 73, 75.

If no prior training in economics and business is presented by the candidate, the program will require approximately 2 years.

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 an honor point ratio of 1.00 is required for admission.

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

First Year

	Credits—*f*, *w*, *s*		
Draw 14, 16—Engineering Graphics	3	—	3
Engl 14, 15, 16—Written and Spoken Communication	3	3	3
GE 21—Orientation	1	—	—
ITM 11, 12, 13a—College Algebra and Trigonometry I; College Algebra and Trigonometry II; Calculus I: Analytic Geometry and Calculus	5	5	5

ME 18—Materials and Processes	....	3	....
Phys 11, 12, 13—General Physics	5	5	5
Total credits	17	16	16

ITM 10, Solid Geometry, 0 credits, to be taken before Draw 14 if solid geometry is not presented as an entrance unit.

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

Second Year

	Credits—f, w, s		
BA 54, 55—Elementary Accounting: Combined Course	....	4	4
Econ 5B—Elements of Statistics	....	....	3
Econ 8, 9—General Economics	3	3	....
Econ 57—Money and Banking	....	....	5
InCh 14, 15—Inorganic Chemistry	4	4	....
ITM 91—Calculus	4	....	....
MM 84—Principles of Statics and Dynamics	....	....	5
Met 56—Physical Metallurgy	3	....	....
Phys 14—Intermediate General Physics	....	4	....
Total credits	14	15	17

Third and Fourth Years

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

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

Core Group Requirements—The following courses constitute a core of material which must be covered by all students. In addition to these courses, there are certain required subjects in the major area or sequence.

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

1. Business Law:	
BA 51—Business Law: Contracts	3
2. Accounting and Statistics:	
One advanced course in accounting	3
One of the following:	
BA 74—Business Statistics A BA 78—Business Statistics B	3
3. Economic Theory and Methods:	
Econ 80—Intermediate Economic Analysis: Income and Employment	3
Econ 81—Intermediate Economic Analysis: Firms and Households	3
4. Basic Functional and Background Courses:	
Econ 50—Insurance Principles	3
Econ 73—Manpower Economics and Labor Problems	3
Econ 75—Corporation Finance	3
Econ 85—Government Regulation of Business	3
BA 71—Transportation: Services and Charges I	3
BA 77—Survey in Marketing	3
BA 89—Production Management	3
BA 58—Elements of Public Finance	3
Total credits	39

For BA 74 and 78 consult sequence statements in the *Bulletin of the School of Business Administration* for specific requirements.

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 250 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, Group III (see section on Nontechnical Required Courses), and electives.

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 MM 26 and Phys 51 or OrCh 16:

	Credits—f, w, s		
InCh 11—Semimicro Qualitative Analysis			4
MM 84—Principles of Statics and Dynamics			5
MinE 1—Mineral Engineering Laboratory			1
Phys 14A, 50A—Physics Laboratory	1	1	

Third Year

	Credits—f, w, s		
Geol 1, 2—General Geology (Physical and 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, Tech. Elect.—Oil Field Development; Oil Field Production; a technical elective	3	3	3
CE 18, 19, 20—Surveying	3	3	3
Hydr 103—Fluid Mechanics	....	....	5
Hydr 104—Fluid Mechanics Laboratory	....	....	1
MM 28—Engineering Mechanics II (for those who have had MM 27)	3	....	....
MM 85, 142—Principles of Solid Mechanics; Experimental Mechanics	....	3	2
Nontech. Req. (see Index for "Nontechnical Required Courses")	....	3	....
Total credits	16	19	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 15—Mine Surveying Field Work	6 credits
Geol 100—Field Work in Northern Minnesota	3 credits

Fourth Year

	Credits—f, w, s		
Geol 106—Petrography	3	....	....
Geol 107—Paleontology	3	....	....
Geol 110, 111—Economic Geology	....	3	3
Geol 125—Structural Geology	4	....	....
Geol 131—Petrology	....	4	....
Geol 151—Stratigraphy	....	3	....
Geol electives (any geology course 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	....
Nontechnical electives	....	....	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	....
Geol 171—Geologic Report	1	....	....
Geol electives (any geology course numbered 100 or over)	3	3	3
GPhy 108—Introduction to General Geophysics	3	....	....
MinE 131—Rock Mechanics I	3	....	....
MinE 141—Mineral Economics	3	....	....
MinE 180—Geochemical Exploration	....	3	....
CE 53—Elements of Soil Mechanics	....	....	3
GE 103—Professional Problems (optional as technical elective)	1	....	....
Engl 85, 86—Advanced Technical Communication	....	3	3
Technical electives	....	....	1
Nontechnical electives	....	3	3
Total credits	17	15	13

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

IT: Anch 57; GE 101; IE 150; ME 42, 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

SLA: Econ 8, 9; BA 54, 55; Geol 101, 112, 114, 120, 121, 132, 137, 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 15—Mine Surveying Field Work	6 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—Petroleum Processing			2
PetE 134—Natural Gas Engineering		2	
PetE 138—Oil Field Maps and Charts			2
PCh 101, 102—Physical Chemistry	4	4	
Technical electives			3
Nontechnical electives		3	3
Total credits	17	16	17

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		
Geol electives (geology courses numbered 100 or over)		3	3
GPhy 108—Introduction to General Geophysics	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
GE 103—Professional Problems (optional as technical elective)		1	
Technical electives		3	
Nontechnical electives		3	3
Total credits	16	16	15

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

IT: AnCh 57; GE 101; IE 150; ME 24, 128, 198; EE 36; MetE 12, 106, 110, 111, 112; Met 56; MinE 121, 122; PetE 135, 144, 145; Phys 51

SLA: Econ 8, 9; BA 54, 55; Geol 102, 110, 111, 121, 132, 137, 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.

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.

Third Year

	Credits—f, w, s		
Geol 1, 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 108, 109—Introduction to General Geophysics; Elementary Seismology	3	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	3	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 125—Principles of Gravity and Magnetic Exploration	2	....	....
GPhy 126—Principles of Seismic Exploration	....	2	....
GPhy 127—Principles of Electrical Exploration	....	....	2
Engl 85, 86—Advanced Technical Communications	3	....	3
GE 103—Professional Problems (optional as technical elective)	1	....	....
Geol 110—Economic Geology	....	3	....

Phys 123, 124, 125—Thermodynamics, Kinetic Theory, and Statistical Mechanics	3	3	3
Electives	7	7	6
Total credits	16	15	14

Suggested electives: Geol 70, 112, 131, 137, 151; Phys 121, 122; ITM 152, 153; EE 57-59, 58, 60, 143-144-145; InCh 11, 101-103.

Industrial Engineering

Professional training in industrial engineering is offered through industrial engineering options in mechanical engineering 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.

Through industrial engineering, the analytical viewpoint of the engineer is brought to bear on production and management problems. In connection with day-to-day plant operations, industrial engineers plan and schedule the flow of work, control quality, establish production standards, estimate costs of new operations, and administer wage incentive and cost reduction programs. In setting up for the manufacture of new products and reducing costs, the industrial engineer studies product designs to adapt them for economical production, determines the necessary operations, develops work methods, and selects or develops the most economical production equipment and tooling. He is also concerned with the planning and layout of industrial plants and materials-handling systems.

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

A student may be granted a B.S. degree undesignated 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.

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 the nontechnical requirements.

Third, Fourth, and Fifth Years

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

	Credits
IE 150—Elements of Industrial Engineering and Management	3
IE 153—Methods Engineering and Work Measurement	3
IE 170—Production Planning and Control	3

	Credits
IE 171—Quality Control	3
IE 173—Engineering Economic Analysis	3
IE 180—Elements of Supervision	3
IE 190—Industrial Engineering Seminar	1
IE 194—Applied Industrial Engineering	3
Industrial engineering electives (elect 3 courses from IE 154, 155, 163, 165, 167, 182)	9
ITM 90—Elementary Engineering Statistics (or) ITM 132—Introduction to Statistics and Probability	3
Accounting in engineering (consult head of Industrial Engineering Division)	6

Nontech. Req.—Group II and III (see Index for "Nontechnical Required Courses." Econ 8, 9, and 73 are prerequisites for required courses in industrial engineering)

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

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

First Year

See 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 4—Laboratory			1
ITM 26—Calculus III (substitute for ITM 80 for those who entered before fall 1957)			5
Phys 14A, 50A—Physics Laboratory	1	1	
Phys 51—Intermediate General Physics			4

Third Year

	Credits—f, w, s		
ITM 151a—Calculus V: Intermediate Calculus	3		
ITM 152, 153—Calculus VI, VII: Advanced Calculus		3	3
Hydr 103—Fluid Mechanics			5
Hydr 104—Fluid Mechanics Laboratory			1
MM 127—Engineering Dynamics	5		
MM 128—Engineering Solid Mechanics		5	
Technical option (to be selected from one of the departments in the Institute of Technology with the help of an adviser)	3	3	3

Electives	3	3	2
Nontech. Req. (see Index for "Nontechnical Required Courses")	3	3	3
Total credits	17	17	17

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 150a—Ordinary Differential Equations	....	....	3
ITM 168—Elementary Theory of Complex Variables	....	3	....
ITM 169—Mathematical Theory of Flow	....	....	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 below)	6	6	6
Engl 85, 86—Advanced Technical Communication	3	3	....
GE 103—Professional Problems	....	1	....
Phys 100, 102, 104—Mechanics and Electromagnetism	4	4	4
Electives	3	3	3
Nontech. Req. (see Index for "Nontechnical Required Courses")	....	....	3
Total credits	16	17	16

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

	Credits—f, w, s		
ITM 161, 162, 163—Analytical Dynamics	3	3	3
ITM 164, 165, 166—Programming for High Speed Digital Computers with Applications	3	3	3
ITM 173, 174, 175—Elementary Partial Differential Equations	3	3	3
ITM 227, 228, 229—Mathematics of Computers and Control Devices (requires written permission of instructor)	3	3	3
MM 180, 181, 182—Introduction to Theory of Elasticity; Applied Elasticity	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 undesignated 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 consists of five major divisions. Within these divisions work may be taken in the following areas: thermodynamics, heat transmission, heating and air conditioning, refrigeration, internal combustion engines, turbomachinery, steam and nuclear power generation, 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.

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	
ME 1—Mechanical Engineering Orientation	....	....	1
OrCh 16—Carbon Compounds	....	....	4
Phys 14A, 50A—Physics Laboratory	1	1	....

Third Year

		Credits—f, w, s	
ME 33—Mechanical Engineering Laboratory I	2	....	....
ME 34—Mechanical Engineering Laboratory II ME 15—Casting, Working, and Welding of Engineering Materials ME 16—Cold Processing of Materials ME 21—Kinematics and Mechanisms ME 22—Mechanisms of Automatic Machinery (all required)	3	5-6	5-6
ME 130, 131, 132—Thermodynamics	3	3	3
Met 56—Physical Metallurgy	3	....	....
MM 127—Engineering Dynamics	5	....	....
MM 128—Engineering Solid Mechanics MM 142—Experimental Mechanics Hydr 103—Fluid Mechanics Hydr 104—Fluid Mechanics	....	6-7	6-7
Nontech. Req.—Group II or I (see Index for "Nontechnical Required Courses." Econ 8, 9, and 73 are prerequisites for required courses in the industrial engineering option)	3	3	3
Total credits	19	17-19	17-19

Fourth Year

		Credits—f, w, s	
ME 23—Dynamics of Machinery ME 24—Elements of Machine Design ME 121—Machine Design	3	3	3
ME 133—Heat Transmission ME 141—Heat Power Engineering ME 150—Internal Combustion Engines ME 160—Psychrometrics and Air Conditioning ME 180—Mechanical Refrigeration IE 150—Elements of Industrial Engineering and Management	6	6	6
EE 36, 37, 38—Electrical Engineering Survey	3	3	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

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.

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
Engineering design group (minimum of 3 credits from ME 122, 147, 161, 170)	....	3	....

ME 198—Industrial Instrumentation and Automatic Control	3	.....	.....
Engl 85, 86—Advanced Technical Communication	3	3	.....
GE 103—Professional Problems	.....	1	.....
Technical electives (see statement below)	3	3	6
Nontech. Req. (see Index for "Nontechnical Required Courses")	.....	.....	3
Electives (sufficient to complete a total of at least 250 credits for graduation)	3	3	3
Total credits	14	15	14

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.

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 2 years of the regular program with an honor point ratio of 1.0 or better are eligible at the end of the spring quarter of their second year. Application should be filed by February 1 preceding the completion of the first 2 years' work.

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

The awarding of the Bachelor's degree with departmental designation will require the satisfactory completion of all the basic required University work as designated in the regular 5-year mechanical engineering curriculum including 6 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.

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 without designation 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

		Credits—f, w, s		
ME 33—Mechanical Engineering Laboratory I		2	—	—
ME 34—Mechanical Engineering Laboratory II ME 15—Casting, Working, and Welding of Engineering Materials ME 16—Cold Processing of Materials ME 21—Kinematics and Mechanisms ME 22—Mechanisms of Automatic Machinery	all required	3	5-6	5-6

ME 130, 131, 132—Thermodynamics	3	3	3
Met 56—Physical Metallurgy	3	....	....
MM 127—Engineering Dynamics	5	....	....
MM 128—Engineering Solid Mechanics	....	5	....
MM 142—Experimental Mechanics	....	2	....
Hydr 101—Fluid Mechanics	....	....	3
IE 150—Elements of Industrial Engineering and Management	....	....	3
Nontech. Req.—Group II (see Index for "Nontechnical Required Courses." Econ 8, 9, and 73 are prerequisites for required courses in the industrial engineering option)	3	3	3
Total credits	19	18-19	17-18

Fourth Year

	Credits—f, w, s		
ME 24—Elements of Machine Design	....	3	....
ME 133—Heat Transmission	3	....	....
ME 141—Heat and Power Engineering ME 150—Internal Combustion Engines ME 160—Psychrometrics and Air Conditioning ME 180—Mechanical Refrigeration } 3 courses to be taken	3	3	3
ITM 90—Elementary Engineering Statistics (or) ITM 132—Introduction to Statistics and Probability	....	....	3
IE 153—Methods Engineering and Work Measurement	3	....	....
IE 170—Production Planning and Control	....	3	....
IE 171—Quality Control	....	....	3
Accounting in engineering (consult Industrial Engineering Division)	3	3	....
EE 36, 37, 38—Electrical Engineering Survey	3	3	3
Nontech. Req.—Group III (see Index for "Nontechnical Required Courses")	3	3	3
Total credits	18	18	15

Fifth Year

	Credits—f, w, s		
ME 121—Machine Design	3	....	....
ME 198—Industrial Instrumentation and Automatic Control	3	....	....
Engl 85, 86—Advanced Technical Communication	3	3	....
GE 103—Professional Problems	....	1	....
IE 173—Engineering Economic Analysis	3	....	....
IE 180—Elements of Supervision	....	3	....
IE 190—Industrial Engineering Seminar	....	....	1
IE 194—Applied Industrial Engineering	....	....	3
Industrial engineering electives (elect three courses from IE 154, 155, 163, 167, and 182)	3	3	3
Technical electives (see statement below)	....	3	....
Nontech. Req. (see Index for "Nontechnical Required Courses"	....	....	3
Electives (sufficient to complete a total of at least 250 credits for graduation	....	3	3
Total credits	15	16	13

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.

