M Needler

Schools of Engineering

ANNOUNCEMENTS 1970-71

PURDUE UNIVERSITY BULLETIN

University Calendar

1970

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First Semester

September 16
Classes begin
November 24
Thanksgiving vacation begins
November 30
Classes resume
December 19
Christmas vacation begins
January 4
Classes resume
January 16
Classes end and reading period begins
January 19
Final exams begin
January 27
Semester ends

Second Semester

February 8
Classes begin
April 3
Spring vacation begins
April 12
Classes resume
May 29
Classes end and reading period begins
June 1
Final exams begin
June 9
Semester ends
June 13
Commencement

Summer Session, 1971

June 21
Classes begin
July 5
Holiday
August 10
Classes end and reading period begins
August 11
Final exams begin
August 13
Session ends

PURDUE UNIVERSITY BULLETIN

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Schools of Engineering

Announcements for the Year 1970-71

PUBLISHED BY THE UNIVERSITY
WEST LAFAYETTE, INDIANA

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About Purdue University

THE YEAR 1970 marks 101 years of growth and progress for Purdue University. From an institution of six instructors and 39 students, Purdue, Indiana's land-grant college, has grown to a major university with a faculty of 2,100 and a student body of more than 37,000 on five campuses.

One hundred and twenty major buildings now compose a West Lafayette Campus which once boasted of three structures. From the West Lafayette Campus, the University has now expanded to four regional campuses, at Fort Wayne, Hammond, Indianapolis, and Westville.

The Purdue story began with the signing of the Morrill Act by President Abraham Lincoln on July 2, 1862. By this act, the federal government offered to turn over public lands to any state which would use the proceeds to establish and maintain a college to teach the agricultural and mechanical arts.

Three years after passage of the land-grant act, the General Assembly of Indiana voted to take advantage of the act and begin plans for such a college. Competition from various communities in the state ended when the assembly in 1869 voted to accept $200,000 and 180 acres of land from John Purdue and other Tippecanoe County citizens. It was in appreciation of this gift that the legislature of Indiana voted to name the new college Purdue University.

The main campus at West Lafayette has grown to 485 acres. Nearly 13,500 acres in the state are under University control; most of this land is used for agricultural research.

Purdue ranks sixteenth in size among the 2,100 U. S. colleges and universities and is one of the 41 leading institutions with membership in the Association of American Universities. For more than a quarter of a century, the University has been largest or second largest in undergraduate engineering enrollment in America.

In accordance with a long-standing policy of the Board of Trustees, all educational service and programs of the University are available and open to all academically qualified individuals without any discrimination whatsoever with respect to race, creed, or national origin.

The University is the cultural and recreational center for northwestern Indiana. During the past several years, more than 90,000 people annually have attended conferences and short courses on the Purdue campus. Special facilities for student and conference activities are found in the Purdue Memorial Center and Memorial Union. Additional thousands come to Purdue attractions ranging from ballets and concerts in the 6,080-seat Edward C. Elliott Hall of Music to Big Ten football in Ross-Ade stadium.

Purdue's reputation as one of the country's outstanding universities is affirmed by the success attained by its over 100,000 alumni.

But, the Purdue story is not told in numbers alone. It is a story of leadership and influence in almost every academic field offered by the University. Instruction is offered by ten different schools, including:

School of Agriculture. Instruction is offered in agricultural science, agricultural business, and agricultural production. More than 10,000 acres of farmland serve as laboratories for research and instruction. Campus laboratories supplement classroom instruction.

Schools of Engineering. Students in these schools choose from curricula in ten major areas of engineering, ranging from agricultural engineering to nuclear engineering. One out of every 20 engineers in the United States holds a degree from Purdue.

School of Home Economics. With more than 1,000 students, this is one of the largest schools of home economics in the nation. The school is considered outstanding in preparing men and women for professional work in fashion retailing, restaurant management, housing, and dietetics, as well as teaching.

School of Humanities, Social Science, and Education. An 85 percent growth in enrollment in recent years shows the rapid growth made by Purdue's School of Humanities, Social Science, and Education (HSSE). Instruction is offered in most of the "liberal arts" through the school's 14 departments.

School of Industrial Management. The school offers a broad business education, providing an understanding of all major areas of management, bridged to the technological skills of engineering, statistics, and computer sciences.

School of Pharmacy and Pharmacal Sciences. Today, many of the prominent pharmacists and pharmaceutical scientists in Indiana and the nation are Purdue graduates. Students who expect to apply for admission to this school first take one year of the School of Science's prepharmacy option.

School of Science. More students are enrolled in science courses at Purdue than at any other American university. Its research accomplishments and leadership in revitalizing curricula in the sciences have brought wide acclaim.

School of Technology. The Technology School was created to provide educational opportunity for Indiana high school graduates whose technological interests and aptitudes have not previously been adequately served. In addition to regular baccalaureate and graduate degrees, the school awards the two-year degree of Associate in Applied Science.

School of Veterinary Science and Medicine. The only school in the state empowered to grant the Doctor of Veterinary Medicine degree, it graduated its first class in 1963.

Graduate School. All programs of graduate study and research leading to advanced degrees come under the jurisdiction of this school. This includes programs of study leading to the degrees of Doctor of Philosophy, Master of Science, Master of Arts, and Master of Science in the various professional fields. Graduate study in management and economics is offered by the Krannert Graduate School of Industrial Administration.

Schools of Engineering

HISTORY AND ORGANIZATION

ENGINEERING INSTRUCTION has been offered at Purdue University since the institution first opened its doors to students. As a land-grant college, Purdue was founded primarily to teach the agricultural and mechanical arts.

One student was registered in civil engineering in the fall of 1876, and the first engineering degree (C.E.) was awarded in June 1878. The School of Mechanics, established in 1879, led to the founding of the School of Mechanical Engineering in September 1882. Although civil engineering was the first branch of technical instruction to be taught at the University, it was not until 1877 that the School of Civil Engineering was organized. Electrical engineering was organized as a separate school in 1888.

Chemical engineering was established as a course of study in 1906 and made a separate school in 1911. Metallurgical engineering was added to the degree offerings of this school in 1938, and the name was changed to the School of Chemical and Metallurgical Engineering. In 1959 the two were separated into the School of Chemical Engineering and the School of Metallurgical Engineering. In 1965 the School of Metallurgical Engineering became the School of Materials Science and Metallurgical Engineering.

Aeronautical engineering courses were offered as options in mechanical engineering for the first time in 1926. The four years of aeronautical engineering as an offering of the School of Mechanical and Aeronautical Engineering appeared initially in the announcements for the sessions of 1942-43. Twenty-three students received the first degrees in aeronautical engineering in August 1943. The School of Aeronautics, which included the curricula of aeronautical engineering and air transportation with separate staff and facilities, was set up as a school in 1945. When air transportation was transferred to the School of Industrial Engineering and Management in 1955, the school name was changed to the School of Aeronautical Engineering.

In 1944, the Department of Engineering Mechanics was merged with the School of Civil Engineering and the name changed to the School of Civil Engineering and Engineering Mechanics, awarding separate degrees in civil engineering and engineering mechanics. In 1954, the Department of Engineering Mechanics was set up as a separate division and the name changed to

Department of Engineering Sciences. In 1960, engineering sciences was merged with aeronautical engineering, and the combined school was called the School of Aeronautical and Engineering Sciences. In 1964 the name was changed to the School of Aeronautics, Astronautics, and Engineering Sciences.

Agricultural engineering offered jointly by the School of Agriculture and the Schools of Engineering was begun in 1946.

In 1955, the School of Industrial Engineering and Management was formed. This school, composed in part of portions of the former Department of General Engineering, included a Department of Industrial Engineering and a Department of Industrial Management and Transportation, until it was discontinued in 1958. The Department of Industrial Engineering, a separate department within the Schools of Engineering for several years, is now designated as the School of Industrial Engineering.

The Division of Interdisciplinary Engineering Studies was created in 1969 to meet the needs of technologically-oriented students whose interests override traditional disciplinary boundaries. The division is so structured as to embrace emerging technologies—such as bio-engineering, food processing, and urban systems—and to relate to the business world as well as to human values. The structure of the division provides for no designated professionally oriented curriculum, but does provide for a high degree of flexibility and opportunity for innovative and challenging programs to be accommodated. Programs are planned to provide a firm educational foundation for those students who may wish to take professional engineering training at an advanced level or to go into a different profession altogether—law, medicine, or architecture.

ENGINEERING INSTRUCTION

Undergraduate instruction in aeronautical engineering, agricultural engineering, chemical engineering, civil engineering, electrical engineering, engineering sciences, industrial engineering, mechanical engineering, materials science, and metallurgical engineering leads to the degree of Bachelor of Science. The schools of engineering which administer these areas of instruction are responsible for the final three years of the particular curriculum and determine whether students enrolled in each of the individual schools of engineering have acceptably fulfilled the degree requirements. These individual curricula are discussed in detail under separate sections in this bulletin.

Students who wish to become nuclear engineers are encouraged to study in a traditional engineering field at the undergraduate level. The Department of Nuclear Engineering enrolls only graduate students, but some of the courses offered in nuclear engineering are available to undergraduate students with adequate preparation.

The degree of Bachelor of Science in Engineering may be awarded to a student who acceptably carries out an interdisciplinary program which cuts across several of the traditional "school" lines. The School of Materials Science and Metallurgical Engineering offers special programs in materials science and engineering.

Cooperative Programs with Industry

Aeronautical, agricultural, chemical, civil, electrical, engineering sciences, industrial, materials science and metallurgical, and mechanical engineering offer five-year cooperative education programs in which students alternate periods of attendance at the University with periods of engineering experience in selected industries, government agencies, and consulting engineering firms. While completing the requirements for an engineering degree, students gain a realistic concept of the challenge, working conditions, and rewards of being a member of the engineering profession. Students planning a graduate program gain experiences with instrumentation and experimental techniques that are a valuable asset for later thesis work. Students often earn nearly all of their educational expenses while working for their cooperative employer.

Upon completion of the program, the students receive the regular Bachelor of Science degree and a certificate indicating their completion of the cooperative education program. Further details are given in the descriptions of the schools of engineering which offer the cooperative programs.

Cooperative Programs with Liberal Arts Colleges

Cooperative programs have been set up with accredited liberal arts colleges which will permit their students to transfer to the Purdue University campus at the end of the junior year. Students interested in engineering should ordinarily be able to complete the requirements for an engineering degree in two years and one or two summer sessions provided they have the mathematics, physics, and chemistry credits scheduled in the freshman and sophomore years for engineering students.

It is expected that these cooperating colleges will give the student a bachelor's degree either at the end of the student's first year at Purdue University or at the time Purdue awards the engineering degree.

WOMEN STUDENTS IN ENGINEERING

In recent years approximately 30 to 40 young women have enrolled in each new freshman engineering class. With the many growing opportunities in private industry, research institutes, governmental agencies, and engineering education, it is anticipated that this number will grow to a size commensurate with the contributions that women can and will make to the growing status of our technological society. Purdue University's engineering faculty is both pleased and fortunate to have within its group several women engineering graduates. It is believed that in the near future more women will find a rewarding career in the challenging and interesting engineering field.

A student chapter of the Society of Women Engineers is located at the University. Women students in engineering have made this a vigorous and exciting activity in their professional development and understanding.

RESEARCH AND EXTENSION

In addition to the schools and departments of instruction, the Schools of Engineering maintain or cooperate with other engineering services of value to the public through research and extension.

The Engineering Experiment Station. As an integral part of the educational program of the Schools of Engineering, research activities are carried out through the Engineering Experiment Station, an organization established by the Board of Trustees in 1917. This research is described in a biannual engineering bulletin entitled *Research Activities.* The research serves and is supported by federal, state, and local government, by industry, and by foundations and other private agencies.

Some of the research activities of special interest include fluid mechanics, heat transfer, materials properties and processing, chemical reactors, bioengineering, jet and rocket propulsion, automatic control and information systems, stochastics, transportation and highway planning, environmental studies, nuclear fuel management, soil mechanics, water runoff, electric power generation and distribution, and industrial organization as well as research on engineering education itself.

With the expansion and diversification of research activities in recent years, certain areas have given rise to organized units of graduate research and education, some of which are of an interdisciplinary character. Included are the Jet Propulsion Center, the Automatic Control Center, Purdue Laboratory for Applied Industrial Control, Applied Electronics Research Laboratory, the Electronic Systems Research Laboratories, the Aerospace Sciences Laboratory, the Ray W. Herrick Laboratories, the Center for Applied Stochastics, the Thermophysical Properties Research Center, and the Purdue Energy Research and Education Center.

The Thermophysical Properties Research Center (TPRC) was organized in 1957, to become a center for the collection, correlation, and dissemination of data on thermophysical properties of materials and to conduct research in this area. TPRC has achieved both a national and international reputation and its services are sought by researchers throughout the world. TPRC, with offices and laboratories in McClure Park, is designated as a component of the National Standard Reference Data System operated by the National Bureau of Standards and it is the official Information and Analysis Center for the Department of Defense.

TPRC, a unit of the Schools of Engineering, operates four divisions: (1) Scientific Documentation; (2) Standard Reference Data; (3) Theoretical Research; and (4) Experimental Research. Because of the interdisciplinary nature of its operation, students from many schools of engineering take part in TPRC's research and in a number of instances receive their degrees, based on research conducted at this center.

The Regional Campus Administration, operating as a separate division of the University but cooperating closely with the Schools of Engineering, was established by the Board of Trustees in 1958 to coordinate all extension activities of the University except those carried on by the Agricultural Extension Service. Extension instruction, under the direction of the subject-matter departments, is conducted through this division, and includes classes, both credit and noncredit, correspondence study, short courses, conferences, clinics, lectures, demonstrations, and other formal and informal enterprises conducted both on and off the campus.

Extension activities of the Schools of Engineering are carried on through the Regional Campus Administration.

Applied Science programs are administered by the School of Technology in cooperation with the engineering and other schools of the University. The programs are offered on- and off-campus and furnish specialized, intensive study designed to meet the needs of industry for technically trained persons. Associate in Applied Science degrees are offered in these major fields of study: architectural technology, aviation technology, chemical technology, computer technology, metallurgical engineering technology, civil engineering technology, electrical engineering technology, industrial engineering technology, industrial illustration technology, mechanical engineering technology, and nursing.

The Purdue Research Foundation is a nonprofit corporation affiliated with Purdue University. The foundation serves as a fund-raising and development agency providing for educational and research needs of Purdue beyond state appropriated resources. Research and training grants and contracts from industry and government are administered by the foundation for the University. Patent policy and development are also Purdue Research Foundation responsibilities.

Admission

REQUIREMENTS FOR ADMISSION

For admission to the freshman class an applicant must present credits in 15 units of secondary school work.

For all applicants to the Schools of Engineering the prescribed 15 units of credit must be distributed as follows:

English	3	units
History or social studies	1	unit
Algebra	1½	units
Plane geometry	1	unit
Trigonometry	½	unit
Laboratory science	1	unit
Additional English, language, mathematics, science, or social studies	3	units
Other high school subjects	4	units
	15	units

A student who meets only the minimum entrance requirements should expect to take more than four years (established by the regular program) to receive the B.S. degree in Engineering.

An upper-third graduate may be considered for admission with up to one unit of deficiency if recommended by his high school principal. No one without at least one unit in algebra and one in plane geometry will be admitted to engineering regardless of his class standing or test scores.

If an applicant is accepted with a subject deficiency, his admission will be conditional for one year, at the end of which his record must justify continuance without further restriction or reservation.

College Board Examinations Required

All beginning students are required to take the C.E.E.B. Scholastic Aptitude Test and achievement tests in English, mathematics, and chemistry. A student who has not had or is not taking chemistry may substitute the test for the science area which he has studied. It is recommended that the SAT be taken in May of the junior year (results from tests taken at other dates are acceptable) and that the achievement tests be taken in the spring of the senior year. The tests should be taken even though the admissions application has already been filed.

Indiana residents are expected to rank in the top half of their graduating class, and to make reasonable scores on the College Entrance Examination Board tests. A marginal applicant may:

1. Be granted unconditional admission.
2. Be admitted on probation.
3. Have his admission postponed or denied.

RECOMMENDED QUALIFICATIONS

It is highly recommended that high school students take the maximum amount of college preparatory mathematics, laboratory sciences, and English offered at their particular high schools. If choices are possible, these courses, highly dependent upon knowledge and reasoning, should take precedence over courses in which the emphasis is on manual skill.

High school students who desire to take engineering at Purdue University and who expect to get the degree in four years under the regular engineering curriculum should obtain credit in the following high school subjects:

English	4	units
History	1	unit
Algebra (including college algebra)	2	units
Plane and solid geometry	1	unit
Trigonometry	½	unit
Physics	1	unit
Chemistry	1	unit
Additional English, language, science, mathematics, or social studies	3	units
Other high school studies	1½	units
	15	units

If the student's high school offers courses in analytical geometry and calculus, either as these specific courses or in a course entitled Mathematics Analysis, it is urged that these subjects be included, if possible, in addition to the recommended mathematics courses specified in the above list.

It is urged that the applicant make every effort to get credit in the courses listed prior to entering the regular freshman engineering program.

German is recommended for those who expect to study chemical engineering.

Placement in Courses

The majority of beginning freshman engineering students are assigned to MA 161 the first semester. MA 161 includes analytical geometry (plane and solid), three weeks on vectors, a few lessons on velocity and acceleration, and the concept of the integral.

Students who have mastered analytical geometry in high school are encouraged to take Purdue's MA 161 advanced placement tests during the "Day on Campus Program" in the summer prior to the beginning of school. The successful students receive five hours of advanced credits and are assigned to MA 171 the first semester, followed by MA 172 the second semester. MA 171 and 172 are each five-credit-hour courses in calculus and are designed for beginning students who will complete their calculus requirements during the first year.

Students who have studied analytical geometry and calculus for a year in high school are encouraged to take one of the following examinations to earn ten credit hours of advanced credit: the College Board Advanced Placement Examination in mathematics offered at many high schools each year during the month of May or Purdue's MA 162 Advanced Placement Examination offered during the "Day on Campus Program" which runs for four weeks during the summer. A student successful in either of the above examinations would receive advanced credit for both MA 161 and 162 and would be assigned to MA 261A, the second course in calculus. MA 261A is especially designed to meet the requirement of students who have earned ten advanced credits by examination.

The chemistry sequences are similar to the mathematics sequences. The majority of beginning students are assigned to CHM 115 in the first semester and CHM 116 in the second semester. These two four-credit-hour courses in college chemistry are designed to satisfy the chemistry requirements in the freshman engineering program.

Students with high achievement scores in chemistry are qualified to select CHM 123 in the first semester. The CHM 123 course is designed to permit the well-qualified student to complete his eight credit hours requirement in freshman chemistry in a single semester. An alternative to CHM 123 is to establish credit in CHM 115 (or CHM 115 and 116) by means of the College Board Advanced Placement Examinations given at the various high schools during the month of May or Purdue's Advanced Placement Examinations given during the summer "Day on Campus Program."

A student who is qualified for CHM 123 but desires to continue his study of chemistry beyond the freshman engineering requirement may select CHM 117 the first semester to be followed by CHM 126 the second semester. The CHM 117-126 sequence of ten credit hours is a more theoretical approach to the study of chemistry than the CHM 115-116 sequence and is recommended only for those students who plan to do additional work in chemistry.

Students who did not study chemistry in high school and students with low achievement scores in chemistry are encouraged to take a sequence of three courses: CHM 111, CHM 115, and CHM 116. The CHM 111 course for three credit hours is intended to help prepare these students for the CHM 115-116 sequence.

Transfer Students

Purdue University will accept transfer students from accredited colleges to most of the curricula of engineering if these students meet the entrance requirements in engineering as outlined on pages 11 and 12 and have an honorable dismissal from the college. Credits in all subjects which apply to the engineering curriculum will be accepted, providing the grades received in the subjects are C or better and if the land-grant college or state university within the state in which the college is located will accept the credits.

A transfer student who has 18 semester-hour credits in mathematics through differential equations, or 21 semester hours (college algebra, trigonometry, and analytical geometry, 10 semester hours; calculus, 8 semester hours; and differential equations, 3 semester hours); physics, 8 semester hours; and chemistry, 8 semester hours, should be able to complete the requirements for the engineering degree in about two years plus one or two semester sessions.

Students planning to transfer from another school to Purdue University should contact the engineering school of their choice or the Department of Freshman Engineering early in their college career in order to obtain assistance in planning their programs of study.

An applicant transferring from another college or university must follow the following procedure:

1. Submit an application for admission on the prescribed form through the director of guidance of the high school from which he was graduated.

2. File the application for admission as soon as possible after the *completion of the first semester (second quarter) of college work.* The application *must* be filed three months prior to expected date of admission.

3. Forward an official transcript of work done in institutions previously attended. A separate transcript must be sent directly from each institution, regardless of whether credit is requested. If the credentials are not sufficiently definite, a personal consultation with the applicant may be necessary.

4. Nonresidents pay the $20 out-of-state application fee. Nonresidents must have an average of B or better with a minimum of three semesters or five quarter equivalence.

5. The applicant must file a formal report which will be furnished by Purdue from the dean of men, dean of women, or an authorized official in the school last attended. An average of at least C is required for Indiana applicants for all courses previously taken at a recognized college or university.

Advanced Credit

Credit for courses in Purdue University will be given for work of equivalent character and amount successfully done in another college. On the basis of these credits, advanced standing will be determined. Advanced credit will be regarded as provisional and may be withdrawn by the director of admissions upon recommendations of the head of the department concerned or if dependent work is not satisfactorily completed.

When credit earned at another college or university is transferred to Purdue University and is accepted toward advanced standing, the credit is converted into terms of Purdue courses and applied on the program of study. Credit will not be allowed for a course in which the lowest passing grade was received. Grades are not transferred; only credit in the course is recorded.

For credit in EG 118 (Engineering Graphics), based on work done in industry or elsewhere than in an educational institution of recognized standing, the applicant must pass an examination and may be required to submit letters of qualification from his employers and samples of his drawings.

Graduates of Liberal Arts Colleges

Properly qualified holders of the degree of Bachelor of Arts or Bachelor of Science from recognized four-year liberal arts colleges should be able to complete the requirements for the degrees of Bachelor of Science in most of the schools and curricula of engineering at Purdue University in about two years including a summer session. They must submit, in addition to the entrance requirements in force at Purdue for the Schools of Engineering, the following college credits: mathematics, 21 semester hours (college algebra, trigonometry, and analytical geometry, 10 hours; calculus and differential equations, 11 hours); physics, 8 hours; chemistry, 8 hours.

Such college graduates may usually be registered as junior students in engineering. These students are allowed to substitute credits earned in subjects not listed in the engineering curriculum for military training, freshman engineering lectures, and nontechnical subjects, and for such other subjects as the dean of the Schools of Engineering may approve. They will find it to their advantage to make up at least in part during the summer session previous to entrance such subjects as engineering graphics, or other required technical subjects of the first two years.

Out-of-State Applicants

Purdue is a publicly supported institution of the state of Indiana, and therefore it must give preference to the admission of well-qualified applicants from Indiana. In addition to meeting the subject matter requirements, out-of-state applicants *to be eligible for consideration* must meet these qualifications:

1. Out-of-state beginners must rank in the highest quarter (25 percent) of their high school graduating class or rank in the highest quarter (25 percent) on the SAT section of College Entrance Examination Board tests.