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 undesignated. 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 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 undesignated 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.

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 the following courses instead of MM 26 and Phys 51 or OrCh 16. InCh 11 is a prerequisite for AnCh 7 in the third year.

	Credits—f, w, s		
MetE 1—Metallurgical Engineering Laboratory	.....	.....	1
InCh 11—Semimicro Qualitative Analysis	.....	.....	4
MM 84—Principles of Statics and Dynamics	.....	.....	5
Phys 14A, 50A—Physics Laboratory	1	1	.....

Third Year

		Credits—f, w, s	
MetE 11—Elements of Metallurgical Engineering	3	.....	.....
AnCh 57—Quantitative Analysis	4	.....	.....
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—Engineering Mechanics II (for those students with MM 27 instead of MM 84)	3	.....	.....
MM 85, 142—Principles of Solid Mechanics; 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 Metallurgical Engineering	3	4	4
MetE 110, 111, 112—Mineral Dressing	4	4	4
ChEn 101, 102—Unit Operations	3	5	.....
Geol 106—Petrography	3	.....	.....
Met 53, 154, 155—Physical Metallurgy	3	3	3
Nontech. Req. (see Index for "Nontechnical Required Courses") or technical electives (see list of recommended electives below)	2-3	2-3	6
Total credits	18-19	18-19	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—Electrical Engineering Survey	3	3	3
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	3	3
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; Phys 107, 109, 111, 144; InCh 112; ChEn 111, 112, 119, 120; Geol 1, 2; GE 101; IE 150; ME 24, 198; Met 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 250 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.

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 MM 26 and Phys 51 or OrCh 16:

	Credits—f, w, s		
MM 84—Principles of Statics and Dynamics	....	....	5
InCh 11—Semimicro Qualitative Analysis	....	....	4
MinE 1—Mineral Engineering Laboratory	....	....	1
Phys 14A, 50A—Physics Laboratory	1	1	....

Third Year

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

Geol 1, 2—General Geology (Physical and Historical) (counts toward nontechnical requirements)	3	3	....
Geol 23, 24, 25—Mineralogy; Rock Study	4	4	2
CE 18, 19, 20—Surveying	3	3	3
Hydr 103—Fluid Mechanics	....	....	5
Hydr 104—Fluid Mechanics Laboratory	....	....	1
MM 28—Engineering Mechanics II (for those who have had MM 27)	3	....	....
MM 85, 142—Principles of Solid Mechanics; Experimental Mechanics	....	3	2
Nontech. Req. (see Index for "Nontechnical Required Courses")	....	3	....
Total credits	16	19	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 Trips

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

Fourth Year

	Credits—f, w, s		
MinE 16—Mine Maps	....	....	1
MinE 121, 122—Mine Plant Engineering; Mine and Petroleum Plant Engineering	....	2	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, 37—Electrical Engineering Survey	3	3	....
ME 42—Heat Engines (see statement below)	4	....	....
IE 150—Elements of Industrial Engineering (see statement below)	....	3	....
Nontechnical electives	....	3	3
Total credits	18	18	14

Student has choice of either of the following as substitute for ME 42 and IE 150:

	Credits—f, w, s		
ME 130, 131—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 on iron ranges and in several other mining areas ..... 6 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	....
GE 103—Professional Problems (optional as technical elective)	....	1	....
GPhy 110—Introduction to Exploration Geophysics	....	....	3
MetE 12—Metallurgical Processes	3	....	....
MetE 121—Iron Ore Beneficiation	3	....	....
Technical electives	....	....	3
Nontechnical electives	....	3	3
Total credits	18	15	13

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

IT: CE 53, 147, 159; GE 101; GPhy 108; IE 150; ITM 90; ME 24, 128, 132, 198; MM 180; Met 56; PCh 101, 102

SLA: Econ 8, 9; BA 54, 55, 167; 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

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

Options: Either Geol 150 and 171 or MinE 15 and Geol 100. MinE 15 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—Petroleum Processing	...	...	2
PetE 134—Natural Gas Engineering	...	2	...
PetE 138—Oil Field Maps and Charts	...	...	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, 37—Electrical Engineering Survey	3	3	...
ME 130, 131—Thermodynamics	...	3	3
PCh 101, 102—Physical Chemistry	4	4	...
Nontechnical electives	...	3	3
Total credits	17	15	15

Summer Field Trip

PetE 135—Inspection Trip	3 credits
Geol 150—Field Geology (see statement under third year)	6 credits

Fifth Year

		Credits—f, w, s	
PetE 144, 145—Advanced Petroleum Engineering	...	2	4
PetE 152, 153, 154—Petroleum Production Technology	3	3	3
MinE 141—Mineral Economics	3	...	...
CE 37—Elementary Structural Engineering	3	...	...
Engl 85, 86—Advanced Technical Communication	3	3	...
GE 103—Professional Problems (optional as technical elective)	...	1	...
GPhy 110—Introduction to Exploration Geophysics	...	...	3
ME 24—Elements of Machine Design	...	3	...
ME 150—Internal Combustion Engines	3	...	...
Met 56—Physical Metallurgy	...	...	3
Technical electives	...	2	2
Nontechnical electives	3	3	...
Total credits	18	17	15

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

IT: GE 101; GPhy 108; IE 150; ITM 90; ME 132, 134, 198
SLA: Ast 51; Econ 8, 9; BA 54, 55; Geol 106, 107, 131, 151; Phys 107, 109, 111, 114

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 Junior College. Two additional years in the Senior College are normally required to complete the major sequence offered by the School of Architecture. It is intended for students who wish to combine some study of architecture with their general education. This curriculum does not in itself constitute terminal professional training. It does, however, provide an advantageous approach to professional training in 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 Senior College 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

The first year of prearchitectural work may be taken at any of the following:

1. The University of Minnesota in the College of Science, Literature and the Arts. English and mathematics (college algebra, trigonometry, and analytic geometry) are required:

	Credits—f, w, s		
Engl 14, 15, 16 or Comp 4, 5, 6	3	3	3
Math 6, 7—Trigonometry; College Algebra	5	5	....
ITM 13a—Calculus I: Analytic Geometry and Calculus	....	....	5
Approved electives	7	7	7
Total credits	15	15	15

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

2. The University of Minnesota in the common first-year course offered by the College of Engineering.

3. Any accredited institution offering work equivalent to the above programs.

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 (for those with ITM 13a) (or) ITM 91—Calculus (for those with ITM 13)	5 or 4	....	....
MM 92, 93—Elements of Statics: Elements of Solid Mechanics	....	4	4
Phys 1, 2, 3—Introduction to Physical Science (if Phys 11, 12, 13 has not been taken)	3	3	3
Total credits	15 or 16	15	15

Third Year

	Credits—f, w, s		
Arch 57, 58, 59—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
Total credits	15	15	15

Fourth Year

		Credits—f, w, s		
Arch 51, 52, 53—History of Architecture	4	4	4	4
Arch 74, 75, 76—Building Technology	4	4	4	4
Arch 111, 112, 113—Architectural Design III	8	8	8	8
Approved electives	3	3	3	3
Total credits	19	19	19	19

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	3
Total credits	15	15	15	15

FOUR-YEAR CURRICULUM

First and Second Years

The first- and second-year work is taken in the Junior College 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 Senior College: High school or college equivalents of Math 1 (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 Senior College 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	4
Arch 81, 82, 83—Architectural Design I	6	6	6	6
Arch 91, 92, 93—Architectural Design II	6	6	6	6

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

SIX-YEAR CURRICULUM

First and Second Years

The first- and second-year work is taken in the Junior College 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 Senior College and for completion of the professional work in the last 2 years:

		Credits—f, w, s		
Math 6, 7—Trigonometry; Algebra	5	5		
ITM 13a—Calculus I: Analytic Geometry and Calculus				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 or college equivalents of Math 1 (Higher Algebra), solid geometry, InCh 4, 5 if the student does not have credit for high school chemistry.

Third and Fourth Years

During the third and fourth years the student is registered in the Senior College 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
ITM 24a—Calculus II: Analytic Geometry and Calculus (for those with ITM 13a)	5	.....	.....
ITM 91, MM 92, 93—Calculus; Elements of Statics; Elements of Solid Mechanics (ITM 91 for those who had ITM 13)	4	4	4
Approved electives to make minimum total of 180 credits acceptable for B.A. degree.			

Note—CE 38, 39, 41 (Structural Design) or Arch 57, 58, 59 (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 Senior College 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 57, 58, 59—Building Technology	4	4	4
Arch 74, 75, 76—Building Technology (continuation of 57, 58, 59)	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 two 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 206 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. Pharma-

ceutical 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 of 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 and this outlet alone provides many more jobs than can be filled.

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; College Algebra and Trigonometry II; Calculus I: Analytic Geometry and Calculus	5	5	5
Draw 11, 12—Engineering Drawing	....	2	2
Engl A, B, C—English Composition and Literature	5	5	5
Electives	2	....	....
Total credits	17	17	17

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

ITM 10, Solid Geometry, 0 credits, to be taken before Draw 11 if solid geometry is not presented as an entrance unit.

Comp 4, 5, 6, Freshman English, 9 credits, may be taken as a replacement for Engl A, B, C along with an additional 6 credits of 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 24, 25—Calculus: Differential and Integral (for those who had ITM 13; see statement below)	5	5	....
ITM 80—Differential Equations (see statement below)	....	....	3
Phys 7, 8, 9—General Physics	5	5	5
Electives	3	3	3
Total credits	17	17	17

Students who had ITM 13a should take ITM 24a, 25a (Calculus II, III: Analytic Geometry and Calculus) and ITM 26a (Calculus IV: Differential Equations and Calculus), 5 credits per quarter.

Third Year

	Credits—f, w, s	
AnCh 51, 52—Quantitative Analysis	2	2
AnCh 53, 54—Quantitative Analysis Laboratory	3	3

InCh 103, 104—Atomic Structure and the Properties of the Elements Based Thereon; Chemistry of the More Representative Elements	3	3	.....
OrCh 102—Organic Qualitative Analysis	4	.....	.....
PCh 101, 102, 103—Physical Chemistry	4	4	4
Ger 24, 25, 26—Chemical German	3	3	3
Electives	3	3	6
Total credits	17	18	18

Ger 27, 28, 29, 9 credits, to be taken instead of Ger 24, 25, 26 if 2 years of high school German are presented as an entrance unit, or if the student has had 1 year of college German.

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	.....
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	9	9	12
Total credits	17	17	17

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

Electives—Electives total 53 credits for students who take Engl A, B, C (59 credits for those who take Comp 4, 5, 6). Of these 53 (or 59) elective credits, 29 (or 35) must be in nonscientific elective courses and 24 may be in scientific elective courses.

Of the 24 science elective credits, 6 must be in one of the sequences of Group I of the nontechnical requirements (see Index for "Nontechnical Required Courses"). Eighteen more credits may be chosen from the following list:

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

Nonscience electives are defined as subjects other than those listed above as scientific electives. Of the minimum of 29 (or 35) 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.Ch.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 256 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 physicochemical, 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.

First Year

		Credits—f, w, s	
InCh 24, 25, 26—Introduction to Chemical Principles	5	5	5
Draw 11, 12—Engineering Drawing	....	2	2
Engl 14, 15, 16—Written and Spoken Communication	3	3	3
GE 21—Orientation	1	....	....

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	17	18	18

Second Year

	Credits—f, w, s		
OrCh 61, 62, 63—Elementary Organic Chemistry	4	4	3
OrCh 64—Elementary Organic Chemistry Laboratory	....	....	3
ITM 24, 25, 26—Calculus I: Differential; Calculus II: Integral; Calculus III: Calculus and Differential Equations (ITM 80, 3 credits, may be taken instead of ITM 26 for those who had ITM 13; see statement below)	5	5	5
Phys 7, 8, 9—General Physics	5	5	5
Nontech. Req.—Group I or II (see Index for "Nontechnical Required Courses")	3	3	3
Total credits	17	17	19

Students who had ITM 13a should take ITM 24a, 25a (Calculus II, III: Analytic Geometry and Calculus) and ITM 26a (Calculus IV: Differential Equations and Calculus), 5 credits per quarter.

Third Year

	Credits—f, w, s		
ChEn 100—Chemical Engineering Stoichiometry	3	....	....
ChEn 101, 102, 103—Unit Operations	3	5	5
ChEn 119, 120—Chemical Engineering Thermodynamics	....	3	3
AnCh 51, 52—Quantitative Analysis	....	2	2
AnCh 58—Quantitative Analysis	....	....	3
PCh 101, 102, 103—Physical Chemistry	4	4	4
MM 84—Principles of Statics and Dynamics	5	....	....
MM 85—Principles of Solid Mechanics	....	3	....
Total credits	15	17	17

Students who choose the Biochemical Engineering Option should take Bact 53 (5 credits) in the third year in place of MM 84 or 85 (which should then be taken in the fourth year).

Fourth Year

A student may be granted a B.S. degree undesignated 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. These students may find it desirable to take German or other approved foreign languages as one of their electives.

	Credits—f, w, s		
ChEn 111, 112, 113—Unit Operations Laboratory	2	2	2
ChEn 131, 132—Chemical Reactor Analysis	....	3	3
PCh 104, 105, 106—Physical Chemistry Laboratory	2	2	2
PCh 109—Physical Chemistry	4	....	....
Phys 107, 109, 111—Modern Physics (or) InCh 103, 104, 122—Atomic Structure and the Properties of the Elements Based Thereon; Chemistry of the More Representative Elements; Advanced Inorganic Chemistry Laboratory (or) Bact 121, ChEn 122—Physiology of Bacteria; Biochemical Engineering (see statement following third year)	3	3	3-0
Electives	3	3	1-4
Nontech. Req.—Group III (see Index for "Nontechnical Required Courses")	4	4	4
Total credits	18	17	15-17

Fifth Year

	Credits—f, w, s		
ChEn 116, 117, 118—Process Evaluation and Design	3	3	3
ChEn 171, 172—Process Control	3	3	....
EE 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
MetE 160—Physical Metallurgy	.....	.....	3
MetE 161—Corrosion of Metals	.....	.....	1
Electives	3	3	3
Total credits	16	16	17

Chemical Engineering Advisers for Seniors: Professors Amundson, Ceaglske, Piret, Stoppel, Isbin, Madden, Preckshot, Tsuchiya, Earle.