2. Transfer applicants must have a B average in work done at previously attended colleges.

From these applicants, the out-of-state roster will be selected; the number will be determined by the space available.

No out-of-state application will be considered or even processed unless it is accompanied by the required $20 out-of-state application fee. This fee is not refundable and may not be applied to fees, tuition, or housing.

Nondegree Students

A mature person who is a local resident and who desires to avail himself of the instruction offered in any of the departments of the University without undertaking one of the regular plans of study, and without becoming a candidate for a degree, may be admitted as a nondegree student. An applicant must give evidence of prerequisite background for the course or courses for which he is applying.

PROCEDURE FOR MAKING APPLICATION

All inquiries regarding admission should be addressed to: Director of Admissions, Purdue University, West Lafayette, Indiana 47907. The first letter of inquiry concerning admission should include:

1. The amount of school training completed
2. Plans for further education, indicating field of specialization
3. The approximate date to enter Purdue
4. A request for information concerning admission requirements
5. A request for application form.

A personal visit to the University for a conference with an admissions counselor is always desirable and helps a prospective student evaluate his preparation and plans for further education. It also affords an opportunity to give additional information and explanations that apply to the individual case. Such a visit and conference are especially appropriate at the beginning of or during the junior year in high school.

Students who wish to begin their university studies at one of the University regional campuses should contact the admissions officer at the campus instead of writing the West Lafayette Campus.

Admissions Office
Purdue University North Central Campus
Junction Indiana Toll Road and U.S. 421
Westville, Indiana 46391

Admissions Office
Purdue University Calumet Campus
2233 171st Street
Hammond, Indiana 46323

Admissions Office
Indiana-Purdue University Fort Wayne Campus
2101 East U.S. 30
Fort Wayne, Indiana 46805

Admissions Office
Indiana-Purdue University Indianapolis Campus
1125 E. 38th Street
Indianapolis, Indiana 46205

The Application

The application for admission must be made on the official form provided by the University. The applicant and his family should complete the necessary sections of the application for admission and then submit it to his high school director of guidance who should complete the remainder of the form. The high school forwards the entire application to the Office of Admissions, Purdue University, West Lafayette, Indiana 47907.

Those who apply after completing *six* semesters of high school work should request the high school to include on the transcript of record the courses in progress for the seventh semester *and* those planned for the eighth semester. Those who apply after *seven* semesters should request the high school to record the grades for the entire seven semesters *and* include the courses in progress for the eighth semester. *Failure to have the transcript so prepared will delay processing the application.*

The physical examination report should be completed by the family physician and forwarded by him directly to the Student Health Center, Purdue University, West Lafayette, Indiana 47907.

Qualified applicants entering directly from high school are encouraged to file their application for admission as soon as possible after October 1, or after completing six semesters of high school work. Indiana residents must file their application prior to June 15, while applicants from out-of-state must file prior to April 15.

ORIENTATION AND SUMMER REGISTRATION

During the summer prior to the beginning of a first semester, new students are urged to come to the campus for one day of advance enrollment. In addition to being a day for orientation, it is a day set aside to confer with academic counselors, to decide upon a set of classes for September, and to enroll in those classes. Upon receipt of fees, the University will complete the registration process and mail a class schedule to the student. *Registration*

will then be complete. Students who find it impossible to attend the summer advance enrollment will be required to report to the campus for delayed registration four days early in the fall. They must pay the additional residence hall charges.

The remainder of the orientation program takes place during the two or three days before classes begin. In this part of the program, the students are given information on University organization and procedures and a further opportunity to consult with members of the staff. It is the desire of the University to give students every opportunity to succeed in their work, and the orientation plan is one means of giving this help to those who are new to the Purdue campus.

Expenses and Financial Aid

COSTS

THE EXPENSES of a year's work at Purdue University will depend a great deal upon how much a student can and wants to spend. Basic costs for a two-semester school year on the West Lafayette Campus:

Items	Estimated Costs Resident	Nonresident
University fees	$ 700	$ 700
Tuition		900
Books and supplies	150*	150*
Board and room	1060	1060
Sunday evening meals	55	55
Miscellaneous	400	450
Total	$2,365	$3,315

Rates are subject to change without published notice.

Male students electing Army or Air Force ROTC will be required to pay a $20 two-year military uniform deposit in addition to the regular University fees.

University fees include the general service, student activity, recreation facilities, and infirmary and medical fees. The medical fee covers the services of the University physicians, nurses, and infirmary. The activity and recreation facilities fees admit students to athletic events and the convocation series.

Miscellaneous expenses include such items as clothing, transportation, telephone, newspapers and magazines, dry cleaning and laundry, movies, haircuts, etc.

* The cost of drawing instruments, slide rule, and other supplies adds approximately $60 for those who enter engineering.

FINANCIAL AID

Purdue University maintains a complete program of financial assistance for new and continuing students. Most types of aid are based upon financial need and academic ability. Qualified students may obtain assistance in the form of scholarship, grant, long-term loan, part-time employment, or some combination of these aids.

Scholarship, grant, and loan funds are provided by alumni and friends of the University, the state and federal government, business and industry, and the University itself. Most aids are available without regard to the student's course of study, but some scholarship and loan funds are specifically designed for those applicants in a particular curriculum.

Additional information can be found in the Purdue University bulletin *Financial Aid for Students* or by contacting the Division of Financial Aids, Agriculture Annex II, Purdue University, West Lafayette, Indiana 47907.

Student Welfare

PROFESSIONAL ORGANIZATIONS

Technical Societies

ASSOCIATED WITH THE VARIOUS schools and departments of technical instruction are student branches of the major national technical or scientific societies, including:

American Institute of Aeronautics and Astronautics
American Institute of Chemical Engineers
American Institute of Industrial Engineers
American Institute of Mining, Metallurgical, and Petroleum Engineers
American Society of Agricultural Engineers
American Society of Civil Engineers
American Society of Heating and Ventilating Engineers
American Society of Mechanical Engineers
American Society of Tool and Manufacturing Engineers
Institute of Electrical and Electronics Engineers
National Defense Transportation Association
Society of American Military Engineers
Society of Automotive Engineers
Society of Engineering Science

Other technical and semitechnical organizations of special interest to engineering students include Aeromodelers, Amateur Radio Club, Catalyst Club, Glider Club, and Student Engineering Council.

Honorary Fraternities

Designed to recognize students who excel in scholarship and give promise of being leaders in professional areas, honorary fraternities are branches of national societies and with one exception are open to juniors and seniors only.

The following honorary fraternities have chapters at Purdue University:

Alpha Epsilon (Agricultural Engineering)
Alpha Pi Mu (Industrial Engineering)
Alpha Sigma Mu (Materials Science and Metallurgical Engineering)
Chi Epsilon (Civil Engineering)
Eta Kappa Nu (Electrical Engineering)
Omega Chi Epsilon (Chemical Engineering)
Phi Eta Sigma (Freshman and Sophomore Engineering)
Pi Tau Sigma (Mechanical Engineering)
Sigma Gamma Tau (Aeronautical Engineering and Engineering Sciences)
Sigma Xi (Scientific—All Schools)
Tau Beta Pi (All Engineering)

LIVING ACCOMMODATIONS

PURDUE STUDENTS may secure living accommodations in residence facilities operated by the University, fraternities and sororities, cooperatives, and privately-operated facilities in the local community. Application for accommodations in University-operated facilities is made on a separate application form and in addition to the application for admission to the University. The student may request information about the various types of housing by indicating interest on the application for admission to the University. Application for residence halls may be made as soon as the student is informed of admission to Purdue University. Acceptance for admission to the University does not guarantee the availability of housing accommodations. *Two separate applications are required.*

Residence Halls for Undergraduate Men and Women

University owned and operated self-supporting residence halls now provide accommodations for approximately 10,000 single undergraduate men and women.

The halls for men are comprised of both the traditional type residence halls and the one-story court-type residence hall units. The traditional type halls are Cary Quadrangle, providing accommodations for 1,600 students, and Owen, Tarkington, and Wiley Halls, each providing space for 700 men. Two eight-story structures, McCutcheon and Harrison Halls, house approximately 800 students each. Harrison Hall is a co-educational unit with men students assigned to the north wing and women students assigned to the south wing.

The court-type halls provide double-room accommodations in small living groups of 16-20 that have their own living rooms and washroom facilities. The Fowler Courts provide 600 of these spaces; board services are provided in the adjacent cafeteria known as Fowler House. For several years, the Fowler Courts have been operated as a co-educational facility and this plan of operation is expected to continue. The Terry Courts and O. P. Terry House are comparable to the Fowler Courts and Fowler House and are expected to also operate co-educationally with men and women housed separately by unit buildings.

Duhme, Shealy, Wood, Warren, and Vawter Halls comprise the original group of women's residence halls and normally are referred to as the Windsor Residence Halls. Meredith Hall accommodates 600 women and Earhart Hall houses 800 co-eds. All contain lounge space, recreation room, dining room, kitchen, and post office facilities.

In the fall of 1970, a new residence hall, Shreve Hall, will be operated as a co-educational residence hall and will accommodate approximately 850 students. Men will be housed in one wing and women in the other, similar to the operation of Harrison Hall.

All accommodations provide for a combined room and board agreement. The cost for two semesters varies from $970 to $1090. (Rates quoted are subject to change as approved by the Board of Trustees.)

Married Student Apartments

Furnished efficiency apartments and furnished and unfurnished one- and two-bedroom apartments are available. Rent, which includes utilities, ranges from $90 to $111 per month for unfurnished accommodations and from $78 to $126 per month for furnished apartments. (Rates quoted are subject to change as approved by the Board of Trustees.)

Graduate Housing for Single Men and Women

Purdue's two graduate houses are specifically intended to fulfill the needs for housing and services of graduate men and women. The two buildings, accommodating approximately 1,500 people, are both multi-story units which offer a mixture of completely furnished single and double rooms. All floors have comfortable lounges, study areas, and television rooms. Those floors devoted to the exclusive housing of graduate women provide for their special needs and include hair dryers, pressing rooms, sewing rooms, and facilities for laundering of lingerie.

Both buildings provide the residents with additional storage space, formal and informal lounges, vending machine snack bars, fully equipped laundry rooms, and postal service. A limited number of surface and underground parking spaces are available at reasonable rates.

Because the academic pursuits of most graduate students do not permit their keeping regular meal hours, the graduate houses do not provide required contract meal services. A cafeteria is located in Graduate House West and offers food service to residents of graduate housing.

The buildings are located within walking distance of practically all classrooms and laboratories. Both units are served by high-speed elevators and are fully air-conditioned all months of the year.

For further information regarding room rates, description of facilities, and application form, write to: Manager's Office, Box 100, Graduate House, West Lafayette, Indiana 47907.

PLACEMENT SERVICES

Two placement offices on the campus are available to students: University Placement Service and the Educational Placement Office.

The University Placement Service maintains contacts with a large number of firms in the industrial and business world and with government agencies. It provides facilities for informing students of employment possibilities and for arranging personal interviews with employer representatives.

The Educational Placement Office provides information about teaching, administrative, and supervisory positions in public and private elementary and secondary schools and colleges and universities, maintains a life-time repository of credentials for registrants, and arranges for personal interviews of candidates by prospective employers who come to the campus seeking qualified personnel. Candidates may have their names placed in a central repository where, by electronic data processing, their names and qualifications can be made available to employers all over the country. Constant effort is made to assist in the professional advancement of graduates of the University who have demonstrated their interest and proficiency in the teaching profession.

The staff is available to students and alumni for assistance with their employment search and career development. Other services available are counseling, guidance, testing, and a wide variety of vocational and employer information.