Metallurgy

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

A total of 249 credits, exclusive of summer field trips 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, metallurgical engineers 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 undesignated 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.

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 elect the following courses:

		Credits—f, w, s	
Met 1—Metallurgy Laboratory	.....	.....	1
InCh 11—Semimicro Qualitative Analysis	.....	.....	4
MM 84—Principles of Statics and Dynamics (elective for students entering prior to fall 1957 only)	.....	.....	5
Phys 14A, 50A—Physics Laboratory	1	1	.....

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	
ChEn 101, 102—Unit Operations	3	5	.....
AnCh 57—Quantitative Analysis	4	.....	.....
PCh 101, 102, 103—Physical Chemistry	4	4	4
MM 85—Principles of Solid Mechanics	.....	3	.....
MM 142—Experimental Mechanics	.....	.....	2
Phys 51—Intermediate General Physics	.....	.....	4
Technical Electives	3	3	3
Nontech. Req. (see Index for "Nontechnical Required Courses")	3	3	3
Total credits	17	18	16

Fourth Year

		Credits—f, w, s	
Met 53, 154, 155—Physical Metallurgy	5	5	5
Met 163A-163B-163C—Thermodynamics of Alloys and Solid State Reactions	3	3	3
MetE 106, 107, 108—Principles of Process Metallurgical Engineering	3	4	4
Technical Electives	3	3	3
Nontech. Req. (see Index for "Nontechnical Required Courses")	3	3	3
Total credits	17	18	18

Field Trip

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

Fifth Year

		Credits—f, w, s	
Met 164—Modern Theory of Metals and Alloys	.....	3	.....
EE 36, 37—Electrical Engineering Survey	3	3	.....
Engl 85, 86—Advanced Technical Communication	3	3	.....
Technical Electives	12	6	12
Nontech. Req. (see Index for "Nontechnical Required Courses")	.....	.....	3
Total credits	18	15	15

Recommended technical electives: ChEn 161, 162, 163; PCh 104, 116, 117, 118; GE 101, 103; EE 38; ITM 142, 143; Met 57, 158, 161, 162, 165, 170, 171, 172; MetE 11, 134, 135, 136, 138, 141, 142, 143; Phys 126, 127, 128.

SCHOOL OF PHYSICS

A 5-year curriculum is offered which leads to the degree bachelor of physics, B.Phys. Students who meet the requirements outlined under General Information section may elect to receive a bachelor of science degree without designation at the end of the fourth year and enter the Graduate School. The School of Physics reserves the right to limit the registration in its program to those students who give evidence of being able to profit from it.

The School of Physics will generally require each physics major to decide no later than the end of his third year whether he intends to enter the Graduate School at the end of the fourth year or intends to complete the regular 5-year program leading to a bachelor of physics degree. For those

who elect the latter alternative, the fourth and fifth years of study will be worked out by the student and his adviser in an attempt to satisfy the needs for graduation and to prepare the student for work in government or industrial laboratories, with emphasis on the specialty within physics that is his major interest.

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 250 credits for graduation at the end of 5 years; 200 credits are required for termination at the end of 4 years. 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.

Those students undecided between a career in physics or chemistry are advised to take the basic curriculum for the School of Chemistry and to make their choice before starting the second year. In either case registration is handled by the College of Engineering procedure.

First Year

The first-year curriculum may be that of either (a) the College of Engineering, or (b) the Departments of Chemistry and Chemical Engineering.

Second Year (for those who entered 1st-year curriculum in College of Engineering)

	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	.....
InCh 11—Semimicro Qualitative Analysis (or) OrCh 16—Carbon Compounds	.....	.....	4
ITM 24, 25—Calculus I: Differential; Calculus II: Integral (for those who had ITM 13; see statement below)	5	5	.....
ITM 80—Elementary Differential Equations (see statement below) (or) ITM 26—Calculus III: Calculus and Differential Equations (see statement below)	.....	.....	3 or 5
Nontech. Req.—Group I or II (see Index for "Nontechnical Required Courses")	3-4	3-4	3-4
Total credits	17-18	17-18	16-18

Students who had ITM 13a should take ITM 24a, 25a (Calculus II, III: Analytic Geometry and Calculus) and ITM 26a (Calculus IV: Differential Equations and Calculus), 5 credits per quarter.

Second Year (for those who entered 1st-year curriculum in Chemistry and Chemical Engineering)

	Credits—f, w, s		
Phys 7, 8, 9—General Physics	5	5	5
ITM 24, 25—Calculus I; Differential; Calculus II: Integral (for those who had ITM 13; see statement below)	5	5	.....
ITM 80—Elementary Differential Equations (see statement below) (or) ITM 26—Calculus III: Calculus and Differential Equations (see statement below)	.....	.....	3 or 5
Electives	4	4	4

Nontech. Req.—Group I or II (see Index for "Nontechnical Required Courses")	4	4	4
Total credits	18	18	16-18

Students who had ITM 13a should take ITM 24a, 25a (Calculus II, III: Analytic Geometry and Calculus) and ITM 26a (Calculus IV: Differential Equations and Calculus), 5 credits per quarter.

The third, fourth, and fifth years are the same as for those entering through the School of Physics *with one exception:* those electing to enter the physics curriculum through the School of Chemistry must take Phys 50 and 50A (5 credits, 1 quarter) sometime in their third year. This can be accomplished by choosing as part of the electives in the second year some of the nontechnical requirements normally taken in the third year, thus leaving space in the third year for Phys 50 and 50A.

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—Physical Optics (and) Phys 133A—Physical Optics Laboratory	....	....	4
PCh 101, 102, 103—Physical Chemistry (see statement below)	4	4	4
ITM 151a, 152, 153—Calculus V, VI, VII	3	3	3
Nontech. Req.—Group I or II (see Index for "Nontechnical Required Courses")	3	3	3
Total credits	18	18	18

The following is a list of courses which may be substituted for PCh 101, 102, 103 with the consent of the student's adviser: Phys 131, 133, 134, 135, 136 (any 9 credit hours); ITM 132, 133, 134, 133B-134B, 142-143; Math 121, 122, 123, 131 (any 9 credit hours); EE 51, 53, 55.

Fourth Year

	Credits—f, w, s		
Phys 107, 109, 111—Modern Physics	3	3	3
Phys 120—Atomic Physics	3	....	....
Phys 121—Experimental Nuclear Physics I	....	3	....
Phys 122—Experimental Nuclear Physics II (or) Phys 134—Experimental Optics	....	....	3
Phys 123-124-125—Thermodynamics, Statistical Mechanics, and Theories of the Structure of Matter	3	3	3
Ger 50, 51, 52—Reading German for Juniors and Seniors (see statement below)	3	3	3
Nontech. Req.—Group III (see Index for "Nontechnical Required Courses")	5	5	5
Total credits	17	17	17

With the consent of the student's adviser, any of the following language sequences may be substituted: Ger 1, 2, 3; Ger 24, 25, 26; Russ 1, 2, 3. Students not planning to pursue graduate work may, with the consent of their adviser, substitute an elective. Those students who intend to enter graduate study and can demonstrate a proficiency in reading scientific German may petition the department for permission to substitute an elective; students in this latter category planning to pursue graduate work beyond the Master's degree are strongly urged to choose French or Russian language as this elective. Electives may be chosen from suitably selected courses in technical or nontechnical areas. For the list of technical electives which the student may substitute with the consent of his adviser, see courses following the fifth year.

Fifth Year

	Credits—f, w, s		
Phys 126, 127, 128—Solid State Physics	3	3	3
Engl 85, 86—Advanced Technical Communication	3	3	....
Technical and nontechnical electives	12	12	15
Total credits	18	18	18

Technical Electives

(Fourth Year or Fifth Year Physics)

ChEn 161, 162, 163—Nuclear Reactor Design
PCh 116, 117, 118—Thermodynamics and Chemistry; Fundamentals of Reaction Kinetics; Advanced Physical Chemistry
EE 51, 53, 55—Electrical Engineering
EE 143, 144, 145—Electromechanical Vibrating Systems
EE 157, 158, 159—Industrial Electronics
EE 161, 162, 163—Electric Communication
EE 164, 165, 166—Communication Circuits
EE 167, 168, 169—Radio Communication
EE 187, 188, 189—Problems in Electrical Engineering
EE 194, 195, 196—Servomechanisms
GPhy 125, 126, 127—Geophysical Exploration
ITM 132, 133, 134, 133B, 134B—Statistics and Probability
ITM 142, 143—Vector and Matrix Theory with Applications
ITM 154, 155, 156—Vector Analysis; Vector Analysis and Tensors with Applications; Elements of Tensor Analysis
ITM 168, 169—Elementary Theory of Complex Variables; Mathematical Theory of Flow
ITM 173, 174, 175—Elementary Partial Differential Equations with Applications
Math 121, 122, 123—Mathematical Theory of Statistics
Math 131—Advanced Algebraic Theory
Math 144, 145, 146—Fourier Series and Orthogonal Functions
Math 157, 158, 159—Methods of Applied Mathematics
Math 170, 171, 172—Introduction to Modern Algebra
Phys 131, 133, 133A, 134, 135, 136—Geometrical, Physical, Laboratory, Experimental Optics; Spectroscopy; Spectrum Analysis
Phys 181, 183, 185—Atomistics and Elementary Quantum Mechanics
Phys 191, 192, 193—Introduction to Mathematical Physics

NONTECHNICAL REQUIRED COURSES

Social-Humanistic Area—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 30 credit hours. These credits, in addition to the 15 credits of engineering English, comprise the group of nontechnical credits required for the Bachelor's degree in engineering.

GROUP I—Minimum of 6 credits from any one sequence

1. NSci 7-8-9
2. Bot 1-2-3
3. Psy 1-2, 155
4. Zool 1-2-3

GROUP II—Minimum of 6 credits from any one sequence

1. Econ 8-9 or 1-2 may be followed by Econ 73, 164
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

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.

SECTION A. If the total number of credits completed from the 3 groups above is less than 30, 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.

ROTC—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 balance of NROTC credits may be used as electives.

Students who complete the program in Air ROTC or ROTC may substitute 15 credits in air or military science for an equivalent number of credits in the required 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 balance of the ROTC credits may be used as electives.

ADDITIONAL COURSE INFORMATION

Credit for Summer Employment—Consult your department or college office regarding credit for summer employment.

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

Course	Substitute Course
AnCh 132 (3 cr)	AnCh 105 (3 cr)
Draw 11 (2 cr)	Draw 14 (3 cr)
Draw 12 (2 cr)	Draw 15 (3 cr)
Hydr 101 (3 cr)	Hydr 103 (5 cr)
ITM 80 (3 cr)	ITM 26 (5 cr)
ITM 91 (4 cr)	ITM 24 and 25 (10 cr) or ITM 13a and 24a
MM 84 (5 cr)	MM 26 and 127 (10 cr)
MM 84 (5 cr)	MM 27 and 28 (6 cr)
MM 85 (3 cr)	MM 128 (5 cr)
MM 92 (4 cr)	MM 26 (5 cr)
MM 92 (4 cr)	MM 84 (5 cr)
MM 93 (4 cr)	MM 85 (3 cr)
MM 93 (4 cr)	MM 128 (5 cr)

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:
   Aero 1; CE 146; Draw 4, 6, 44; Engl 14, 15, 16; GE 70; ITM 9, 10, 11, 12, 13, 24, 25; MM 26, 127, 128; Nontechnical Required Courses (Social-Humanistic Area).

3. Evening Courses:
   InCh 24, 25, 26; AnCh 1, 2, 7, 123; Draw 4, 5, 6, 38; Engl 14, 15, 16; ITM 9, 10, 11, 12, 13, 24, 25, 80; MM 26, 127, 128; Nontechnical Required Courses (Social-Humanistic Area).

III. COURSE DESCRIPTIONS

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

Aeronautical Engineering (Aero)

1. Aeronautics. History. Nomenclature. Resistance of simple bodies. Theoretical aerodynamic theory of flight. The airplane and its parts. Constructional details. Performance. (3 cr; prereq ITM 24 or 24a; 3 lect hrs per wk)

4. Laboratory. System of measuring units and their interrelations. (1 cr; no prereq)

5. Laboratory. Familiarization with physical properties of materials. (1 cr; no prereq)

6. Laboratory. Inspection and demonstration of aeronautical facilities. (1 cr; no prereq)

20-21-22. Flying: Theory and Practice. Consists of 12 hours of ground instruction and 10 hours of flying. (2 cr per qtr; no prereq; 1 lect hr and about 1 flying hr per wk; lab fee by ar)

46. Orientation Course. Indoctrination course on Link instrument flying. (2 cr; prereq 4th yr, 5th yr, or grad in aeronautical engineering or △; twelve 2-hr periods, lect and practice)

83. Stresses in Simple Structures. Statically determinate trusses and beams. Graphic statics. Combined stresses. Short and long struts. Airplane structures. (4 cr; prereq MM 128; 3 lect and 2 lab hrs per wk)

100-101-102. Aerodynamics. Fluid mechanics; Prandtl's wing theory. Performance, stability, propeller theory. Motion of body in fluids in three dimensions. (3 cr per qtr; prereq 1 and ITM 25 or 25a; 3 lect hrs per wk) Heinrich

103-104-105.‡ Advanced Aerodynamics. Dynamic stability and control and flutter analysis. (3 cr per qtr; prereq 102; 3 lect hrs per wk)

106. Compressible Flow. Comparison of compressible and incompressible flow influences on aircraft. (3 cr; prereq 102; 3 lect 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)

115. Airplane Stresses. Deflection of structures. Theory of statically indeterminate structures. (3 cr; prereq 83; 2 lect and 2 lab hrs per wk) Scipio

116. Advanced Airplane Stresses. Frames, space frameworks, secondary stresses, beams, columns, curved beams, rings, multispar and unit wing construction, monocoque fuselages. (3 cr; prereq 115; 3 lect hrs per wk) Graves

117. Advanced Airplane Stresses. Analysis of thin-shelled plates and membranes used in aircraft wings and fuselages. Local, initial, thermal, and combined stresses. Theories of failure. (3 cr; prereq 115; 3 lect hrs per wk) Graves