MILITARY SERVICES

ROTC programs are offered by all three services—the Army, the Navy, and the Air Force. The choice of a particular service is an individual matter. Each of the military departments at Purdue can provide information upon which a student can determine his choice. Each service offers programs which lead to a commission as an officer upon graduation. Military programs are pursued in conjunction with the academic curriculum. Credits earned in basic ROTC courses are not applicable to degree requirements. However, upon satisfactory completion of four full semesters of Advanced ROTC, six credits earned in these advanced courses will be allowed toward a bachelor's degree in the several engineering curricula.

Special Facilities*

LIBRARIES

THE UNIVERSITY LIBRARIES OFFER more than one million volumes housed in the General Library located in the Memorial Center, in 25 departmental or special libraries, in the regional campuses, and in several deposit collections. Holdings in agriculture and engineering amount to more than 135,000 volumes

* The facilities of the individual engineering schools are listed with the descriptions of each school on the following pages.

in each field. Over 15,000 serial titles are received, including more than 12,000 periodicals and the publications of societies, institutions, and state and federal governments. The libraries are a long-time depository for both federal and state government publications.

Special collections include the Charles Major library of history and general literature, the George Ade collection, the Anna Embree Baker collection of books designed and printed by Bruce Rogers, the Gilbreth library of industrial management, and the W.F.M. Goss memorial library of engineering history.

The University has a long tradition of strong departmental libraries; some 500,000 volumes are shelved in various buildings around the campus. These libraries hold the bound sets of journals in each field, books in foreign languages, advanced treatises, and the special bibliographies and services needed for carrying on advanced research in the various subjects.

The Goss Library

The William Freeman Myrick Goss Library of the History of Engineering, or briefly, the Goss Library, was established in 1928 when Purdue University received the personal library, consisting of approximately 900 volumes, from William Goss, dean of engineering at Purdue University from 1879 to 1907. Two years later Mrs. Edna D. Goss, his widow, presented to the University a trust fund of $20,000 as an endowment for the library. The library now contains over 5,000 volumes and is considered the most complete library of engineering history available in any university. Most of this collection is housed in the Krannert Library; certain exhibits of the Goss collection are on display in the Engineering Administration Building.

AUDIO-VISUAL CENTER

The Audio-Visual Center, located in the Memorial Center (ground floor and basement), produces and makes available to students and staff many types of teaching materials such as films, filmstrips, slides, transparencies, and audio tapes. It provides an advisory and demonstration service for these materials and the equipment required in their use. It has a library of 3,000 films and 4,800 audio tapes that can be used in the center, the Purdue campuses, or by borrowers throughout the United States.

Graduation Requirements

SCHOLASTIC INDEX REQUIREMENTS

IN GENERAL, THE SCHOLASTIC standing and probation standards of all regular students enrolled in engineering programs shall be the same as those for the University as a whole. They are spelled out in the *General Information Bulletin* in the section on "Scholarship Indexes and Probation Standards."

PASS/NOT PASS OPTION

In order to provide students with the opportunity to broaden their educational foundations with minimal concern for grades earned, an alternate grading system, the Pass/Not Pass Option, is permitted for a limited portion of the student's required graduation hours. The detailed limitations upon this option can be different for each degree granting unit, but the following general rules are some that are currently applicable:

1. Subject to the regulations of his school, a student may elect this option in any course which does not already appear on his academic record and in which he is otherwise eligible to enroll for credit with letter grade. A student may not elect this option for more than 20 percent of the total credit hours required for his graduation.

2. The registrar's class rosters will indicate which students have elected this option.

3. A student who is enrolled in a course under this option has the same obligations as those who are enrolled in the course for credit with letter grade. When the instructor reports final grades in the course, he will report that any such student who would have earned a grade of A, B, or C has "passed" the course and that any other such student has "not passed." The registrar will make an appropriate notation on the student's academic record in place of a letter grade but will not use the course in computing grade indices.

4. In engineering, the Pass/Not Pass Option shall *not* be available for required courses (those specifically designated by course number) in the student's engineering program.

5. This option shall *not* be available to students on probation.

6. This option shall be available for a maximum of two courses in any one semester, one course during a summer session.

7. Consistent with the policy of the Schools of Engineering, a student receiving the grade of "Pass" in a course taken under the Pass/Not Pass Option may not take the same course for a letter grade.

These are general or minimum guidelines for those electing this option, but the individual schools and departments of engineering may impose further restrictions.

GENERAL EDUCATION PROGRAM

The number of credit hours required for graduation is given at the beginning of each plan of study.

A minimum of 23 hours of general education courses is required in most of the engineering curricula, and these hours are distributed as indicated below.

1. Six credit hours in communications are required in the Freshman Engineering Program. These are ENGL 101 or 103 and COM 114.

2. The remaining 18 credit hours must be selected from two groups of course sequences.

3. Each student must select one 12-hour sequence from one group and one 6-hour sequence from the other. No student may elect a 6-hour sequence from the same group from which he chose a 12-hour sequence.

Group I	Group II
Languages	Interpersonal Communication
Economics	(Speech) and Theatre
Political Science	Independent Reading
Psychology	History
Sociology	Philosophy
Anthropology	Creative Arts
Literature	General Studies

The above sequences provide depth to the various programs in the social sciences, fine arts, and humanities.

A pamphlet is available from student counselors for the benefit of all the engineering students, stating the objectives of the program in general education. Included in the pamphlet are an analysis and description of the objectives of each of the sequences.

Some students will have special needs in the area of general education. The heads of the various engineering schools, or their designated representatives, are authorized to make substitutions insofar as the substitution will lend greater depth to the course sequence. The student should consult with his counselor to obtain prior approval for any such variations.

Plans of Study

THE ENGINEERING CURRICULA, course descriptions, and graduation requirements of each of the engineering schools as presented in this catalog are those which were in effect at the time of printing. Course content and curricula, however, do gradually evolve, reflecting the changing needs of the engineering profession. The student is therefore encouraged to obtain the latest course and curriculum information from his academic adviser.

It is of importance to the student to recognize that general flexibility of academic curricula is provided in order to make possible allowances for individual differences in students' backgrounds and academic goals. It is the student's responsibility to consult with his academic adviser about using this flexibility to design a program to fit his particular needs.

The traditional length of a college degree program is four academic years. For this reason, the catalog presents all engineering curricula as four-year programs. Well qualified students with excellent high school preparation can complete the program in the four-year period—or even less. However, other students may require four and one-half or even five years to complete all

requirements. Such students also prove to be successful professional engineers, and the University regards their advancement through the nine or ten semesters as satisfactory academic progress toward an engineering degree. Insufficient high school backgrounds usually are most noticeable during the first and second year of a student's program in engineering. By the time the student reaches a junior level of work, the course sequence which he has used to prepare himself usually meshes so well that high school insufficiencies present no scheduling difficulties such as may have occurred during the first part of his engineering program.

ABBREVIATIONS

A&ES—Aeronautics, Astronautics, and Engineering Sciences

AGEN—Agricultural Engineering

AGRY—Agronomy

ANSC—Animal Sciences

BCHM—Biochemistry

BIOL—Biological Sciences

BNUC—Bionucleonics

CHE—Chemical Engineering

CE—Civil Engineering

CHM—Chemistry

COM—Communication

CS—Computer Sciences

ECON—Economics

EE—Electrical Engineering

ESC—Engineering Sciences

ENGL—English

ENGR—Engineering, Freshman

GEOL—Geology

IED—Industrial Education

IE—Industrial Engineering

INDM—Industrial Management

MA—Mathematics

ME—Mechanical Engineering

MSE—Materials Science and Metallurgical Engineering

NUCL—Nuclear Engineering

PHAR—Pharmacy

PEM—Physical Education for Men

PHYS—Physics

STAT—Statistics

FRESHMAN ENGINEERING

The Department of Freshman Engineering administers the program of study which leads to admission into one of the schools of engineering. The freshman program of study in which the individual student is placed is determined by the College Entrance Examination Board tests and school record data and will usually vary in length from one year to a maximum of two years.

The Freshman Engineering Program of study which can be completed in one year and which is pursued by a majority of the engineering students is tabulated below. The alternate programs of study requiring more than two semesters (one academic year) to complete are discussed in *Your Freshman Engineering Program* and may be obtained by directing a letter of inquiry to the director of admissions or Department of Freshman Engineering.

First Semester	Second Semester
(5) MA 161 (Mathematics for Engineering and Physical Sciences I)	(5) MA 162 (Mathematics for Engineering and Physical Sciences II)
(4) CHM 115 (General Chemistry)	(4) CHM 116 (General Chemistry)
(2) ENGL 101 (English Composition I)	(4) PHYS 152 (Mechanics and Sound)
(3) COM 114 (Fundamentals of Speech Communication)	(2) EG 117 (Engineering Graphics)
(2) EG 116 (Engineering Graphics)	(1) ENGR 179 (Freshman Engineering Lectures)
(0) ENGR 178 (Freshman Engineering Lectures)	
(16) + ROTC if elected	(16) + ROTC if elected

Honors Program

Since 1958, the Department of Freshman Engineering has made available an honors program to the students with high academic ability who matriculate from an outstanding high school program in mathematics, science, and communications. The objectives of the program are: (1) to place entering students at a substantially higher level for first course assignment in mathematics, English, chemistry, and physics (this provides students who were enrolled in accelerated high school programs an opportunity to include in their senior year at Purdue University courses having graduate school credit); (2) to increase the flexibility of initial college assignments, and, thereby, make use of time which might be spent unwisely on subjects covered well in high school; (3) to identify the imaginative honors student as a group for special programs and career counseling; and (4) to provide one or two stimulating courses of recent development in engineering and science.

Admission to the honors program is by invitation of the Department of Freshman Engineering. Even though a student in the program may qualify for a Bachelor of Science degree in less than four years, it usually is advantageous to continue for four years and earn extra credits. A number of students continue on for the Master of Science degree.

The Department of Freshman Engineering will provide additional information to any student who believes he can meet the challenges of the program. Inquiries should be directed to the department, preferably early in the senior year of high school so maximum advantage can be made of the individual high school programs.

DIVISION OF INTERDISCIPLINARY ENGINEERING STUDIES

The primary responsibility of the Division of Interdisciplinary Engineering Studies is to provide a coordinated and controlled educational opportunity for students whose interests and talents, while strongly oriented towards engineering and science, do not coincide with the established professional curricula in the Schools of Engineering. The division does not have a designated professionally-oriented curriculum, but is constituted so as to accommodate programs providing a high degree of flexibility and opportunity for interdisciplinary studies. These programs will be broad, innovative, and challenging in themselves and hopefully will lead to better solutions to complex socio-economic-technical problems.

Each student will be assigned a counselor to help with the selection of a program in keeping with the student's personal educational objectives, and meeting the minimum requirements determined by the engineering faculty. It is envisioned that programs will be formulated by coupling disciplines within the Schools of Engineering or by coupling engineering studies with other areas, such as industrial management, economics, the humanities and social sciences, pharmacy, science, technology, etc.

Although the division may have no full-time faculty or specific courses under its jurisdiction, it will utilize the experience of the entire engineering faculty. Engineering courses as well as specialized laboratory facilities will be available to all students enrolled in the division. In keeping with the interdisciplinary character of the programs, the degree of Bachelor of Science in Engineering will be awarded to those who successfully complete the degree requirements.

Students, prospective students, or high school counselors who seek information about the division should contact the office of Prof. Richard E. Grace, acting head, or one of the counselors in freshman engineering concerning admission to the division.

AERONAUTICS, ASTRONAUTICS, AND ENGINEERING SCIENCES

The School of Aeronautics, Astronautics, and Engineering Sciences offers undergraduate and graduate degrees in aeronautical and astronautical engineering and in engineering sciences.

Laboratories

The Aerospace Sciences Laboratory, located at the Purdue Airport, is a center of experimental research activities of the school.