118. Stresses on Aircraft Structures. Theory of flexure of flat plates. Bucklings of plates. Combined bendings and axial stress in plates. Application and design of seaplane floats and hulls. (3 cr; prereq 115; 3 lect hrs per wk) Graves

119. Testing of Aircraft Structures and Models. Theory of model studies, Mohr's circles of stress and circles of strain. Measurement of deflection. (3 cr; prereq 115)

120-121-122.* Airplane Design. Discussion of aerodynamic and structural parameters in subsonic and supersonic aircraft design. (2 cr per qtr; prereq 83 and 102; 2 lect hrs per wk) Stolarik

123-124-125.* Advanced Airplane Design. Problems in airplane design or development. (2-5 cr per qtr; prereq 121)

126.* Airscrew Propulsion. Theory common to the propulsive and lifting airscrews. Theory of the helicopter performance. (3 cr; prereq 120 or ‡) Stolarik

127-128.* Advanced Problems in Airscrew Design. (2-5 cr per qtr; prereq 126) Stolarik

130. Aerodynamic Design Laboratory. Preliminary airplane design. (2 cr; prereq ¶120; 6 lab hrs per wk) Stolarik

131-132. Airplane Design Laboratory. Air loading analysis. Load factors. Structural design and analysis. (2 cr per qtr; prereq ¶121 for 131, ¶122 for 132; 6 lab hrs per wk) Stolarik

135. Airplane Static Testing. Theory and use of electrical strain gauges as applied to aircraft structures. Tests of wing structures and aircraft components. (2 cr; prereq 140; 1 lect and 3 lab hrs per wk)

138-139. Summer Employment I and II. (2 cr per qtr; prereq completion of 3rd yr or △)

140. Aeronautical Laboratory. Airplane parts and construction. Fittings. Rigging. Inspection and maintenance. (4 cr; no prereq; 3 lect and 3 lab hrs per wk)

141. Aerodynamics Laboratory. Wind tunnel test procedure. Calibration of wind tunnels. Wind tunnel testing of wings, propellers, and airplane models. (2 cr; prereq 101; 6 lab hrs per wk)

158. Physics of the Atmosphere. Physical properties of the air. Atmosphere, troposphere, and stratosphere. Basic effects on functioning of the human body, performance of aircraft. (2 cr; prereq 3rd yr; 2 lect and 1 rec hr per wk)

164. Problems Relating to the Stratosphere. (3 cr; prereq 102; 3 lect hrs per wk) Akerman

165-166-167.*‡ Advanced Aeronautical Laboratory. Research problems in aeronautical engineering requiring laboratory of field research facilities. (2-4 cr per qtr; prereq 141 and ♯; 1 lect and 3 lab hrs per wk) Akerman

173. Introductory Meteorology. Survey of meteorological phenomena and physical principles; atmospheric statics, thermodynamics; equations for simple atmospheric motions. The laboratory work on principles involved. (3 cr; prereq 3rd yr; 2 lect and 3 lab hrs per wk) Mantis

174. Applied Meteorology. Meteorological observation; the collection and dissemination of meteorological data. Elementary weather analysis and the interpretation of weather charts. (4 cr; prereq 173; 1 lect and 6 lab hrs per wk) Mantis

175. Advanced Meteorology. Physical meteorology. Atmospheric stability; heat balance; the equations of atmosphere hydrodynamics, cyclones, and anticyclones. (4 cr; prereq 173; 3 lect and 3 lab hrs per wk) Mantis

190-191-192.*‡ Seminar. Readings, reports, conferences, and discussions. (1 cr per qtr; prereq 101 or ♯; 1 rec hr per wk)

193-194-195.* Advanced Problems in Aeronautical Engineering. (2-6 cr per qtr; prereq 5th yr or grad in aeronautical engineering)

For Graduate Students Only

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

204. Supersonic Aerodynamics Laboratory

208. Aerodynamics of Compressible Viscous Fluid. Chang

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

220.* High Speed Performance and Design. Hermann

230. Aerodynamics of Supersonic Inlet Diffusers. Hermann

231. Aerodynamics and Flight Performance of Supersonic Missiles. Hermann

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

238. Joint Seminar. (AeroE, ITM)

240. Dynamics of Aircraft Structures. Graves

241.* Dynamics of Aircraft Structures. Graves

272-273-274.* Research in Aeronautical Engineering

Agricultural Engineering (AgEn)

(College of Agriculture, Forestry, and Home Economics)

8. Laboratory. Engineering units and measurements. (1 cr; no prereq; 2 lab hrs per wk)

9. Laboratory. Engineering materials, their characteristics and use. (1 cr; no prereq; 2 lab hrs per wk)

10. Laboratory. Introduction to agricultural engineering applications. (1 cr; no prereq; 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 128 or ¶MM 128; 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)

82. Introduction to Soil and Water Management. The hydrologic cycle and its component parts—precipitation, transpiration, evaporation, infiltration, and runoff. Availability and development of surface water and ground water. Managing water by drainage, irrigation, and erosion control practices. (3 cr; no prereq; 3 lect hrs per wk)

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 38 or integral calculus and 25 or equiv) Hustrulid

141. Agricultural Drainage. Soil-water-plant relationships. Principles of surface and subsurface drainage. Design of tile drainage systems, open ditches, and drainage structures. Economics and legal aspects of drainage. (3 cr; prereq 82, Hydr 103, Soil 1; 3 lect hrs per wk) Manson

142. Erosion Control. Principles of soil erosion by wind and water. Practices for soil and water conservation. Design, cost, and construction of terraces, diversions, grass waterways, earth dams, and erosion control structures. (3 cr; prereq 141; 3 lect hrs per wk)

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 142; 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 38; 2 lect and 3 lab hrs per wk)

167. Advanced Farm Structures. Design of structural members and assemblies for farm buildings. Wind loads and wind resistant construction. 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)

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)

176. Management of Power and Machinery. Principles of power and machinery management. (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 1957-58 and alternate 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 143 or ¶143; 2 lect and 6 lab hrs per wk; offered 1957-58 and alternate 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. A survey of the adaptation, distribution, and uses of major groups of economic plants and the factors and hazards of their production. (3 cr; no prereq)

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

Air Science (Air)

(Department of Air Science)

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

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

The Air Force ROTC student is not in the military service and is therefore not subject to the uniform code of military justice.

31-32-33. Air Science I. Introduction to Air Force; introduction to aviation; fundamentals of global geography; international tensions and security organizations; military instruments and national security; command and leadership laboratory. (1 cr per qtr)

34-35-36. Air Science II. Careers in the Air Force; introduction to aircraft and bases; introduction to targets and weapons; operations; command and leadership laboratory. (1 cr per qtr; prereq 31-32-33)

131-132-133. Air Science III. Commander and his staff; problem solving; military justice; navigation; weather; air base functions; communicating and instructing in the Air Force; command and leadership laboratory. (3 cr per qtr; prereq 34-35-36)

134-135-136. Air Science IV. Military aspects of world political geography; principles of leadership and management; military aviation and evolution of warfare; career guidance; briefing for commission service; command and leadership laboratory. (3 cr per qtr; prereq 131-132-133)

Architecture (Arch)

1. Introduction to Architecture. The philosophy and principles of architecture as an art, a science, and a profession. (1 cr; no prereq; 1 lect hr 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) Koeper

57-58-59. Building Technology. Principles, techniques, materials, and equipment involved in building. (4 cr per qtr; prereq 2nd yr; 4 lect hrs per wk)

74-75-76. Building Technology. (Formerly 71-72-73) Continuation of 57-58-59 (4 cr per qtr, §71-72-73; prereq 57-58-59; 4 lect hrs per wk)

81-82-83.† Architectural Design I. (Formerly AD 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, §AD I; prereq 2nd yr for IT students, jr for SLA students and △; 18 lab hrs per wk; entrance fall qtr only) Bliss

91-92-93.† Architectural Design II. (Formerly AD 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, §AD II; prereq 83; 18 lab hrs per wk) Myers

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) Koeper

104. Planning. (Same as Econ 108, 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) Caplow, Broek, Holloway, Vivrett, Warp

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

106. Planning. Technical phases of modern city planning with special reference to the architect's function therein. (3 cr; prereq 105; 3 conf hrs per wk) Vivrett

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

111-112-113.† Architectural Design III.** (Formerly AD 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, §AD III; prereq 93 and MM 93; 24 lab hrs per wk) Vivrett

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

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

** 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.

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) Cavin

For Graduate Students Only

201.* Special Research in Architectural History. Koeper

231-232-233.* Planning

251-252-253.* Architectural Design VI. Cerny, Close, Rapson

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 6 or ITM 12) Albers

101. Celestial Mechanics. (3 cr; prereq Math 51 or 51a or ITM 25 or 25a; 3 rec hrs per wk) Luyten

Bacteriology and Immunology (Bact)

(Medical School)

53. General Bacteriology. Morphology, physiology, taxonomy, and ecology of bacteria. Practical applications of fundamental principles in science and industry. (5 cr; prereq soph with a C average in prereq courses, 10 cr in chemistry and 4 cr in biological sciences or ♯)

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, ♯)

122. Physiology of Bacteria Laboratory. Bacterial physiology and metabolic analysis techniques. (3 cr; prereq 121, ♯)

123. Bacterial Metabolism. Advanced treatment of metabolism; enzymes; biological energy; fermentation; respiration; nitrogen metabolism. (3 cr; prereq 122, biochemistry, ♯; offered 1957-58 and alternate years)

Botany (Bot)

(College of Science, Literature, and the Arts)

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

Chemical Engineering (ChEn)

100. Chemical Engineering Stoichiometry. Energy and material balances, plant processes. (3 cr; prereq 3rd yr; 3 lect and rec hrs per wk) Ceaglske, Tsuchiya, Earle

101. Unit Operations. Fundamental principles of unit operations, materials of construction, performance and uses of equipment, fluid flow, and filtration. (3 cr; prereq 3rd yr and §PCh 101; 2 lect and 2 rec hrs per wk) Stoppel, Earle, Tsuchiya

102. Unit Operations. Continuation of 101. Heat transfer, evaporation, solid-liquid and liquid-liquid extraction. Their applications and the solution of problems. (5 cr; prereq 101; 3 lect and 3 rec hrs per wk) Stoppel, Earle, Tsuchiya

103. Unit Operations. Continuation of 101 and 102. Drying, distillation, absorption, and humidification, with problems. (5 cr; prereq 102; 3 lect and 2 rec hrs per wk) Stoppel, Earle, Tsuchiya

104. Unit Operations. 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. Unit Operations 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) Preckshot, Ceaglske, Earle, Garlid

112. Unit Operations Laboratory. (See 111) (2 cr; prereq 102; 4 lab hrs and ½ lab conf hr per wk) Preckshot, Ceaglske, Earle, Garlid

113. Unit Operations Laboratory. (See 111) (2 cr; prereq 103; 4 lab hrs and ½ lab conf hr per wk) Preckshot, Ceaglske, Earle, Garlid

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) Isbin

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) Preckshot, Earle

122. Biochemical Engineering. Application of biochemical and microbiological principles to industrial processes. (3 cr; prereq Bact 53 and 121; 3 lect hrs per wk) 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 PCh 103; 3 lect hrs per wk)

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)

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

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

173. Advanced Process Control. Continuation of 171-172. Additional methods such as 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. Piret

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

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

217. Analysis of Chemical Engineering Problems. Amundson

218. Advanced Topics in Chemical Engineering

219-220. Advanced Chemical Engineering Thermodynamics. Preckshot

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

225-226-227. Fluid Mechanics and Related Topics. Amundson

264. General Survey of Chemical Engineering

301-302-303. Research in Chemical Engineering. Amundson, Ceaglske, Piret, Stoppel, Isbin, Madden, Preckshot, Tsuchiya

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

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 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

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, grad, 127) Bruckenstein

For Graduate Students Only

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

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. (Limited to students enrolled in the College of Engineering) Fundamental principles and survey of inorganic chemistry. (4 cr per qtr; 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

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 OrCh 62; 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 OrCh 62 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 1958-59 and alternate years) 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 1958-59 and alternate years) 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 1957-58 and alternate years) 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 1958-59 and alternate years) 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 1957-58 and alternate years) 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) Heisig

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

For Graduate Students Only

201-202-203.‡ 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) Kreevoy

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

63. Elementary Organic Chemistry. Continuation of 61-62. Lecture course. (3 cr; prereq 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) Parham

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 week) 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) Fenton

105-106-107.* Advanced Organic Chemistry. Advanced descriptive course covering the field of organic chemistry, together with an introduction to the literature of organic chemistry. Lectures and outside reading. Ability to read German is assumed. (3 cr per qtr; prereq 63 and 64; 3 lect hrs per wk) Smith

110. Organic Qualitative Analysis. Advanced course. Identification of pure organic compounds, separation and identification of constituents of mixtures. (4 cr; limited to 20 students; prereq 102 and ‡; 9 lab hrs per week) Koelsch

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 1957-58 and alternate years) Parham

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 German is assumed. (2-5 cr; limited to 20 students; prereq 63 and 64; course should be taken during winter quarter...‡ required to take it at any other time) Noland

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

141.* Reagents in Organic Chemistry. Discussion of typical reagents used in organic reactions; their limits of applicability, methods of use, and types of substances with which they react. (3 cr; prereq 63 and 64; 3 lect hrs per wk; offered 1958-59 and alternate years) 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 1958-59 and alternate years) Fenton

163. Elementary Organic Chemistry. Discussion of important classes of organic compounds, both aliphatic and aromatic, together with some heterocyclic compounds. (2 cr; prereq 62; 3 lect and 1 quiz hr per wk) Parham

For Graduate Students Only

201-202-203.*‡ Organic Chemistry Seminar

205.* Stereochemistry. Lauer

206.* Polymerization and High Polymers. Lauer

212.* Mechanisms of Organic Reactions. Fenton, Noland, Kreevoy

215. Theoretical Organic Chemistry. Kreevoy

261. General Survey of Organic Chemistry. Smith

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 Δ], ITM 25 or 25a or Math 51 or 51a; 3 lect and 1 rec hr per wk) Crawford

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) Schellman

107-108.† Elementary Physical Chemistry. (Premed) (3 cr per qtr; prereq 1 yr college chemistry, 1 yr college physics, Math 15-16 or 6-7; 2 lect, 1 rec, and 3 lab hrs per wk) Livingston

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 1958-59 and alternate 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 1958-59 and alternate 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 1958-59 and alternate 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, Wolf

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) Prager

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) Livingston

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) Lipscomb

119. Kinetics of Reactions: Selected Topics. Effect of solvents and electrolytes on reaction velocity, diffusion processes; induced reactions; homogeneous and heterogeneous catalysis. (3 cr; prereq 117; 3 lect hrs per wk; offered 1957-58 and alternate yrs) Livingston

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 1958-59 and alternate 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 1957-58 and alternate 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 1958-59 and alternate yrs) Livingston

For Graduate Students Only

204-205-206. Atomistics. Lumry

214. Kinetics and Mechanism of Enzymic Reactions. Lumry

217-218. Thermodynamics and Chemistry. Prager

221-222-223.‡ Colloid Seminar. Reyerson

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

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

256-257-258.‡ Seminar in Molecular Structure. Lipscomb

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 the Physical Chemistry of Proteins. Schellman

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

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

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, 232, 234-235, 236, 237-238-239, 240-241-242, 243-244, 247-248-249.