An instructional laboratory for experimental investigations by senior students is housed in the laboratory. This facility includes: a blow-down supersonic wind tunnel, an arc-heated wind tunnel, a shock tube and subsonic tunnels, apparatus for the investigation of flame stability and temperatures, equipment for studying the effect of thermal stress fields on the static and dynamic response of structures, and adequate instrumentation for a variety of projects. A metallographic and X-ray diffraction laboratory for studying microstructures of materials is available.

The Aerospace Sciences Laboratory, in addition to housing the above, also houses the following:

1. The **Materials Research Laboratory** is equipped with programmed thermal and mechanical loading facilities. Thermomechanical properties of nonlinear materials with memory are investigated. Deformation and/or temperature histories are preprogrammed and the stress is recorded as a function of time. Various forms of constitutive equations are then fitted to various classes of viscoelastic materials. This experimental facility is presently being extended to include tests on non-Newtonian viscous fluids.

2. The **Magneto-Fluid-Mechanics Laboratory** emphasizes experimental studies for the exploration of the structure of magneto-fluid-mechanic turbulence. Companion studies are made in magneto-hydrodynamic power generation and astrophysical applications. A liquid mercury facility is available in conjunction with a large electromagnet and special hot film anemometry equipment. An electromagnetic shock tube is also available.

In the campus facilities there are the following:

1. The **Computer Laboratory** contains an IBM 1130 digital computer and a teletype terminal connected to the CDC 6500 in the Computer Sciences Center. These are available to all staff and students to use in research problems. Also available is the Computer Sciences Center of the University which houses an IBM 7094 and a CDC 6500 among other computers.

2. **An Experimental Stress Analysis Laboratory** is equipped for modern methods of stress analysis including: (a) two- and three-dimensional photoelasticity, (b) birefringent coatings, (c) brittle lacquer and Moire techniques, (d) optical and electric resistance strain gages. Facilities are available for design and fabrication of special transducers needed in research work.

3. **The Random Environments Laboratory** is part of the school's Center of Applied Stochastics. The facilities of this laboratory include modern equipment for the simulation and generation of random environments and for the analysis of system behavior when subjected to such environments. Along with an analog computer, the laboratory contains a large random shaker with complete compensating console for the generation of random vibrational environments.

4. The **Dynamics Laboratory** contains modern equipment to accurately measure a number of phenomena. Dynamic phenomena, including accelerations, displacements, and rapidly changing strains, pressures, and temperatures may be measured by electrical means. Included are continuously recording inking galvanometers, with associated carrier bridges for making low frequency measurements; cathode ray oscillographs and associated circuits suitable for making high frequency measurements; recording potentiometers for continuously sampling thermocouples; an electronic switch for high speed sampling of electrical strain gages; representative transducers, such as SR-4 strain gages, piezoelectric crystals, thermocouples, and differential transformers for changing various mechanical phenomena into measurable electrical quantities.

5. The **Experimental Engineering Sciences Laboratory** provides facilities to demonstrate and to explore physical laws which are fundamental to engineering. Adequate equipment is available to study heat, light, electricity, and the laws of dynamics.

6. The **Systems Laboratory** is equipped with three TR-20 analog computers, totalling 30 amplifiers, and two servo-systems, one hydraulic and one electrical. The equipment is used primarily to simulate, study, and design various control and guidance systems in senior and graduate level courses.

Cooperative Program with Industry

A five-year cooperative program, which provides industrial experience related to engineering with selected companies, is offered a limited number of qualified students. Students are selected at the end of the freshman year and begin the cooperative program in the sophomore year. Alternate periods, including summers, are spent in industry and at the University. The student should file an application with the cooperative coordinator of the school upon completion of the first semester of the freshman year.

Library

The Aeronautics, Astronautics, and Engineering Sciences Library, located on the third floor of Grissom Hall, houses 20,000 volumes and 50,000 technical reports. The rapidly growing collection deals with solid and fluid mechanics, dynamics, stress analysis, thermodynamics, heat transfer, solid state physics, nuclear engineering, electricity and magnetism, electric circuits, electronics, electromechanical systems, space sciences, and applied mathematics. It is used as a source of reference material for undergraduate and graduate students, and staff.

PLANS OF STUDY

1. Aeronautical and Astronautical Engineering

The field of aeronautical and astronautical engineering includes the challenging problems encountered in the design of many types of airplanes, missiles, and space vehicles. Supersonic speeds, guidance systems, and recent developments in propulsion put a constant demand on research and development groups for an even better understanding of basic physical phenomena.

The aeronautical and astronautical engineering curriculum concentrates on the fundamental subject area necessary to all of the research and development jobs available in the aerospace industry. There is broad grounding in mathematics and physics and in the fundamental aeronautical engineering courses, such as aerodynamics, structural analysis, and propulsion. Elective hours are available in the senior year which the student may use for further specialization in aerodynamics, dynamics, structural design, or power plant design. A student with exceptional ability may, with the approval of his counselor, follow a program tailored individually to his needs. Further, a student with an exceptional undergraduate record may elect certain advanced courses which will provide an excellent preparation for graduate study.

Technical electives will be assigned in conferences with academic counselors. Several areas of specialization may be chosen by the selection of electives from the following fields: solid mechanics, fluid mechanics, propulsion, physics of fluids, stochastics, structures, guidance and control systems, dynamics, and orbit mechanics.

Students successfully completing the curriculum will be eligible for the B.S. in Aeronautical and Astronautical Engineering.

The curriculum of aeronautical and astronautical engineering is accredited by the Engineers' Council for Professional Development.

Curriculum in Aeronautical and Astronautical Engineering

(Credit Hours Required for Graduation: 129)

FRESHMAN YEAR

(See page 27)

SOPHOMORE YEAR

Third Semester		Fourth Semester	
(4)	MA 261 (Mathematics for Engineering and the Physical Sciences III)	(4)	MA 262 (Mathematics for Engineering and the Physical Sciences IV)
(3)	PHYS 241 (Electricity and Optics)	(3)	A&ES 208 (Basic Mechanics II)
(2)	ESC 221 (Basic Mechanics I)	(3)	A&ES 232 (Introduction to Mechanics of Solids)
(3)	EE 201 (Introduction to Electrical Engineering)	(3)	Electrical Engineering Elective
(1)	EE 207 (Electrical Engineering Laboratory I)	(3)	General Education Elective
(3)	General Education Elective		
(16)		(16)	

JUNIOR YEAR

Fifth Semester

(3) MA 302 (Mathematical Methods in Engineering I) or (3) MA 422 (Differential Equations for Engineering and the Physical Sciences)
(3) ME 305 (General Thermodynamics I)
(3) A&ES 352 (Structural Analysis I)
(3) A&ES 333 (Fluid Mechanics)
(2) A&ES 351 (Digital Computers)
(3) General Education Elective

(17)

Sixth Semester

(3) A&ES 372 (Propulsion I)
(3) A&ES 334 (Applied Aerodynamics and Performance)
(3) ME 306 (General Thermodynamics II) or A&ES 361 (Introduction to Random Variables in Engineering)
(3) A&ES 453 (Structural Analysis II)
(3) A&ES 340 (Dynamics and Vibrations)
(3) General Education Elective

(18)

SENIOR YEAR

Seventh Semester

(3) A&ES 416 (Aerodynamics II)
(3) A&ES 464 (Control Systems Analysis)
(3) A&ES 402 (Aerospace Engineering Laboratory)
(3) Design Elective
(3) General Education Elective

(15)

Eighth Semester

(12) Elective
(3) General Education Elective

(15)

2. *Engineering Sciences*

The principal object of the curriculum in engineering sciences is to prepare students for careers in research and development in the engineering field. The program, therefore, emphasizes fundamental principles and techniques. The same basic principles and techniques form the foundation of all engineering endeavor.

The demand for graduate engineers trained in engineering sciences has grown rapidly in the past few decades. This demand will continue to grow as basic research and development play an increasingly important role in industry and government.

Graduates in engineering sciences find employment in the aircraft, automotive, electrical, and electronics industries, in industrial and governmental research laboratories, and in many other such organizations. The broad basic training of the engineering sciences graduate makes him a desirable addition to almost any engineering staff. His breadth of vision of all fields of engineering often leads him to supervisory and administrative posts or to the front of a new field of engineering development.

The research engineer is primarily concerned with the analysis and synthesis of engineering structures, machines, and processes. This analysis and synthesis requires a high degree of physical insight, sound engineering judgment, and skill in the use of analytical and experimental research tools. For this reason, the curriculum in engineering sciences contains extensive mathematics and basic science courses to develop the student's skill in precise physical reasoning, analysis, and synthesis. The curriculum also contains courses to give a knowledge of materials and to develop engineering judgment.

A student who wishes to pursue advanced studies and research in engineering sciences will find fertile fields in the following areas: dynamics, elasticity, plasticity, fluid mechanics, thermodynamics, materials, nuclear engineering, systems analysis and synthesis, and modern computers.

The curriculum of engineering sciences is accredited by the Engineers' Council for Professional Development.

Curriculum in Engineering Sciences

(Credit Hours Required for Graduation: 132)

FRESHMAN YEAR

(See page 27)

SOPHOMORE YEAR

Third Semester

(4) MA 261 (Mathematics for Engineering and the Physical Sciences III)*
(3) PHYS 241 (Electricity and Optics)
(3) A&ES 207 (Basic Mechanics I)
(3) EE 201 (Introduction to Electrical Engineering)
(1) EE 207 (Electrical Engineering Laboratory)
(3) General Education Elective

(17)

Fourth Semester

(4) MA 262 (Mathematics for Engineering and the Physical Sciences IV)*
(3) A&ES 208 (Basic Mechanics II)
(3) A&ES 232 (Introduction to Mechanics of Solids)
(2) A&ES 351 (Digital Computers)
(1) A&ES 290 (Introduction to Engineering Sciences)
(3) General Education Elective

(16)

JUNIOR YEAR

Fifth Semester

(4) Mathematics Elective*
(3) A&ES 361 (Introduction to Random Variables in Engineering)
(3) PHYS 515 (Thermodynamics)
(3) A&ES 333 (Fluid Mechanics) or PHYS 342 (Modern Physics)
(3) General Education Elective†

(16)

Sixth Semester

(4) Mathematics Elective*
(3) A&ES 307 (Advanced Dynamics)
(4) PHYS 432 (Electromagnetism)†
(3) A&ES 309 (Statistical Mechanics)
(3) General Education Elective†

(17)

* These courses may be replaced or filled by an experimental engineering sciences sequence or by appropriate mathematics courses approved by the academic counselor.

† An engineering sciences student who elects to take the Large Scale Systems Option will replace the courses indicated with a dagger above by the courses in the option.

SENIOR YEAR

Seventh Semester

(3) A&ES 461 (Continuum Mechanics I)
(3) A&ES 463 (Systems Analysis)
(1) A&ES 475 (Physical Measurements Laboratory I)
(2) A&ES 533 (Theory of Materials I)*
(2) CHM 584 (Advanced Physical Chemistry of Materials)*
(3) Technical Elective*
(3) General Education Elective

(17)

Eighth Semester

(3) A&ES 462 (Continuum Mechanics II)
(1) A&ES 476 (Physical Measurements Laboratory II)
(2) A&ES 534 (Theory of Materials II)*
(2) CHM 585 (Advanced Physical Chemistry of Materials)*
(3) A&ES 564 (Systems Analysis and Synthesis)*
(3) Technical Elective
(3) General Education Elective

(17)

3. *Large Scale Systems Option*

Effective September 1970 the School of Aeronautics, Astronautics, and Engineering Sciences offers the opportunity to its undergraduate students to elect an option in large scale systems. The option consists of an integrated sequence of 21 credit hours distributed as follows:

Fifth Semester

(3) SOC 312 (American Society)

Sixth Semester

(3) INDM 481 (Elements of Industrial Management)
(3) A&ES 381 (Modeling Techniques for Large Scale Systems I)

(6)

Seventh Semester

(3) A&ES 400 (Modeling Techniques for Large Scale Systems II)
(3) A&ES 483 (Problems in Large Scale Systems I)

(6)

Eighth Semester

(3) A&ES 484 (Problems in Large Scale Systems II)
(3) Technical Elective

(6)

These 21 credit hours will replace 21 credit hours of certain electives in the existing aeronautics and astronautics curriculum or 22 credit hours of courses indicated by a dagger in the engineering sciences curriculum as advised and approved by the counselor. There will be no change of the titles of the degrees to be awarded upon graduation.