Surveying: CE 17, 18, 19, 20, 23, 24, 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; no prereq; 3 lab hrs per wk; recommended in 2nd yr)

17. Surveying. Short course including problems in chaining, transit and tape surveys; differential leveling, stadia mapping with transit and plane table, computations and platting of notes, etc. (3 cr; open to students other than civil engineers; prereq ITM 12; 2 lect and 4 lab hrs per wk)

18. Surveying. Taping practice; transit adjustments and use; level adjustments and use. Azimuth by solar observation. Field problems in traverses and level circuits. Adjustment of traverses and level circuits. (3 cr; prereq ITM 12, Draw 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. Land surveying. Field problems in cross-sectioning, slope staking, grade staking, and curve staking. 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 of Summer Session in the field at summer camp)

24. Railway Engineering. Study of the construction and maintenance of railway roadbed, track, and structures. Study of design of turnouts, crossovers, frogs, and track parts. (3 cr; prereq 20; 2 lect and 3 lab hrs per wk)

31. Elementary Structural Analysis. Algebraic and graphical analysis of structural framework, influence lines. Equivalent loads. (3 cr; prereq Draw 14, MM 26; 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 128; 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. (3 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 128; 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 128; 2 lect and 3 lab hrs per wk for 51, 2 lect and 3 lab hrs per wk for 52) 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. Location of boundaries by geodetic methods. State-wide co-ordinate system. Establish and compute state-wide co-ordinates for monuments on the campus to first- and second-order accuracies. (3 cr; prereq 23 or ♯; 2 lect and 3 lab hrs per wk) Fant

111. Land Surveying. Study of Minnesota Public Land Survey. Field survey of a city block. Field survey and subdivision of a section of land. Preparation of standard plats and descriptions. (3 cr; prereq 23 or ♯; 1 lect and 6 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 ♯; 1 lect and 6 lab hrs per wk) Fant

124. Transportation. History of transportation in the U. S. from the establishment of the Interstate Commerce Commission. Operating statistics for railroad, air, highway, waterway, and pipeline transportation. Operating characteristics of steam and Diesel-electric locomotives. (3 cr; prereq 24; 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 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 precise moment distribution. (3 cr; prereq 33; 2 lect and 3 lab hrs per wk)

142. Reinforced Concrete Design. Continuation of 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 fabri-

cation. 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 32; 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 or ¶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 course 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 course 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 or ‡; 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

232. Advanced Structural Problems. Graves

234-235.*‡ Advanced Theory of Structures. Andersen

236.* Advanced Structural Design. Andersen

237-238-239. Structural Model Analysis

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

Drawing and Descriptive Geometry (Draw)

(Mechanical Engineering Department)

11. Engineering Drawing. (Chem and ChemE) An abbreviated course in graphical representation as applied to chemistry. Charts and graphs, sketching, orthogonal projection, sectional views, dimensioning principles, piping diagrams, flow charts, and pictorial drawing. (2 cr; no prereq; 6 lect and lab hrs per wk) Springer and staff

12. Engineering Drawing. (Chem and ChemE) Graphic solutions of basic space problems with chemical applications. An introduction to curve fitting, nomographs, and the graphic computation of simultaneous equations. Perspective sketching, shading methods, and field sketching. (2 cr; prereq 11; 6 lect and lab hrs per wk) Springer and staff

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)

28. Drafting. (AeroE) Applications of descriptive geometry to aircraft drafting problems. Detail and assembly drawings of aircraft equipment using AN standard parts and materials. Schematic electrical and fluid drawings. (2 cr; prereq 16; 6 lect and lab hrs per wk)

38. Reading Drawings. Calculations and estimates of areas, volumes, and weights. Tabulation of quantities from working drawings. Problems concerned with fabrication, manufacture, and construction. (2 cr; prereq 15; 2 lect and rec hrs per wk) Potter and staff

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) Potter and staff

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) Potter and staff

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) Barich and staff

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) Potter and staff

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 25 or 25a; 3 lect and rec hrs per wk) Eggers and staff

115-116-117. Curve Fitting. Finite differences and their application to curve fitting. Fitting of data to type form of curves. (3 cr per qtr; prereq 16, ITM 25 or 25a; 3 lect and rec hrs per wk) Eggers and staff

118. Short Course in Curve Fitting. Derivation of formulas to fit experimental data. Combination of graphic and algebraic methods. (3 cr; prereq 16, ITM 25 or 25a, or #; 3 lect and rec hrs per wk) Eggers and staff

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 25 or 25a or #; 3 lect and rec hrs per wk) Eggers and staff

157-158-159. Graphical Mathematics. Correlation of descriptive and algebraic geometry. Geometrography. Graphical calculus. Graduation of experimental data. Interpolation. (2 cr per qtr; prereq 16, ITM 25 or 25a; 2 lect and rec hrs per wk) Eggers and staff

Economics and Business Administration

(School of Business Administration)

Economics (Econ)

1-2. Principles of Economics. The fundamental principles of economics intended to serve as a foundation for advanced courses in business administration and economics. (3 cr per qtr, §old 6, 8, 62; prereq 2nd year)

5. Elements of Statistics. Elementary concepts in statistical method. Statistical description; sources of data, techniques of presentation (tabular, graphic); frequencies; averages, index numbers; dispersion. Collection of data; sampling; sampling error and reliability. Inference. (Student may take either 5A [no math prereq] or 5B [see prereq below]). (5A: 4 cr, §5B, Soc 45; prereq 2nd yr; 5 hrs, incl 2 lab) (5B: 3 cr, §5A, Soc 45; prereq 2nd yr, Math 7 or 8 or 15 or equiv; 3 hrs)

8-9. General Economics. Principles of economics with special emphasis upon their application to current problems such as money, banking, conservation, insurance, international commerce, monopolies, transportation, labor, socialism, public ownership, and finance. (3 cr per qtr, §1-2, 6-7, 62-63; prereq 2nd yr, consent of adviser)

28. Business Law. The law of contracts, agency, partnership, corporations, negotiable instruments, real estate, deeds, mortgages, fixtures, leases, mechanics' liens, workmen's compensation. (3 cr, §BA 51; prereq 2nd yr, or 3rd yr with 6 cr in economics, or 4th yr without economics cr and consent of adviser; not equivalent to BA 51 as a prereq for other courses)

57. Money and Banking. The historical development, present pattern, and economic role of financial institutions, with special emphasis upon commercial banks, the money supply, and the Federal Reserve System. (3 cr; prereq 3rd yr, 9 or equiv)

73. Manpower Economics and Labor Problems. Covers (a) the marketing of manpower resources; (b) the institutional structure of labor markets; (c) economic and social problems arising out of labor marketing processes; and (d) methods, procedures, and proposals for solving these problems. (3 cr, §161; prereq 2 or 7 or equiv)

161. General Manpower Economics and Labor Problems. Includes (a) marketing of manpower resources; (b) institutional structure of labor markets; (c) economic and social problems arising out of labor marketing processes; and (d) methods, procedures, and proposals for solving these problems. This course covers the basic materials of 73 plus advanced discussion and special assignments. (3 cr, §73; prereq 3rd yr with ♯ or grad, or 2 or 7 or equiv and ♯)

164. Labor Legislation: Collective Bargaining. An analysis of (a) employer-employee-union relationships and their social control; emphasis is placed upon the actions of legislative, executive, and judicial branches of the government; and (b) the economic and social implications of issues arising in this area. (3 cr; prereq 3rd yr, 73 or 161)

Business Administration (BA)

54-55.†† Elementary Accounting. (Combined course) A combination of Econ 24-25-26, Principles of Accounting, for School of Business Administration students and for 5-year combined engineering and business students. (4 cr per qtr, §Econ 24-25-26; prereq 3rd yr)

66. Managerial Costs. A general survey of cost accounting from the point of view of the executive who must use cost information in the conduct of his business. (3 cr, §130, 152, 153; prereq 3rd yr, Econ 26 or equiv)

77. Survey in Marketing. Introductory analysis of (a) marketing institutions and their control; (b) market areas; (c) marketing costs; and (d) the operation of supply and demand in marketing. (3 cr, §Econ 185; prereq 3rd yr, Econ 2 or 7 or equiv)

167. Introduction to Industrial Relations. A survey of policy and practice in manpower management. The course provides a professional viewpoint toward major functions, including policy formulation, determination of labor needs, job analysis, recruitment, selection, training and safety, service rating, employment stabilization, collective bargaining, and wage and salary administration. (3 cr; prereq 3rd yr, Econ 73 or 161)

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†† To be counted as a Junior College course when transferred to the College of Science, Literature, and the Arts.

Electrical Engineering (EE)

12-14-16. Elements of Electrical Engineering Laboratory. Principles, materials, safety, instruments, circuit calculations, and laboratory techniques. (1 cr per qtr; prereq ITM 13 or 13a; 2 lab hrs per wk)

36-37-38. Electrical Engineering Survey. (AeroE, AgEn, CE, MechE, MinE) Basic course in direct and alternating current circuits, measurements, motors, generators, electron tubes and circuits. (3 cr per qtr; prereq ITM 26 or 26a or 80 for 36, 36 for 37 and 38; 3 lect hrs per wk for 36, 2 lect hrs and 2 lab hrs per wk for 37 and 38)

51-53-55. Electrical Engineering. Analysis of 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, dynamics of charged particles in electric and magnetic fields. (5 cr per qtr; prereq ITM 26 or 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. Electrical Engineering Problem Solving Laboratory. Supervised problem sessions. (1 cr per qtr; prereq ¶51-53; 2 lab hrs per wk)

57-59. Engineering Electronics. Analytical and graphical analyses of the following electron devices and their associated circuitry: vacuum and gas tubes, photoelectric cells, semi-conductors 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 transistor 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 3rd yr)

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) Caverley

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 electro-mechanical 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. (2 cr per qtr; prereq ¶121-123-125; 3 lab hrs per wk)

129. Electrical Transients. Transients in linear systems studied by means of transform theory. (3 cr; prereq 55; 2 lect and 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 129, 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. Power circuit analysis, symmetrical components. Control of motors, generators, metadynes, applications of magnetic amplifiers, telemetering. (3 cr per qtr; prereq 125; 2 lect and 2 lab hrs per wk)

141. Electrical Engineering Materials. Dielectric, magnetic, and conductive properties of materials used in electrical engineering including methods of measurement and examples of application. (3 cr; prereq 55, 59; 3 lect 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 ITM 26 or 26a or 80 and MM 127) Lambert or Lyon

157-158-159. Industrial Electronics. Single-phase and polyphase rectifiers, timing circuits, and photoelectric systems. Theory of servomechanisms and regulating systems, with applications. Theory of induction and dielectric heating, with applications. (3 cr per qtr; prereq 129, 163; 2 lect and 2 lab hrs per wk)

161-162-163. Electrical Engineering Networks. Theoretical study of lumped and distributed constant networks. General lumped constant network analysis; two terminal pair networks, amplifier networks, feedback, oscillators, principles of modulation theory; transmission line theory and wave phenomena. (3 cr per qtr; prereq 55, 59, ¶161A-162A-163A; 3 lect hrs per wk)

161A-162A-163A. Networks Laboratory. Laboratory study of lumped and distributed constant 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 communication. Network theory, complex frequency, reactive network synthesis, filter design, active networks. Theory of modulation, A.M., F.M., pulse modulation, large signal analysis. Noise, elements of information theory, system analysis. (3 cr per qtr; prereq 129, 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 163; 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 125; faculty sponsor required)

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 163; 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 129 and ITM 26 or 26a or 80)

177. Analog Computing Laboratory. (1-3 cr; prereq 129, ITM 26 or 26a or 80)

180. Electrical Pulses and Transients. Application of Fourier integral and transform methods, network response, distortion of wave form, response of multistage amplifiers. (3 cr; prereq 129, 163) Anderson

181. Communication Frequency Measurements. Bridge circuits for measurement of resistance, inductance, and capacitance at audio and radio frequencies. (2 cr; prereq 163)

183-184-185.‡ Special Electrical Laboratory. Special problems in electrical engineering. (1-3 cr per qtr; prereq 3rd yr; faculty sponsor required)

187-188-189. Problems in Electrical Engineering. Transmission lines and four-terminal networks. Nonlinear circuits. Interaction between electric circuits and fields. (3 cr per qtr; prereq 125, 129, 163)

190. Theory and Application of Nonsinusoidal Wave Forms. Transmission of pulses through linear networks, design of pulse amplifiers, generation of non-

sinusoidal wave forms, time bases, cathode-ray oscilloscopes. (3 cr; prereq 129, 163) 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, 129, 163; 3 lect hrs per wk for 194, 2 lect and 2 lab hrs per wk for 195 and 196)

197-198-199. Advanced Electrical Design. 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) Kuhlmann

For Graduate Students Only

201-202-203. Industrial Electronics. Anderson

204-205-206. Metadyne Statics and Linear Dynamics. Cartwright

207-208-209. Metadyne Nonlinear Dynamics. Cartwright

211-212-213. Network Analysis and Synthesis. Lambert

221-222-223.* Electric Power Seminar

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

230-231-232. Introduction to the Properties of Solids. Dekker

233-234-235. Fluctuation Phenomena. van der Ziel

236-237-238. Solid-State Theory. Dekker

239-240-241. Solid-State Devices. van der Ziel

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

261-263-265. Problems in Electromagnetism. Shepherd

262-264-266. Communication Seminar

267-268-269. Theory of Communication. Staff

272-273-274. Fundamentals of Acoustics. Lambert or Lyon

275-276-277. Advanced Electrical Design. Kuhlmann

287-288-289. Vacuum Tube Analysis. Staff

291-292-293. Electronics Seminar. van der Ziel

294-295-296. Advanced Control Theory. Murphy

English (Engl)