* An engineering sciences student who elects to take the Large Scale Systems Option will replace the courses indicated with a star above the courses in the option.

AGRICULTURAL ENGINEERING

Agricultural engineering is the engineering of machines and systems for the production and processing of feed, fiber, and food. The agricultural engineering curriculum combines courses in the life sciences with certain basic engineering courses to form a background for advanced courses in the design of biological production systems. A number of electives in the senior year gives the student some flexibility in selecting a program of study to meet his own needs. This curriculum is fully accredited by the Engineers' Council for Professional Development.

Employment opportunities for agricultural engineering graduates are available in the areas of design in manufacturing industries, engineering management, private consulting, teaching in colleges and universities, research in industry and government, extension in industry and public service, sales engineering, and foreign service.

The plan of study outlined below leads to the degree of Bachelor of Science in Agricultural Engineering and is administered jointly by the Schools of Engineering and the School of Agriculture. Beginning students should apply for admission to the Schools of Engineering and complete the freshman engineering program. For qualified agricultural students who develop an interest in agricultural engineering during their freshman year, an alternate program in the School of Agriculture is available. The department also offers graduate study leading to the degrees of Master of Science and Doctor of Philosophy.

Cooperative Program with Industry

Students in the upper half of their freshman class are eligible for the Cooperative Engineering Education Program which leads to the B.S. in Agricultural Engineering over a five-year period. In this program, the freshman and senior years are spent on campus, while the three intervening years are spent intermittently on campus and on a job with an agriculture-related company or agency. Interested students should contact the cooperative program coordinator for the Department of Agricultural Engineering during the second semester of their freshman year.

Honors Program

An honors program is offered for superior students who wish to pursue individual programs either with more time for self-study in areas of special interest relevant to agricultural engineering or with more flexibility in choice of courses in the agricultural engineering curriculum. Substitution can be made for up to one-fourth of the required courses and technical electives in the junior and senior years. Honor studies are conducted under the guidance of a professional staff member of the department.

Admission into the honors program is based on a written application submitted by the student before registering for the junior year and approved by the agricultural engineering faculty. The application should include a brief statement of the objectives and content of the proposed program. To enter and remain in the honors program, a student must maintain at least a 5.0

graduation index and must show a reasonable rate of progress toward his program objectives. Successful completion of the honors program will be recognized by the awarding of an honors certificate at graduation.

Laboratories and Facilities

The **Processing Laboratory** includes working models of crop-drying and processing equipment used in obtaining engineering data for the design of full-scale systems. Various kinds of electronic measurement and control equipment are available for work in the laboratory.

The **Power and Machinery Laboratories** include many instruments for measuring tractor and engine power and the performance of field machinery. A soil-vehicle reaction simulator utilizing artificial soil is available for investigating the dynamics of tires and tillage tools.

The **Structures Laboratory** provides space for the study of the functional design of agricultural buildings for storage of products or housing of animals. Equipment for the development and testing of structural components of buildings such as electronic strain and force measuring instruments are available.

The new **Environmental Laboratory** provides facilities including control chambers for the study of environmental factors on plant and animal growth. In addition large controlled-environmental chambers of the Herrick Laboratories are available for use in cooperation with the Department of Animal Sciences and the School of Mechanical Engineering.

Newly equipped **Physical Properties Laboratories** provide space and facilities for investigating properties of biological materials and systems. These facilities include equipment for studying mechanical, thermal, optical, electrical, and hygroscopic properties of agricultural materials.

The **Water Resources and Waste Management Laboratory** is equipped for investigating methods of treating and handling animal wastes, flow through porous material, the mechanics of water flow over hydraulic models, and the processing of surface waters for domestic consumption. This laboratory contains recirculating water control systems, sand tank models, electrical analogs, rainfall simulators, radiological detection apparatus, and complete laboratory facilities for animal waste research.

The **Soil Erosion Mechanics Laboratory** contains equipment for studying the influence of erosion-producing variables such as slope steepness, slope length, particle size and packing, and mulching rates on the erosion process. Rainfall is simulated at approximate drop sizes and energies of an intense natural rainfall on a bed containing the soil material being studied.

An **Automatic Control Laboratory** provides facilities for the investigation of automatic control systems for process and machine control. Equipment is available for investigating environmental control, grain dryer moisture control, automatic control of agricultural machines and other applications.

Computer Facilities include a modern, high-speed analog computer with a large complement of digital logic to provide capabilities for hybrid computing as well as automatic data acquisition and experimental control. Students also use the University's IBM 7094 and CDC 6500 digital computers for problems in agricultural engineering courses. Teletype terminals located in the agricultural engineering computer laboratory provide excellent remote access to the digital computer facilities.

Shop Facilities are provided by a well-equipped machine shop which is available for the construction of research equipment. Some senior students may elect to take a special problem course. These students, working with their adviser and the shop foreman, may make use of the shop facilities in the design and fabrication of needed special equipment.

(Total Credits—135 Semester Hours)

FRESHMAN YEAR

(See page 27)

SOPHOMORE YEAR

Third Semester

(1) AGEN 200 (Introduction to Agricultural Engineering Design)
(4) MA 261 (Mathematics for Engineering and the Physical Sciences III)
(4) BIOL 108 (Introduction to Botany)
(3) ESC 221 (Basic Mechanics I)
(3) PHYS 241 (Electricity and Optics)
(3) General Education Elective

(17)

Fourth Semester

(3) ESC 223 (Mechanics of Materials)
(4) MA 262 (Mathematics for Engineering and the Physical Sciences IV)
(4) BIOL 109 (Introduction to Zoology)
(3) AGRY 255 (Soil Science)
(3) General Education Elective

(17)

JUNIOR YEAR

Fifth Semester

(3) AGEN 305 (Physical Properties of Biological Materials)
(3) ESC 206 (Basic Mechanics II)
(3) ME 307 (Elements of Thermodynamics)
(3) EE 317 (Electrical Engineering)
(3) AGRY 410 (Grain Crops)
(3) ANSC 431 (Environmental Physiology of Domestic Animals)

(18)

Sixth Semester

(3) AGEN 310 (Environmental Relationships)
(4) CE 342 or ME 310 (Fluid Mechanics)
(4) ME 315 (Heat and Mass Transfer)
(3) EE 318 (Electrical Engineering)
(3) BIOL 220 (Introduction to Microbiology)

(17)

SUMMER EXPERIENCE

Eight weeks of approved agricultural or industrial experience are required of each student enrolled in the agricultural engineering curriculum, except those in the cooperative engineering education program.

SENIOR YEAR

Seventh Semester	Eighth Semester
(3) AGEN 425 (Soil-Water-Plant Systems Design)	(1) AGEN 490 (Professional Practice in Agricultural Engineering)
(3) AGEN 430 (Design of Crop Production and Harvesting Machines)	(6) General Education Electives
(3) AGEN 475 (Design of Facilities for Animal Production and Crop Storage)	(9) Technical Electives
(6) General Education Electives	
(3) Technical Elective	
(18)	(16)

CHEMICAL ENGINEERING

The School of Chemical Engineering offers courses of study leading to the degree of Bachelor of Science in Chemical Engineering and the advanced degrees of Master of Science in Chemical Engineering and Doctor of Philosophy.

The chemical engineering curriculum is designed to prepare engineers for research, development, operation, design, and supervision in the chemical and process industries. The principal fields of study are engineering and chemistry, with basic courses in mathematics, physics, mechanics, electricity, and metallurgy to give a wide view of engineering knowledge. Courses in English and interpersonal communication (speech) and general education elective courses furnish an educational background in the humanities and social sciences.

The chemical and process industries are under technical control by the chemical engineer. The plants of the chemical industry (making chemicals, dyes, medicines, plastics, etc.) and the factories of the process industries such as oil refineries (making many of our useful goods by application of a chemical process or chemical change to raw materials) require supervision by chemical engineers. These are vigorous and expanding industries continually supplying new products to American and world markets. These industries spend much money in research, development of new products, building new plants, improving manufacturing processes, economic studies, and market research. This progress leads to ever-increasing opportunities for the employment of chemical engineers.

The training of the chemical engineer is broad, and strong in science and mathematics. Because of this, chemical engineers are employed extensively in the new and developing fields such as nuclear power, rocket fuels, automatic process control, high polymers and plastics, antibiotics manufacture, and extraction of products from natural materials.

It is traditional that more of the graduates in chemical engineering have continued their studies to the level of the M.S. and Ph.D. degrees than those in almost any other field of engineering. Those interested in the more advanced

Chemical and Metallurgical Engineering Building

work of research, development, and college teaching will find it to their advantage to continue their studies to obtain a graduate degree.

Students who have completed high school chemistry in a recognized high school and receive high scores in the orientation tests, given at the time they enter the University, are urged to elect CHM 117 and 126 in the freshman year.

Engineering students will be accepted for admission to the curriculum in chemical engineering during the second semester of their freshman year, effective at the beginning of the third semester, provided they have credit in CHM 117 or a grade of C or better in CHM 116. Students who do not meet this requirement must have the approval of the head of the School of Chemical Engineering before being admitted to the curriculum in chemical engineering.

Prominent men from the chemical industry are brought to the campus to speak to students and introduce modern advances and practices from industry.

The curriculum in chemical engineering is accredited by the Engineers' Council for Professional Development.

Cooperative Program with Industry

A limited number of qualified students may enter a cooperative work-study plan which leads to the degree of Bachelor of Science in Chemical Engineering over a five-year program. The first (freshman) and the fifth year of the program will be spent as a full time student on the Purdue University campus. Half of the second, third, and fourth years will be spent on the campus, and the other half will be spent on a job in the chemical industry with a selected cooperating company. Two men will usually share one job so that one is working while the other is a student on the regular scheduled program of study.

Students must have a scholastic average in the upper half of their freshman class if they wish to enter the cooperative program. Those interested in the program should contact the cooperative program coordinator for the School of Chemical Engineering during the second semester of their freshman year.

At the completion of the program the student will receive the regular engineering degree and a certificate indicating completion of the cooperative program with industry.

Laboratories and Shops

Transfer Operations Laboratory. This laboratory contains both small and large scale apparatus for the study of fluid flow, heat transfer, and the physical changes of evaporation, distillation, drying, filtration, air conditioning, and absorption. Some of the equipment are small scale reproductions of industrial process machinery.

Process Dynamics and Control Laboratory. Bench scale equipment is available for experiments in dynamic testing and automatic control of typical processes. Analog computers are used to simulate these processes and supplement the study of control systems.

Shops. Electronics and machine shops with skilled technicians in charge are available for building new research equipment and keeping existing equipment in good operating condition.

Student Shop. A shop, supervised by a full-time mechanic, is available to the student for constructing special apparatus when it is needed in his laboratory work.

(Total Credits—134 Semester Hours)

FRESHMAN YEAR

(See page 27)

Chemistry Sequences. The freshman chemistry requirement for chemical engineering students is eight credits of general chemistry and qualitative analysis. These may be earned by taking one of the following sequences:

CHM 115, 116 (8 credits)

CHM 117, 126 (10 credits)

Placement in these sequences is made on the basis of ability demonstrated in freshman orientation tests. The curriculum is based upon the CHM 115, 116 sequence. The extra two credits from the CHM 117, 126 series may be used as technical elective credit. CHM 220 (3 credits), a sequel course to CHM 115, 116 is recommended as a technical elective. This course would bring the CHM 116 student to the same level as the CHM 126 student. Equivalent work from other institutions will be accepted for a maximum of ten credits.

Some students choose to distribute the work in this curriculum over eight semesters and a summer session, or over nine semesters.

The freshman engineering student who is interested in chemical engineering must fulfill all the first year requirements of the Department of Freshman Engineering before he can enter the School of Chemical Engineering.

SOPHOMORE YEAR

Third Semester

(3) CHE 205 (Chemical Engineering Calculations)
(3) CHM 261 (Organic Chemistry)
(1) CHM 263L (Organic Chemistry Laboratory)
(5) PHYS 251 (Heat, Electricity, and Optics)
(4) MA 261 (Mathematics for Engineering and the Physical Sciences III)

(16)

Fourth Semester

(2) CHE 206 (Stagewise Operations)
(3) CHM 262 (Organic Chemistry)
(1) CHM 264L (Organic Chemistry Laboratory)
(3) CHM 373 (Physical Chemistry)
(4) MA 262 (Mathematics for Engineering and the Physical Sciences IV)
(2) ESC 221 (Basic Mechanics I)
(1) CS 200 (Laboratory Programming Digital Computers)

(16)

JUNIOR YEAR

Fifth Semester

(3) CHE 311 (Introductory Chemical Engineering Thermodynamics)
(4) CHE 337 (Transfer Operations)
(3) CHM 374 (Physical Chemistry)
(2) CHM 374L (Physical Chemistry Laboratory)
(3) Technical Elective*
(3) General Education Program I

(18)

Sixth Semester

(3) CHE 338 (Transport Phenomena)
(2) CHE 344 (Chemical Engineering Laboratory I)
(3) PHYS 342 (Modern Physics)
(3) EE 201 (Intro-Electrical Engineering)
(1) EE 207 (Electrical Engineering Laboratory I)
(3) Technical Elective*
(3) General Education Program I

(18)

SENIOR YEAR

Seventh Semester

(3) CHE 439 (Reaction Kinetics and Chemical Equilibrium)
(2) CHE 445 (Chemical Engineering Laboratory II)
(2) CHE 449 (Math Application in Econ. and Optimization)
(0) CHE 491 (Professional Guidance)
(3) CHE 456 (Process Dynamics and Control) or Technical Elective*
(3) General Education Program I
(3) General Education Program II

(16)

Eighth Semester

(3) CHE 450 (Chemical Process Design and Economics)
(3) Technical Electives or CHE 456 (Process Dynamics and Control)
(3) MSE 411 (Engineering Materials)
(3) Technical Elective*
(3) General Education Program I
(3) General Education Program II

(18)

The Pass/Not Pass Option is allowed in the General Education Program. Technical electives may be allowed under the Pass/Not Pass Option and petition and approval of the Chemical Engineering Undergraduate Committee.

* A minimum of two technical electives must be in chemical engineering. The elective courses are to be selected by the student in consultation with his faculty adviser to best fulfill the objectives of the individual student's program. A maximum of six credit hours for advanced military courses may be substituted.

RECOMMENDED ELECTIVES

Lists are available in the undergraduate office of the school suggesting technical electives for a number of programs of interest to chemical engineers. Examples are:

Advanced Chemical Engineering: CHE 510, 511, 524, 527, 539, 542, 558, 597.

Bioengineering: CHE 511; BIOL 221, 520, 537; CHM 533, 534; or BCHM 561, 561L, 562, 562L.

Chemical Process Engineering: CHM 525, 561, 563; CHE 511, 542, 543, 559.

Nuclear Engineering: NUCL 500, 505, 510, 520; CHE 511, 527; MA 501, 502 or 302, 510; PHYS 550, 556.

Process Control Engineering: CHE 527, 597; MA 501, 502 or 302, 510; EE 483, 515, 516, 585; ME 475, 575.

Materials Science and Metallurgical Engineering: MSE 202, 353, 522, 523, 536, 575.

Production and Sales: IE 365; INDM 200, 201, 420, 585, 586; ECON 332, 417, 425, 434, 482, 522; PSY 572; STAT 511, 512, 513.

Preparation for Graduate Program

Students with a high scholastic index who are interested in the more creative and technical phases of engineering, such as research, development, design, and teaching are advised to follow a program leading to the degree of Master of Science in Chemical Engineering or Doctor of Philosophy. It is recommended that such students take at least a year of foreign language in their nontechnical elective program. Their technical electives should be chosen from advanced courses in mathematics or statistics, chemical engineering, chemistry, or physics.

Descriptions of chemistry, mathematics, bacteriology, and physics courses listed as electives will be found in the catalog of the School of Science. Descriptions of other courses are in the catalogs of the schools of Industrial Management and Humanities, Social Science, and Education.

Honor Students

Students with high scholastic indexes (5.50 or better) are classified as honor students. Many of them will go on to graduate school in some area of study. They are allowed more freedom than usual in the choice of elective courses and are given special assistance by a guidance counselor in coordination and selection of courses to prepare them for advanced study.

CIVIL ENGINEERING

The civil engineering curriculum prepares its graduates for professional careers in planning, design, and construction in the fields of hydraulic engineering, environmental engineering, transportation engineering, urban engineering, soil mechanics and foundation engineering, surveying and mapping, engineering materials, and structural engineering.

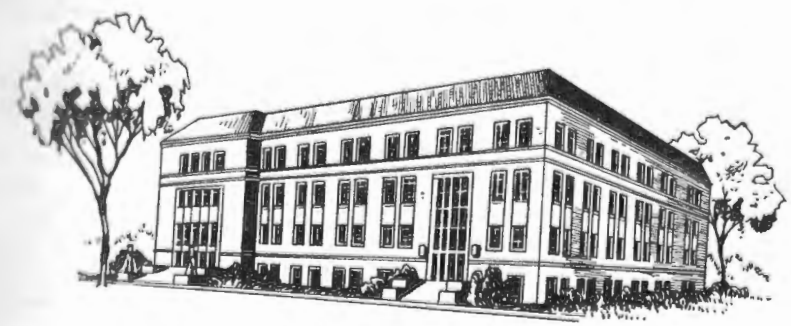
The curriculum also emphasizes preparation for graduate work for those students who are interested in research and development and engineering education. Opportunities for graduate programs emphasizing the planning, design, and construction functions of civil engineering are also available.

The wide range of interests in the civil engineering profession—bridges, dams and levees, harbors, waterways and irrigation facilities, buildings, airports, highways, pipelines, railroads, power lines, water supply systems, waste treatment facilities, and many urban systems—supplemented by the changing needs of our civilization—provides a unique and unlimited opportunity for service and professional development.

Civil Engineering Laboratories

The Hydromechanics Laboratory provides Purdue University with a major facility for the study of the mechanics of incompressible fluid flow. It constitutes the focal point for theoretical and experimental research in the areas of hydromechanics, hydraulic engineering, hydrology, and water resources.

The laboratory covers the greater part of three floors of a 60 by 180 ft. wing of the Civil Engineering Building The basement floor houses a 160 ft. long, 11 ft. wide, and 5 ft. deep towing tank, and an electronics shop. The research floor is equipped with 40 ft. and 90 ft. long tilting flumes, a 90 ft. long wind tunnel, and various other research flow facilities. This equipment is supplemented by hot-wire anemometers, pressure transducers, tape recorders, and miscellaneous measuring devices and data reduction facilities. The upper floor of the laboratory houses the equipment for instruction at the undergraduate and graduate levels, and includes some flumes, a wind tunnel, air jet, and table-top facilities.



Civil Engineering Building

The **Environmental Engineering Laboratories** are equipped to provide facilities for instruction and research in all major areas of environmental pollution control including: industrial waste treatment, municipal waste treatment, solid waste management, air pollution control, radiological health, water treatment and supply, and advanced waste treatment. Well-equipped, air conditioned research laboratories and study areas are provided for graduate students. Special research facilities include: a modern microbiology laboratory, analytical chemical laboratory, analytical instruments laboratory, pilot plant, constant temperature rooms, radiochemical laboratory, and air pollution laboratory. Highly sensitive analytical instruments are available for microbiological, radiochemical, spectrochemical, electrochemical, and chromatographic studies in support of both basic and applied research.

The **Soil Mechanics Laboratory** is equipped with facilities for undergraduate and graduate instruction in soil-testing methods for engineering purposes and provides opportunities for carrying on research in soil mechanics and its application to engineering problems. The laboratory has equipment for general soil classification tests (Atterberg limit, mechanical analyses, specific gravity, compaction, etc.) and for the study of pressure-volume relationships, stress-strain relationships, and the strength characteristics of soils. Facilities are available for studying the effects of temperature changes on soils, including the effects of frost action, for studying the response of soils to dynamic loading, for model studies of fluid flow through soils, and of bearing action of plates for producing clay sediments artificially in the laboratory, and for producing dehydrated specimens without disturbing soil particle orientation.

The **Rock Mechanics** facilities are shared jointly with the soil mechanics laboratory. The Rock Mechanics Laboratory is designed for graduate instruction, research into rock properties, and the solution of civil engineering problems concerned with rock as a major component of a structure or as its foundation. The laboratory is equipped to perform petro-fabric analysis and photomicrographs of thin sections, determine the stress-strain characteristics and the unconfined and triaxial strengths of any rock up to 300 kips vertical load and 10 kips lateral load, perform automatic cyclic and constant static loading to evaluate rock fatigue and creep, derive elastic moduli by dynamic resonance and high-voltage pulse techniques, and determine rock anisotropy by electrical pulses. Use is made of solid-state electronic readout equipment and electromechanical transducers such as the piezoelectric crystal, strain gages, and the inductive displacement transducers. There is complete coring, sawing, and polishing equipment for the preparation of rock test specimens.

The **Structural Engineering** facilities consist of the main laboratory, two small laboratory areas for models work, and storage areas for the equipment and materials needed for teaching and research.

The main Structural Engineering Laboratory is housed in a 60 ft. by 60 ft. room specifically designed for structural testing. The thick structural floor is heavily-reinforced concrete; a 6 ft. square grid of tie-down and lateral thrust anchors is incorporated in the floor. A large-capacity (600,000 lbs.) hydraulic testing machine for static compression or tension tests is mounted in a specially constructed recess in the structural floor. This machine, which has liberal lateral and vertical clearance dimensions, is situated so that the floor can be used as an extension of the test bed. A conventional 120,000 lb. hydraulic testing machine is also located in the main laboratory.

Universal static and fatigue loading equipment, including a pendulum dynamometer, hydraulic pulsator, accumulator, and four special hydraulic jacks, is on hand. These jacks are capable of applying both static and pulsating loads with capacities up to 110,000 lbs. Complementing this equipment is an additional collection of hydraulic jacks, with capacities ranging up to 115,000 lbs., which together with the requisite accessories and the pendulum dynamometer comprise another static loading system. An adjustable structural steel loading frame and a prestressed concrete portal-type loading frame are available for mounting jacks in a variety of configurations.

The main laboratory is serviced by two 2-ton travelling cranes and a 3-ton hydraulic floor crane. A one-half yard concrete mixer and associated equipment required for concrete manufacture are on hand. An inventory of electronic, mechanical, and optical instruments is maintained so as to make possible both automatic and manual measurement and recording of engineering quantities of interest. Noteworthy electronic instruments are: a 100-channel digital data acquisition system, digital voltmeter, oscillographic recorder, X-Y recorder, precise power supplies, portable strain indicators, switch-and-balance units, oscilloscopes, and a thermocouple potentiometer.

A **Plastic** Models Laboratory is located in a 20 ft. by 28 ft. room adjacent to the Civil Engineering Machine Shop located on the basement floor. Equipment required for accurate machining of plastic is available. In addition, this laboratory contains a hydraulically operated loading frame designed for use in small model work. Another small general purpose area serves as a laboratory for model work micro-concrete. The well-equipped and expertly staffed machine shop services the entire School of Civil Engineering.