14-15-16. Written and Spoken Communication. Elementary technical writing and speaking integrated with analytic reading in class and pleasure reading outside of class. (3 cr per qtr; prereq placement test; 3 rec hrs per wk)

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 16 or A-B-C or Comp 4-5-6 or Comm 1-2-3 or exemption from requirement; 3 rec hrs per wk)

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 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; required of all 1st yr students; no prereq; 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; no prereq; 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; 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 1-2 or ¶1-2; 4 lab hrs per wk)

5-6. Engineering Geology. Materials of the earth and geologic processes. Applications of geology to engineering problems. Brief survey of occurrence, properties, production, and use of building stones, cements, clays, fuels, and road material. (3 cr per qtr; no prereq; 3 lect hrs per wk) Schwartz

8. Earth Features and Their Meaning. An introductory course. A general education elective. An explanation of the natural landscape as produced by such agents as the atmosphere, water, glaciers, volcanoes, and mountain-building forces acting on the materials of the earth. (5 cr; no prereq; 5 lect hrs per wk) Thiel

23-24. Mineralogy. The crystal systems; morphological, physical, and chemical characters of minerals; classification and description of common minerals. Determinative work in laboratory, blowpipe analysis, sight identification. (4 cr per qtr; prereq 1 term college chemistry; 3 lect and 4 lab hrs per wk) Gruner

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) Goldich

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, or 8; prereq 1 yr 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. Environments of sedimentation. The 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. Methods used in the study of sediments and 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. The study and classification of Foraminifera, Ostracoda, and other small fossils, and their use in stratigraphy. (3 cr; prereq 107) Swain

104. Micropaleontology. Advanced study of selected groups of microfossils. (2 cr; prereq 103; offered 1957-58 and alternate yrs) Swain

106. Petrography. Optical methods for identification of minerals in thin sections and immersion media; introduction to microscopic work on rocks. (3 cr; prereq 25; 1 lect, 1 rec, and 4 lab hrs per wk) Goldich

107. Invertebrate Paleontology. Morphology and classification of important fossil groups. Principles of paleontology. (3 cr; prereq B; 2 lect and 2 lab hrs per wk) Sloan

108.* Stratigraphic Paleontology. The 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. The composition and origin of petroleum, methods of exploration and the geology of the important oil producing regions. (3 cr; prereq 125 and 151; 3 lect hrs per wk) Swain

114.* Geology of Minnesota and Adjoining Areas. The structure, stratigraphy, and lithology of the rocks and their associated mineral resources, with emphasis on the Pre-Cambrian. (3 cr; prereq 25; 3 lect hrs per wk; offered 1957-58 and alternate yrs) 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, with emphasis on the landforms and Cenozoic history. Map study. (3 cr; prereq 118 or 125; 2 lect hrs per wk, lab ar; offered 1957-58 and alternate yrs) Wright

119B.* Geomorphology of Western United States. General geology of the physiographic provinces from the Great Plains westward, with emphasis on the landforms and the Cenozoic history. Complementary to 119A. Map study. (3 cr; prereq 118 or 125; offered 1958-59 and alternate yrs) Wright

120.* Glacial Geology. Physics of modern glaciers. Glacial erosion and deposition. Stratigraphy and chronology of the Pleistocene in glaciated and nonglaciated areas. Causes of Pleistocene climatic changes. (3 cr; prereq B; 3 lect hrs per wk) Wright

121.* Crystallography. The symmetry relations in the 32 crystal classes and 230 space groups. Crystal drawings and measurements. Projections and mathematical calculations. (3 cr; prereq trigonometry and 1 yr college chemistry) Gruner

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) Goldich

137.* Principles of Chemical Geology. A study of geochemical literature. Methods in geochemical research and application of chemical and physical chemical principles to geologic problems. (3 cr; prereq 25) Gruner

140.* Applied Petrography. Application of petrographic techniques to problems in mining and petroleum geology. (3 cr; prereq 131)

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. The crystal systems; morphological, physical, and chemical characters of minerals; classification and description of common minerals. Determinative work in laboratory, blowpipe analysis, sight identification. (3 cr per qtr; for students in soil science and agriculture and civil engineering; prereq 1 term college chemistry) Gruner

150. Field Geology. 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, South Dakota. (6 cr; prereq 125)

151. Stratigraphy I. Principles of stratigraphic classification and correlation; biostratigraphic zones, sedimentary facies and cycles. Study of typical pre-Mesozoic sequences. (3 cr; prereq 25, 107; 3 lect hrs per wk) Swain

152.* Stratigraphy II. Study of typical Mesozoic and Cenozoic sequences; methods of presentation of stratigraphic data. (3 cr; prereq 151; 3 lect hrs per wk) Swain

153.* Subsurface Stratigraphy. The 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. Study of sedimentary and biological processes in modern oceans and lakes and their application to geology and paleontology. Lectures, laboratory, and field work. (2 cr; prereq 101 and 118 or #; offered 1958-59 and alternate yrs) Swain

155.* Vertebrate Paleontology. The stratigraphic and morphologic aspects of fossil vertebrates. (3 cr; prereq 107 or Zool 22 or #; offered 1957-58 and alternate yrs) Swain

161.* Advanced Mineralogy. Systematic study of mineral groups including some of the less common ones. Laboratory study of select specimens. Special physical and chemical tests. (3 cr; prereq 24) Gruner

166-167.* Mineralography. Methods of studying opaque minerals and 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 at Senior College and graduate levels. (1-3 cr; prereq consent of major adviser)

171.* Preparation of Geologic Report. Preparation under close supervision 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 of field work each week. (3 cr; prereq 118, 120) Wright

176. Pleistocene Geology. Pleistocene history of the 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 1957-58 and alternate yrs) Wright

177. Advanced Geomorphology. Geomorphology of rivers, lakes, and oceans; landforms of arctic, desert, and tropic regions; quantitative geomorphology; other selected subjects. (3 cr; prereq 118; offered 1958-59 and alternate yrs) Wright

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, etc. (3 cr; prereq Phys 9 or 14, Geol 2...Geol 125 recommended) Mooney

109. Elementary Seismology. Physics and geology of earthquakes; causes, effects, distribution. Theory of seismic waves. (3 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 25 or 25a) Mooney

126. Principles of Seismic Exploration. Reflection and refraction seismology; interpretation of data. (2 cr; prereq Phys 14, Geol 125, ITM 25 or 25a) Mooney

127. Principles of Electrical Exploration. Resistivity method and others; theory, interpretation, and instruments. (2 cr; prereq Phys 14, Geol 125, ITM 25 or 25a) Mooney

130. Special Problems in Geophysics. (Cr ar; prereq ‡) Mooney

German (Ger)

(College of Science, Literature, and the Arts)

24-25-26. Chemical German. (3 cr per qtr; for chemists, miners; no prereq)

27-28-29. Chemical Prose. (3 cr per qtr; for chemists; prereq 2 yrs high school German or 1 yr college German)

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. (4 cr per qtr; prereq soph) Osgood, Chambers, Noble

79-80-81.‡ The United States in the 20th Century. A discussion of the 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- . (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 1958-59 and alternate yrs) 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) Heaton

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. The growth of individualism and democracy (with particular attention to minorities) as recorded in American history, social thought, literature, and the arts. (3 cr) Kwiat, Noble, Turpie

22. American Life II. The role of the land, the city, and of religious and philosophic attitudes (from Puritanism to Pragmatism) in the determination of American ideals. (3 cr) Kwiat, Noble, Turpie

23. American Life III. The growth and interrelation of nationalism, regionalism, and internationalism in American culture and thought. (3 cr) Kwiat, Noble, Turpie

51-52-53.‡ Humanities in the Modern World. Similar to 1-2-3 except that it is confined to juniors and seniors. 51: The Old Regime; the French Revolution and the Napoleonic Era. Neoclassicism and Romanticism. Authors: Pope, Voltaire, Rousseau, Burke, Goethe, and Tolstoy's *War and Peace*. 52: The Industrial Revolution, liberalism and socialism, individualism. Authors: Adam Smith, Malthus, Carlyle, Marx, Ibsen, Zola, Flaubert, Tolstoy, and Dostoevsky. 53: The impact of science and evolution; religion and morals in a changing world. Authors: Darwin and the evolutionists, Nietzsche, Chekhov, Kierkegaard, and Thomas Mann. (5 cr per qtr, §1-2-3) Bowditch, Blum, Kwiat

71-72-73.‡ Humanities in the United States. An 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 26 or 84; 3 rec hrs per wk) 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 26 or 84; 5 rec hrs per wk) 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 and MM 127, 128, 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

Industrial Engineering (IE)

150. 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 150 or ¶150; 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 150, 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 150; 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 150; 3 rec hrs per wk)

180. Elements of Supervision. Supervisory functions and relations with employees, other supervisors, staff departments, and management. (3 cr; prereq 150; 3 rec hrs per wk)

182. Industrial Safety and Hygiene. Safety requirements for production processes, equipment, and plants; organization and administration of safety and hygiene programs. (3 cr; prereq 150; 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 134 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 134 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

Mathematics (ITM)

2-3-4. Laboratory. History of mathematics, foundations and mathematical logic, simple computing devices, library facilities, employment opportunities. (1 cr per qtr; no prereq)

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)

10. Solid Geometry (High School). (Formerly Draw 10) 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)

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)

13. Analytic Geometry. Rectangular co-ordinate systems, locus and equation, straight line, conic sections. Transformation of co-ordinates. Polar co-ordinates, higher plane curves. Empirical equations, solid analytic geometry. (5 cr; prereq 10, 11, 12 or equiv; 5 rec hrs per wk; offered last time winter 1958)

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. Elements of integration and applications. (5 cr; prereq 10, 11, 12 or equiv; 5 rec hrs per wk)

24. Calculus I: Differential. Limit, derivative, slope, maxima and minima, differentials, rates, radius of curvature, indeterminate forms, partial differentiation. (5 cr, §91; prereq 13; 5 rec hrs per wk; offered last time spring 1958)

24a. Calculus II: Analytic Geometry and Calculus. Mean value theorem, definite integral. Differentiation of transcendental functions, polar co-ordinates, parametric equations, vectors, geometric applications. Applications of integration: moments, centroids, moments of inertia, hydrostatic pressure, work. (5 cr; prereq 13a; 5 rec hrs per wk)

25. Calculus II: Integral. Integration, definite integral, geometric applications, liquid pressure, work, centroids, moments of inertia, multiple integrals, infinite series, expansion of functions. (5 cr; prereq 24; 5 rec hrs per wk; offered last time fall 1958)

25a. Calculus III: Analytic Geometry and Calculus. Methods of integration. 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)

26. Calculus III: Calculus and Differential Equations. Solid analytic geometry, partial differentiation, total differential, Taylor's formula for several variables, multiple integrals. Differential equations; first order, linear equations, integration factors, equations of higher order, linear differential equations with constant coefficients, systems of differential equations. Solutions by series. Numerical methods. (5 cr, §80; prereq 25; 5 rec hrs per wk; may be substituted for 80; offered last time fall 1958)

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)

80. Elementary Differential Equations. Equations of first order, singular solutions; linear equations with constant coefficients, simultaneous equations, integration in series, numerical solutions. (3 cr, §26 or 26a; prereq 25 or 25a; 3 rec hrs per wk)

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

91. Calculus. (Short course for Arch, Prebus) Derivatives, maxima and minima, integration, definite integrals, areas. (See section on "Additional Course Information" for permissible substitute) (4 cr, §24, 25, 13a, 24a; prereq 13; 4 rec hrs per wk; not for students who took ITM 13a)

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, Kantorovitch, etc., eigenvalues and eigenfunctions. (3 cr; prereq 26, 152, 153 or 26a, 152, 153 or 80, 152, 153 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 26, 132, 153...or 26a, 132, 153...or 80, 132, 153...or 26, 132, 149...or 26a, 132, 149...or 80, 132, 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; prereq 25 or 25a; 3 rec hrs per wk)

147-148-149.* Mathematical Methods in Engineering. Elements of vector analysis and complex variables, line and surface integrals. Numerical and series solutions of ordinary differential equations, Bessel functions, Legendre polynomials, Fourier series, and solutions of partial differential equations by separation of variables. Determinants, matrices, gamma function, and difference equations. (3 cr per qtr, §152, 154; prereq 26 or 80; 3 rec hrs per wk)

150a.* Ordinary Differential Equations. (Formerly ITM 151) Linear equations of second order, successive approximations. Existence theorems, systems of ordinary differential equations. Numerical integration and solution by series. (3 cr; prereq 26 or 80; 3 rec hrs per wk)

151a. Calculus V: Intermediate Calculus. (Formerly ITM 150) Limit concept, derivative, Reimann integral, numerical integration, partial differentiation, multiple integrals. (3 cr, §147, 148, 149; prereq 25 or 25a; 3 rec hrs per wk)

152.* Calculus VI: Advanced Calculus. (Formerly Calculus IV) Maxima and minima in several variables, vector algebra and calculus, Green's and Stokes' theorems, integrals depending upon a parameter. (3 cr, §147, 148, 149; prereq 150 or 151a; 3 rec hrs per wk)

153.* Calculus VII: Advanced Calculus. (Formerly Calculus V) Infinite series, computation with series, series with variable terms, uniform convergence, power series. Fourier series and orthogonal functions, special functions. (3 cr, §147, 148, 149; prereq 150 or 151a; 3 rec hrs per wk)

154.* Vector Analysis. (3 cr; prereq 25 or 25a; 3 rec hrs per wk)

155.* Vector Analysis and Tensors with Applications. (3 cr; prereq 154; 3 rec hrs per wk)

156.* Elements of Tensor Analysis. (3 cr; prereq 155; 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 ‡; 3 rec hrs per wk) Koehler

164-165-166.* Programming for High Speed Digital Computers with Applications. 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; prereq 26 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; prereq 25 or 25a; 3 rec hrs per wk) Stein

167A-167B. Selected Topics in Mathematics for Aeronautical Engineers. Review of calculus and ordinary differential equations, partial differentiation. Partial differential equations of fluid flow with some solutions. Vector algebra and calculus including Green's and Stokes' theorems. Complex variables: elementary theory through the calculus of residues; basic notions of conformal mapping. Operational calculus (Laplace Transform) with applications. Numerical analysis. (3 cr per qtr; prereq 26 or 26a or 80; 3 rec hrs per wk)

168.* Elementary Theory of Complex Variables. Derivative and integral of a function of a complex variable. Cauchy's integral theorem and formula, residues. Application to evaluation of integrals, conformal mapping. (3 cr; prereq 152 and 153, or 149, or ‡; 3 rec hrs per wk)

169.* Mathematical Theory of Flow. Laplace's equation, steady flow of fluids, heat, electricity. Two-dimensional flow, Poisson's integral. Streamlines, circulation, and vertices, application to airfoils. (3 cr; prereq 168, Hydr 103; 3 rec hrs per wk)

173-174-175.* Elementary Partial Differential Equations with Applications. Laplace transform, Fourier series and integrals, Bessel, Legendre, and other orthogonal functions. Boundary and initial value problems of physics and engineering by transform methods and separation of variables. (3 cr per qtr; prereq 26, 152, 153...or 26a, 152, 153...or 80, 152, 153; 3 rec hrs per wk) Koehler or Munro

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.* Advanced Numerical Analysis in Engineering. Approximation of functions and least squares. Approximate solution of ordinary and partial differential equations, Moulton's, Runge's relaxation and iteration methods. Calculation of eigenvalues of matrices and differential problems, Rayleigh-Ritz method. Integral equations. Programming of computers. (3 cr per qtr; prereq 149, 184...or 152, 153, 184; 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 Poincare duality theorem. (3 cr per qtr; prereq 142 or ¶142 or ‡; 3 rec hrs per wk) Calabi

193-194-195.* The Absolute Differential Calculus. Curvature, torsion, Frenet formulas. First and second fundamental forms. Tensors and quadratic forms. Manifolds, Riemannian and non-Riemannian. Geodesics, covariant differentiation, Ricci tensor, affine connections, parallelism. Applications to dynamics, electricity and magnetism, special theory of relativity. (3 cr per qtr; prereq 152, 153, or ‡; 3 rec hrs per wk) Calabi

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 168; 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

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)

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
274-275-276.* Partial Differential and Integral Equations of Applied Mathematics. Rosenbloom
277-278-279.* Calculus of Variations and Minimal Surfaces. Serrin, Nitsche
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. Turrittin
307-308-309.* Mathematical Problems of Theoretical Physics. Rosenbloom

Mechanical Engineering (ME)

Air Conditioning and Refrigeration:

Air conditioning: ME 160, 161, 163, 166, 169, 265, 266, 267

Refrigeration: ME 169, 180, 181, 280, 282

Thermodynamics and Heat Transfer: ME 130, 131, 132, 133, 134, 231, 232, 233, 234, 235

Industrial:

Industrial engineering: IE 150, 153, 154, 155, 163, 165, 167, 170, 171, 173, 180, 182, 190, 194, 195, 196, 197, 198, 199, 251, 252, 253, 261, 262, 263, 271, 272, 273 (See section on Industrial Engineering Options)

Industrial labs: ME 15, 16, 18, 110, 111, 112, 113, 114, 115, 119, 170

Machine Design and Instrumentation:

Machine design: ME 21, 22, 23, 24, 121, 122, 123, 124, 125, 127, 128, 129, 224, 225, 226, 228, 229

Instrumentation: ME 33, 34, 198, 199, 298

Heat Power: ME 40, 42, 135, 136, 141, 142, 146, 147, 150, 151, 152, 154, 156, 157, 158, 159, 242, 243, 244, 250, 252, 253, 255, 256, 257

General: ME 1, 90, 91, 92, 93, 94, 95, 101, 102, 194, 196, 290, 291, 292, 293

1. Mechanical Engineering Orientation. Lectures and inspection trips to acquaint the student with the field of mechanical engineering. (1 cr; no prereq; 3 lab hrs per wk; spring qtr only)

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 Met 56 or ¶56; 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 Met 56 or ¶56; 2 lect and 3 lab hrs per wk)

18. Materials and Processes. (AeroE, ME Work-Study) Properties of metals and alloys and their processing and fabrication. Casting, forming, welding, heat treating, and machining. (3 cr; no prereq; 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 Draw 16; 2 lect and 2 lab hrs per wk)

22. Mechanisms of Automatic Machinery. 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 127; 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 128; 2 lect and 3 lab 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 130 or ¶130; 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)

40. Heat Engines. (EE) Thermodynamics of gases and vapors, fuels and combustion, cycle analysis, operation and performance analysis of internal combustion engines, steam power plants, and related units. (3 cr; prereq Phys 51; 3 rec hrs per wk)

42. Heat Engines. (CE, MinE, GeolE) Elementary thermodynamics, fuels and combustion, construction operation, performance analysis, and selection of heat power equipment. (4 cr; prereq Phys 14; 4 rec hrs per wk)

90-91-92-93-94-95.† 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. (3 cr per qtr; prereq regis in co-operative work-study program) Algren

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 I. 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 128; 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 128; 2 lect and 3 lab hrs per wk)

129. Vibration Engineering. Elementary vibration theory with application to vibration absorption and isolation. (3 cr; prereq MM 193; 3 lect hrs per wk)

130-131-132. 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 25 or 25a, Phys 14; 3 rec 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 132, Hydr 101 or 103 or ¶Hydr 101 or 103; 3 lect or rec hrs per wk)

134. Thermodynamics of Fluid Flow. The energy analysis of the flow of viscous and compressible fluids. Applications to flow processes and components in engineering systems. (3 cr; prereq 132; 3 rec hrs per wk)

135. Turbomachinery. Principles of turbomachinery. Application to turbines, compressors, pumps, and fluid power transmissions. (3 cr; prereq 132; 3 rec hrs per wk)

136. Nuclear Power. Role of nuclear energy in power field, stationary power plants, mobile power plants, economics of nuclear power; current developments in power reactors; thermodynamic cycles; heat exchangers; liquid metal heat transfer including forced convection, free convection and superposed free and forced convection including internal heat generation; liquid metal pumps; fluid flow and heat transfer in noncircular ducts; boiling heat transfer; basic considerations in selection of coolants, thermal stresses; shielding problems; nuclear propulsion, submarine propulsion. (3 cr; prereq ChE 161)

141. Heat Power Engineering. Study of application and control of fuels and combustion, thermodynamics, and heat transmission to steam power and process engineering. (3 cr; prereq 132; 3 rec hrs per wk)

142. Advanced Heat Power Engineering. Practice and economics relating to power plant cycles, steam generators, prime movers, plant controls, and plant auxiliaries. Trends in power development. (3 cr; prereq 141; 3 rec hrs per wk)

146. Fuels and Combustion. Fuel classification and analysis, stoichiometry, rates, combustion processes, combustion equipment, and controls. (3 cr; prereq 141; 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 141, 150; 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 132; 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 pre-ignition, 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. Design of principle components, piston, rod, crankshaft, and valve mechanism, or compressor and turbine for compounded engine. (3 cr; prereq 121 and 150...or 150 and AE 115; 3 rec hrs per wk)

156. High Speed Engine Testing. Advanced laboratory procedure. Effects of fuel, mixture distribution, etc., upon general engine performance. (2 cr; prereq 158 or 159; 6 lab hrs per wk)

157. Gas Turbine and Jet Propulsion Power Plants. Gas turbine cycles and principles; characteristics of compressors and turbines; power and efficiency calculations. (3 cr; prereq 150; 3 lect hrs per wk)

158. Aircraft Power Plant Laboratory. Laboratory performance of piston engine and jet engine components, heat balance analysis, characteristics of com-

pressor, turbine, and combustion chambers, fuels and lubricant properties. (2 cr; prereq 150 and 157; 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 141 and 150; 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 ‡; 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 132 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 132; 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 1.5 hpr; prereq consent of division chief concerned)

196. Inventions and Patents. Study of problems associated with inventions, their patenting, development, evaluation, and exploitation. (3 cr; prereq 4th yr; 3 rec hrs per wk)

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 5th yr; 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 26 or 26a or 80; 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

231.* Advanced Thermodynamics. Ibele

232.* Advanced Fluid Thermodynamics. Ibele

233.* Conduction. Eckert

234.* Convection. Eckert

235.* Radiation. Eckert

242.* Power Plant Specification. Lee

243.* Power Plant Layout. Lee

244.* Power Plant Management. Lee

250.* Dynamics of High Speed Engines. Murphy
252.* Advanced Reciprocating Engines. Murphy
253.* Advanced Gas Turbines. Murphy
255.* Thermal Jets and Rockets
256.* Engine Testing and Research. Murphy
257.* Combustion and Fuels for Gas Turbines and Engines. Murphy, Ibele
265.* Advanced Air Conditioning. Threlkeld
266.* Advanced Ventilation and Air Distribution. Threlkeld
267.* Applied Heating, Ventilation, and Air Conditioning. Threlkeld
280.* Theoretical Refrigeration. Jordan
282.* Reverse Applications of Refrigeration—The Heat Pump. Jordan
290-291-292.* Mechanical Engineering Research
293. Graduate Seminar
298.* Advanced Instrumentation and Automatic Control. LaJoy

Mechanics and Materials (MM)

26. Engineering Statics. Resolution of force systems, equilibrium of rigid bodies and analysis of framed structures. Centroids. Graphical methods. Friction. Virtual work. Moments of inertia. (5 cr; prereq ITM 25 or 25a; 5 rec hrs per wk)
27. Engineering Mechanics I. Vector algebra; application of the equations of equilibrium to the analysis of simple engineering structures and machines; nature and influence of friction, elementary theory of statically determinate framed structures. (3 cr; prereq ITM 25a and Phys 14; 3 lect hrs per wk)
28. Engineering Mechanics II. Application of the principles of particle motion; kinematics, impulse-momentum and work-energy principles, potential and potential energy, planetary motion impact, introduction to forced and free mechanical vibrations. (3 cr; prereq 27; 3 lect hrs per wk)
29. Engineering Mechanics III. Dynamics of rigid body motion; extension of the principles of impulse-momentum and work-energy, Euler's equations of motion; the gyroscope, virtual work, stability, generalized co-ordinates. (3 cr; prereq 28; 3 lect hrs per wk)
84. Principles of Statics and Dynamics. Resolution of force systems, equilibrium of rigid bodies and analysis of framed structures. Centroids and moments of inertia. Kinematics. Applications of Newton's laws of motion. Work, energy, and power. Impulse and momentum. Introduction to mechanical vibrations. (5 cr; prereq ITM 25 or 91; 5 rec hrs per wk)
85. Principles of Solid Mechanics. Introduction to static strength properties of structural materials. Stress and strain. Applications to tension and torsion members, beams, columns, and joints. Design considerations. Statically indeterminate members. (3 cr; prereq 26 or 84; 3 rec hrs per wk)
88. Properties of Structural Materials. Strength properties, their determination and general significance in design and service performance. Introduction to engineering physical metallurgy and the relation of processing and structure to properties. Properties of important classes of engineering metals and nonmetals. (3 cr; prereq 26 or 84; 2 rec hrs and 2 lab hrs per wk)
92. Elements of Statics. Resolution of force systems, equilibrium of rigid bodies and analysis of framed structures. Centroids and moments of inertia. (4 cr; prereq ITM 91; 4 rec hrs per wk)
93. Elements of Solid Mechanics. 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 hrs and 2 lab hrs per wk)
127. Engineering Dynamics. Kinematics of structural elements. Dynamics of particles and of rigid bodies. Work and energy. Impulse and momentum. Introduction to mechanical vibrations. (5 cr; prereq 26)
128. Engineering Solid Mechanics. Stress, strain, and deformation in continuous solids and applications to tension and torsion members, beams, columns, and

joints. Statically indeterminate members. State of stress at a point, combined stress, and Mohr's circles. (5 cr; prereq 26)

129. Strength Properties of Solids. Physical structure and properties of materials. Engineering physical metallurgy, phase diagrams, and heat and mechanical treatment. Strength properties of materials, their determination, relationship to service performance, and general control. General properties of ferrous and nonferrous metals, plastics and laminates, stone and mineral aggregates, and timber. (5 cr; prereq 85 or 93 or 128)

142. Experimental Mechanics. Assumptions made in theoretical mechanics, limitations of theory, and role of experimental mechanics. Mechanical, electrical, optical, and other gauges for measurement of static and dynamic strain. Photoelasticity, brittle coating and other methods for determining localized strain. Verification of equations of solid mechanics. Tests of axial, torsional, and transverse-loaded members. (2 cr; prereq 128) Blatherwick

164-165-166.*‡ Special Problems in Mechanics and Materials. Short duration research problems, literature studies, and reports. (3 cr per qtr; prereq ‡) Graduate staff

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 128 and either ITM 147 or Math 157 or ITM 173) Graduate staff

181. Applied Elasticity I. Stress analysis of structural elements. Flexure of beams on elastic subgrades. Unsymmetrical bending and centers of twist. Buckling of columns, plates, and shells. (3 cr; prereq 128) Graduate staff

182. Applied Elasticity II. 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 128) Graduate staff

193. Introduction to the Theory of Mechanical Vibrations. Fundamental methods for the determination of the dynamic response and natural frequencies of lumped-parameter systems. Transient and steady-state behavior of linear systems having a single degree of freedom; influence of damping; criteria of stability; elements of vibration isolation. This course is prerequisite to further graduate work in vibration theory in the professional divisions of engineering. (3 cr; prereq 127, ITM 26 or 26a or 80) Goodman

For Graduate Students Only

211.* Theory of Vibrations I. Goodman

212.* Theory of Vibrations II. 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

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

297-298-299.* Mechanics and Materials Seminar

Metallurgical Engineering (MetE)

1. Metallurgical Engineering Laboratory. The fields of mineral and metallurgical engineering described in lectures, laboratories, and field trips. (1 cr; no prereq; 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 of 1957-58 and alternate 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 Metallurgical Engineering. Stoichiometry, heat balances, metallurgical fuels, combustion of fuels and heat utilization. (3 cr; prereq 8 cr in inorganic chemistry) Bitsianes

107. Principles of Process Metallurgical Engineering. Heat flow in metallurgical systems. Pyrometallurgical phases. (4 cr; prereq 106) Bitsianes

108. Principles of Process Metallurgical Engineering. Agglomeration, roasting, hydrometallurgy, electrolytic extraction and refining of metals. (4 cr; 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, Iwasaki

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, Iwasaki

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, Iwasaki

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. Determination of methods for economic extraction of minerals from ores. (3 cr; prereq 112) Cooke, Iwasaki

123. Advanced Mineral Dressing. Advanced flotation theory and special research techniques. (3 cr; prereq 122) Cooke, Iwasaki

124-125-126.*‡ Special Problems in Mineral Dressing. (Cr and hrs ar; prereq 112) Cooke, Iwasaki

134.* Metallurgical Unit Processes. Slag-metal equilibria, refining of liquid metals, solidification and segregation of metals, 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 nonferrous metallurgy. (3 cr; prereq 108) Joseph

138. Advanced Process Metallurgy. Heterogeneous chemical reactions. Application of physical chemistry to some advanced problems in metallurgical engineering. (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

For Graduate Students Only

201-202-203.‡ Research in Process Metallurgy. Bitsianes, Joseph

204-205-206.‡ Research in Mineral Dressing. Cooke, Iwasaki

210-211-212.*‡ Seminar in Metallurgical Engineering. Staff

220. Flotation Theory. Cooke

Metallurgy (Met)

(Department of Metallurgy, School of Chemistry)

1. Metallurgy Laboratory. Field of metallurgy, what a metallurgist does, experiments demonstrating behavior of metals and alloys. (1 cr per qtr; no prereq; 1 hr per wk) Mooney

53. Principles of Physical Metallurgy I. Atomic structure, crystal structure of metals, Hume-Rothery rules, elements of phase diagrams. (3-5 cr depending on lab; prereq ‡) 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, 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. (3-5 cr depending on lab; prereq ‡) 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. (3-5 cr depending on lab; prereq 154 or ‡) Nicholson

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. (2 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. (1 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

163A-163B-163C.* Thermodynamics of Alloys and Solid State Reactions. Theory of liquids, heterogeneous equilibria, free energy–composition diagrams and reaction kinetics. (3 cr per qtr; prereq PCh 103 or ‡) Swalin

164.* Modern Theory of Metals and Alloys. Free electron theory of metals and applications. Imperfections in crystals. (3 cr; prereq Phys 51 or ‡) 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

For Graduate Students Only

250.* Thermodynamics of Alloys. Swalin

251.* Kinetics of Solid State Reactions. Nicholson, Swalin

252.* Advanced Theory of Metals and Alloys. Swalin

260.* Dislocation Theory of Crystals. Nicholson

263.* Advanced X-Ray Diffraction of Metals. Nicholson

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 of first aid and military sanitation 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; no prereq; 1 hr per wk) Staff

13. Mine Surveying. Mining claims, bore holes, shaft plumbing, underground traversing, and leveling. (3 cr per qtr; prereq CE 19 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)

15. Mine Surveying Field Work. Surveying of an underground mine located on Iron Range, including shaft plumbing. Survey of open-pit mine, including an estimate of the surface stripping. Solar and stellar observations. (6 cr; prereq 13; 4 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 15. Ore estimates. (2 cr [1 cr for PetE Option in MinE]; prereq 15; 3 lab hrs per wk)

90-91-92. Industrial Employment. Summer work in the mineral industries for a period of 2 or more months. Character of work to be approved by the department. Satisfactory record of employment and an acceptable report required. (2 cr per course; prereq ‡)

111. 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. Fundamentals of 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. (2 cr; prereq 113, MM 84, or ‡; 2 lect and 4 lab hrs per wk) 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 42 or ME 131, EE 37; 3 lect and 3 lab hrs per wk) 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) Fairhurst

131. Rock Mechanics I. Geometry of stress and strain in 2 and 3 dimensions, theoretical solutions to stress and failure of mine openings. Mechanism of failure under static and dynamic stress. Physical properties and testing of rocks. (3 cr; prereq MM 142; 2 lect and 3 lab hrs per wk)

132. Rock Mechanics II. Elastic wave propagation in blasting. Hydrodynamic theory of explosive detonations. Mechanics of drilling, blasting, and crushing operations. Design of mine openings. Experimental methods of investigation. (3 cr; prereq 131; 3 lect hrs per wk)

133. Advanced Rock Mechanics I. Influence of geology on mine layout. Rock bursts and subsidence. Seismic and photographic studies of rock failure by blasting and high earth pressures. Model investigations using strain and pressure gauges and photo-elastic methods. (3 cr; prereq 132 or ‡; 2 lect and 3 lab hrs per wk)

139. Inspection Trip. Study of mining operations, mine plant, and metallurgical plants in several mining camps. Engineering report. (6 cr; prereq ‡; 3 wks beginning about September 1)

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. The 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. The 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. (2 cr; prereq 112 or ‡; 2 lect hrs per wk) Pfleider

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

Natural Science (NSci)

(College of Science, Literature, and the Arts)

7-8-9.† General Biology. An introduction to the study of living things, both plant and animal, and to the major biological concepts, including their relationship to men. (10 cr) Gall, Hall, Merrell

Naval Science (Nav)

(Department of Naval Science)

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. Naval Orientation. 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. Naval Orientation. Naval history and sea power; history of the U. S. Navy; the evolution of sea power; seamanship. (3 cr)
21. Naval Weapons. (3 cr)
22. Principles of Fire Control. (3 cr)
23. Applied Naval Electronics. (3 cr)

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, Administration and Leadership. (3 cr)
62. Naval Operations, Administration and Leadership. (3 cr)
63. Naval Operations, Administration and 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)

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)

** Students in both the Supply Corps and Marine Corps sequence courses take Nav 63 during the spring quarter as this is a required background course toward a commission in the Navy or Marine Corps.

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 3rd yr 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; 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. (2 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. Inspection Trip. Study of several oil field operations, research laboratories, refineries, and supporting technical services. Engineering report. (3 cr; prereq #; 2-wk field trip to be arranged) Lacabanne

138. Oil Field Maps and Charts. A study of methods and practices of graphically displaying, studying, and interpreting oil field data. Oil and gas well logs; property, contour, cross-section, and correlation maps; methods of displaying data and records, etc. (2 cr; prereq 112; 6 lab hrs per wk) 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 to the subject; the main fields of investigation; permanent problems; principal methods and schools of philosophy; historical and contemporary views. (5 cr; prereq 3rd qtr fr)

2. Logic. A study of the difference between logical and fallacious reasoning; the functions and uses of language; rules of good definition and sound argument. (5 cr)

3. Ethics. An examination of the problems which arise when human beings attempt to think systematically about conduct and values (are there absolute

standards?), the problem of free will, and a survey of historical views about the right and the good. (5 cr; prereq 3rd qtr fr)

10. Science and Religion. An inquiry into the nature of science and religion as currently interpreted, with an attempt to find grounds of conflict and/or reconciliation. (2 cr; prereq soph) Holmer

40. Logic of Scientific Reasoning. An introduction to the principles of scientific method; definition and classification; observation, measurement, experiment; elementary statistical concepts; hypotheses, theories, evidence, and confirmations; nature and limits of the scientific enterprise. (3 cr; prereq 2) Terrell

Physical Education (PE M)

(Department of Physical Education and Athletics for Men)

The courses in sports education are offered in the Department of Physical Education to men students of the University for the purpose of providing instruction and practice in sports of a recreational nature in which men may participate as a means of obtaining recreation, regular exercise, and social intercourse.

The facilities of the Department of Physical Education include the golf course, tennis courts, gymnasium, swimming pools, skating rink, handball and squash courts, golf gymnasium, and playing fields and are available for use by the general student body. All men are invited to participate in some form of physical activity. For information regarding the intramural and intercollegiate athletic programs see the physical education handbook published by the Department of Physical Education for Men or inquire at the offices in Cooke Hall.

Sports Education

1A-B-C. Sports Education. (1 cr per qtr)

2A-B-C. Sports Education. (1 cr per qtr)

For details and class programs see *Class Schedule.*

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; 3 lect hrs per wk)

1a-2a-3a. Introduction to Physical Science Laboratory. Laboratory course given in conjunction with 1-2-3. (1 cr per qtr; prereq 1-2-3 or ¶1-2-3; combination of 1-2-3 with 1a-2a-3a may be used to fulfill the laboratory-science group requirement)

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 15, 16...or Math 6, 7 or 8, △ [premedical students should take Math 15-16])

7-8-9. General Physics. Mechanics, heat, electricity, sound, and light. Laboratory work an integral part of course. (5 cr per qtr; prereq ¶ITM 24 or 24a or Math 50 or 50a for 7; 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 6 for 11, ¶ITM 12 or ¶Math 7 for 12, ¶ITM 13 or ¶Math 30 for 13; 4 lect and 1 quiz and 2 rec hrs or 2 lab hrs per wk for 11, 4 lect and 1 quiz and 2 lab hrs per wk for 12 and 13; courses must be taken in order)

14. Intermediate General Physics. Mechanics and electricity, selected topics. (4 cr; prereq 11-12-13, and ¶ITM 24 or 24a or Math 50 or 50a; 4 lect and 1 quiz hr per wk)

14A. Physics Laboratory. Parallel to 14. (1 cr; prereq ¶14; 2 lab hrs per wk; optional course)

50. Intermediate General Physics. Selected topics in modern physics. (4 cr; prereq 9 or 14, ¶ITM 25 or 25a or Math 51 or 51a; 4 lect and 1 quiz hr per wk)

50A. Physics Laboratory. Parallel to 50. (1 cr; prereq ¶50; 2 lab hrs per wk; optional course)

51. Intermediate General Physics. Thermodynamics, kinetic theory. Sound and light. Selected topics. (4 cr; prereq 14 and ITM 25 or 25a or Math 51 or 51a; 4 lect and 1 quiz hr per wk)

51A. Physics Laboratory. Parallel to 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. A theoretical course in mechanics, electricity, and electromagnetism designed to prepare students for advanced work. (4 cr per qtr; prereq 3rd yr, 9 or 51, ¶differential equations or ♯)

101-103-105.‡ Theoretical Physics. An analytical survey of fundamental principles of mechanics, thermodynamics, kinetic theory of gases, electricity, and magnetism, designed to supplement the general course and to prepare students for more specialized graduate courses. (5 cr per qtr; prereq 3rd yr, 9 or 51, ¶differential equations or ♯; 5 lect hrs per wk)

107-109-111. Modern Physics. Selected topics in modern physics such as measurement of e/m, mass spectroscopy, photo and compton effects, relativity, optical spectra, X rays, atomic and nuclear structure, radioactivity, fission and fusion. (3 cr per qtr; prereq 3rd yr, 50 or ♯ and ITM 25 or 25a or Math 51 or 51a, ♯ if taken out of sequence; 3 lect hrs per wk)

114-116-118.‡ Elementary Physical Investigation. Problems, either experimental or theoretical, in which the student may have some special interest. A written report on the work accomplished is required. (3 cr per qtr; prereq 3rd yr or above and △)

120. Atomic Physics. A laboratory course to introduce techniques and methods used in physics research laboratories. Vacuum gauges and systems, properties of charged particles, X-ray diffraction, ionization of gases, mass spectroscopy, photoelectricity, secondary electron emission. (3 cr; prereq 50 or ¶107; 8 hrs per wk)

121. Experimental Nuclear Physics I. A laboratory course in nuclear physics not requiring extensive knowledge of electronic circuits. Natural radioactivity, cloud chambers, ionization chambers, properties of nuclear radiations, alpha, beta, and gamma rays, neutrons; shielding artificial radioactivity, photographic techniques, health protection. (3 cr; prereq 50 or ¶109; 8 hrs per wk)

122. Experimental Nuclear Physics II. A laboratory course in techniques in nuclear physics requiring knowledge of electronic circuits. Geiger, proportional, scintillation, and coincidence counters. Cosmic rays. Nuclear resonance phenomena. Health monitoring instruments. (3 cr; prereq 121 and 146 or ♯; 8 hrs per wk)

123-124-125. Thermodynamics, Statistical Mechanics, and Theories of the Structure of Matter. An 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. The 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 25 or 25a or Math 51 or 51a; 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 25 or 25a or Math 51 or 51a; 3 lect hrs per wk)

133A. Physical Optics Laboratory. Parallel to 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 25 or 25a or Math 51 or 51a; 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 25 or 25a or Math 51 or 51a; integral calculus; 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 25 or 25a or Math 51 or 51a; 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 25 or 25a or Math 51 or 51a; 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.‡ Introduction to Mathematical Physics. Intensive treatment of the equations of mathematical physics using material drawn from the fields of mechanics, small vibrations of continuous media, acoustics, electromagnetic theory, and heat conduction. (3 cr per qtr; prereq 101-103-105 or equiv, differential equations and advanced calculus or Math 159)

For Graduate Students Only

Prerequisites for the following courses are Phys 191-192-193 or consent. 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

228-229-230. Nuclear Physics

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

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
301-302-303.* Research in Physics

Political Science (Pol)

(College of Science, Literature, and the Arts)

1-2.† American Government and Politics. An analysis of the principles, organization, procedures, and functions of government in the United States—national, state, and local. Attention will be given throughout to current issues. (3 cr per qtr) Christensen

A-B.† The State in the Modern World. An examination of principles, structure, and operation of the modern state. Emphasis on nation state; historical development; democratic government: United States, Great Britain; totalitarian government: Nazi Germany, Soviet Russia; conflict between states. (3 cr per qtr) Lippincott

5. American Government and Politics. Covers most of 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. A general introduction to the study of human behavior with emphasis on the development of the individual. (3 cr per qtr; prereq 2nd yr) Clark, Jenkins, MacCorquodale

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 15, 16, 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, §3A or GC 10C)

3. Personal Health. Normal body function; causes and prevention of disease. (2 cr, §2 or 3B or GC 10C)

50. Personal and Community Health. Fundamental principles of health conservation and disease prevention. (3 cr, §3, 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)

100. Elements of Preventive Medicine and Public Health. Occurrence and prevention of communicable, degenerative, and industrial diseases; protection of food, water, and milk; maternal and child health. (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 100 or ¶100)

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 Engl 16 for IT students, or Rhetoric Communication requirement)

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. A study of the characteristics of human group life. An analysis of the factors associated with the development of human group life and man's social environment; the structure of the social environment and its influence upon the individual's behavior. (3 cr) Sirjamaki

2. The American Community. A 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. An attempt is made to familiarize the student with current research methods. (3 cr; prereq 1 or 1A or 3) Martindale

14. Rural Sociology. A presentation of factual data necessary to an understanding of the problems of rural social life. (3 cr) Taves

Soils (Soil)

(College of Agriculture, Forestry, and Home Economics)

1. Soils and Soil Management. Nature and property of soils. Principles of soil fertility and conservation as they apply to land use and management. Lecture and laboratory. (5 cr, §2 or 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, InCh 4-5)

123. Fertilizers and Soil Fertility. Production, properties and use of commercial fertilizers; soil deficiencies, nutrient needs of plants and methods of investigation, new advancements in fertilizer use. (3 cr; prereq 1 or 3, InCh 4-5)

126. Soil Physics. (Formerly 108) A study of the physical characteristics of soils, with consideration given to mechanical composition, consistence, structure, soil-water relationships, soil air, and soil temperature. Lectures and laboratory. (4 cr; prereq 1 or 3, AgEn 11, AgEn 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) Minnich, Stephens, Olson

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