The **Engineering Materials** facilities comprise several laboratories including those Highway Research Laboratories devoted to work on materials. The course offerings in engineering materials, both undergraduate and graduate are designed to familiarize the student with those aspects of materials science important to an understanding of construction materials. The primary emphasis is on the response of materials to loads and on their durability under service conditions. But phenomenological and physio-chemical aspects of the subject also emphasized; current practice and test methods are critically studied.

Laboratory facilities include the following: The Materials Testing Laboratory contains a variety of equipment for the evaluation of the mechanical properties of materials under various modes of loading. The facilities of the Structural Engineering Laboratory are adjacent and are available for the use of students working in engineering materials.

The Chemical Laboratory has facilities for routine and specialized analysis of engineering materials, x-ray diffractometry, infra-red spectrophotometry, differential thermal analysis, surface area determinations, mercury porosimetry, and specialized research on the physico-chemical properties of materials. Chief emphasis has been on work on cement and concrete systems.

The Bituminous Laboratory facilities for evaluating bitumens and bituminous-aggregate mixtures include those necessary for rheological studies, unconfined and triaxial tests, Hubbard-Field, Marshall, and Hveem Stabilometer tests, including kneading compaction, gyratory compaction, response to repetitive loading, and an environmental room for the control of temperature and humidity. Facilities for durability testing include heating and cooling, freeze-thaw, wetting-drying, and sonic evaluation equipment. A modern mechanical testing apparatus permits both static and dynamic loading of specimens of all construction materials under a wide range of programmed loading conditions and with automatic recording of loads and deformations.

The Concrete Laboratory provides facilities for research on cement, concrete, and mortars. Included is an aggregate crushing and preparation area as well as facilities for mixing and curing of concrete. Routine testing equipment is available as well as apparatus for freeze-thaw, sonic evaluation, pulse velocity determination, and microscopical and petrographic analyses of concrete and aggregates.

Although listed separately, all laboratories of the Engineering Materials section are integrated into a combined research facility available to all students working in materials. These laboratories also provide many opportunities for part-time employment of undergraduate students.

The **Transportation and Urban Engineering Laboratories** provide facilities for instruction and research in the planning, design, and operation of transportation systems and urban communities. In addition to the physical aspects of transportation and urban problems, facilities for study of administrative, fiscal, and economic aspects of transportation and urban areas are available.

A well-equipped Airphoto Interpretation Laboratory has extensive photogrammetric equipment, photographic facilities, and a comprehensive library of selected aerial photographic prints from all sections of the United States and other parts of the world.

The Design Laboratory contains the necessary equipment for many laboratory and field tests of soil characteristics for transportation route location and for highway and airport design. Instrumentation for electronic measurement of pavement deflection and stresses is available as is specialized equipment such as nuclear moisture-density gauges.

The Planning and Operations Laboratories contain complete equipment for transportation, traffic and urban studies and for the planning of transportation and urban systems. Extensive computer facilities and programs are also available for analysis of data and development of models for the planning and operation of such systems. Emphasis is placed on the use of systems analysis, operational research and computer techniques for the solution of complex problems.

The **Graphics Laboratories** are located in the Michael Golden Engineering Laboratories. Eight well-lighted rooms equipped with individual desks provide facilities for instruction in elementary and advanced engineering graphics. Specialized equipment permits instruction in the more precise field of problem solving and in artistic representation.

The Surveying and Mapping Instrument Room contains a substantial amount of surveying and mapping equipment for use in classroom demonstrations and laboratory exercises. The equipment includes transits, levels, tapes, plane tables, European theodolites and levels, subtense bar, distance measuring wedge, astrolabe, solar transit, altimeters, tellurometer, stereometer instruments, sketchmasters, planimeters, DBA multilaterative comparator, multiplex, Kelsh, and Wild A-7 stereoplotters, and many other necessary surveying and photogrammetric items. A small workshop is available for minor repair and rehabilitation of equipment. An audio-tutorial instructional booth is available which permits individual instruction in certain topics.

Highway Research Laboratories

The Highway Research Laboratories consist of well-equipped airphoto interpretation, bituminous, chemical, concrete, and design laboratories. In addition, there are facilities for transportation and traffic studies and for urban area research. There are shop facilities and a small tract of land suitable for test sections and other field studies. All laboratories are part of the Joint Highway Research Project and are operated by the School of Civil Engineering in cooperation with the Indiana State Highway Commission. These laboratories provide many opportunities for part-time employment of undergraduate students.

The Highway Research Laboratories include the following: the Bituminous Laboratory, the Chemical Laboratory, and the Concrete Laboratory, described in the section on the engineering materials facility; the Airphoto Interpretation Laboratory, the Design Laboratory and the Planning and Operations Laboratory, reviewed in the section on Transportation and Urban Engineering.

Libraries

The R. B. Wiley Memorial Library, located on the third floor of the new Civil Engineering Building, contains approximately 10,000 volumes of monographs and journals dealing with civil engineering subjects and related areas such as mathematics, physics, chemistry, geology, economics and political science. The library currently receives over 230 journal titles. Special collections include manufacturers' catalogs and highway materials such as traffic surveys, planning and need studies, toll roads and other studies. Open 69 hours per week the library provides excellently lighted, air conditioned study space for 67 people.

Cooperative Program with Industry

A five-year cooperative educational program is offered which enables a limited number of qualified students to obtain industrial experience related to engineering with selected companies, while completing the requirements for the undergraduate degree. Such students are selected at the end of the freshman year and begin the cooperative program in the summer preceding the sophomore year. Alternate periods, including summers, are spent in industry and at the University. In order to qualify for the program, students will be required to have a scholastic index which places them in the upper half of the freshman engineering class at the end of their first year.

Students desiring to participate should file an application with the cooperative coordinator for civil engineering following completion of the first semester of their freshman year. On the basis of the first semester's scholastic index, qualified students will be tentatively selected for the program. Upon completion of the year's work with the required index and upon acceptance as a cooperative employee by a University-approved employer, students may formally enter the program. Upon completion of the program, the students receive the regular engineering degree and a certificate indicating their completion of the cooperative education program with industry.

Honors Programs

Students who have a scholastic index of 5.0 or better have the opportunity to follow special programs suited to their particular talents and interests.

(Total Credits—135 Semester Hours)

(For students who entered as freshmen in September 1966 and later.)

FRESHMAN YEAR

(See page 27)

SOPHOMORE YEAR

Third Semester

(4) MA 261 (Mathematics for Engineering and the Physical Sciences III)
(5) PHYS 251 (Heat, Electricity, and Optics)
(2) ESC 221 (Basic Mechanics I)
(3) CE 206 (Engineering Surveys I)
(1) CS 200 (Laboratory on Programming for Digital Computers)
(0) CE 290 (Civil Engineering Seminar)

(15)

Fourth Semester

(4) MA 262 (Mathematics for Engineering and the Physical Sciences IV)
(3) ESC 206 (Basic Mechanics II)
(3) ESC 223 (Mechanics of Materials)
(2) CE 207 (Engineering Surveys II)
(0) CE 299 (Civil Engineering Seminar)
(3) General Education Elective*

(15)

* The Pass/Not Pass Option (see page 24) may in civil engineering be applied only to elective courses.

JUNIOR YEAR

Fifth Semester

(3) ME 307 (Elements of Thermodynamics)
(3) CE 333 (Engineering Materials)
(3) CE 370 (Structural Mechanics)
(3) CE 342 (Mechanics of Fluids)
(3) Mathematics/Science Elective*
(3) General Education Elective*

(18)

Sixth Semester

(3) EE 314 (Electrical Engineering)
(2) GEOS 381 (Geology for Engineers I)
(2) CE 334 (Materials Science)
(2) CE 350 (Environmental Engineering I)
(3) CE 360 (Transportation Engineering I)
(3) CE 371 (Statically Indeterminate Structures)
(3) CE 380 (Soil Mechanics)

(18)

SENIOR YEAR

Seventh Semester

(3) CE 420 (Construction Engineering and Management)
(3) CE 453 (Environmental Engineering II)
(3) CE 461 (Transportation Engineering II)
(4) CE 473 (Theory of Reinforced Concrete)
(3) CE 481 (Foundation and Earth Structures)
(0) CE 490 (Engineering Inspection Trip)
(3) General Education Elective*

(18)

Eighth Semester

(3) CE 470 (Structural Design in Metals)
(3) CE 498 (Civil Engineering Design Project)
(6) Technical Elective*
(6) General Education Electives*

(18)

* The Pass/Not Pass Option (see page 24) may in civil engineering be applied only to elective courses.

ELECTRICAL ENGINEERING

Electrical engineering encompasses all areas of research, development, design, and operation of electrical and electronic systems and their components. Electrical engineers specialize in such varied areas as bioengineering, circuit theory, communication sciences, computers and automata, control systems, electromagnetic fields, energy sources and systems, and materials and electronic devices.

The electrical engineer must have a strong background in mathematics and physics, a broad base in the humanities, and a command of the English language to provide the breadth essential for optimum professional growth. The curriculum offered by the School of Electrical Engineering meets these objectives. During the early stages of training, emphasis is on the needed mathematics and physics since these disciplines are an integral part of the instruction in electrical engineering.

Two programs of study, the regular electrical engineering program and the honors program, are available to electrical engineering students. The regular program consists of a number of core courses, including circuits, electronics, systems, electromagentic fields, electromechanical energy conversion, and materials, which provide the basis for specialized courses in the fields of interest to the individual student. A separate laboratory sequence serves to emphasize the practical applications of the theory and to provide familiarity with modern experimental techniques. During the senior year, the curriculum permits 19 hours of electives to enable the individual student to study in those areas in which he is most interested.

Talented and highly motivated students, who demonstrate during their first two years that they are capable of profiting from either more freedom in their choice of courses or a more specialized program of study, may participate in the honors program. This program has the inherent flexibility to allow either independent or restricted study, yet satisfy the requirements of either a terminal or advanced study objective.

Graduate programs leading to the degree of Master of Science in Electrical Engineering and Doctor of Philosophy with a major in electrical engineering are offered for outstanding students of both the regular program and the honors program. Many teaching and research assistantships, as well as free-grant fellowships are available to qualified graduate students to help them gain advanced education. Information about the M.S.E.E. and Ph.D. programs may be found in the *Graduate School Bulletin*.

Electrical engineering graduates are sought by all major industries. Electrical engineers hold many unusual and challenging positions in the aerospace, chemical, nuclear, automotive, metallurgical, textile, railway, petroleum, and other basically nonelectrical industries, as well as in electronics, communications, power, and other electrical industries. Their activities span industrial activity, research, development, design, production, marketing, operation, field test, and maintenance of many types of equipment for government, industry, farm, and home.

The curriculum of electrical engineering is fully accredited by the Engineers' Council for Professional Development.

Students who expect to transfer to the electrical engineering curriculum after some previous collegiate study should note that there is a sequence of five required courses in electrical engineering. Since five terms of attendance are required to complete these, transfer at the beginning of a summer session is recommended.

Cooperative Program with Industry

A cooperative education program is offered which enables a limited number of qualified students to obtain paid industrial experience related to engineering with selected industries while completing the requirements for an engineering degree. To qualify for the program, students will be required to have a scholastic index which places them in the upper half of the freshman engineering class at the end of their first year.

Students deciding to participate in the program should file an application with the cooperative education program coordinator by February 15 preceding the end of their freshman year. On the basis of the first semester's scholastic index, qualified students will be tentatively selected for the program. Upon completion of the year's work with the required index and upon acceptance as a cooperative program employee by a University-approved employer, students may formally enter the program.

Upon completion of the program, the students receive the regular engineering degree and a certificate indicating their completion of the cooperative education program with industry.

Honors Program

The School of Electrical Engineering provides a series of honors courses in the sophomore year for those students whose performance in the freshman honors program has been outstanding.

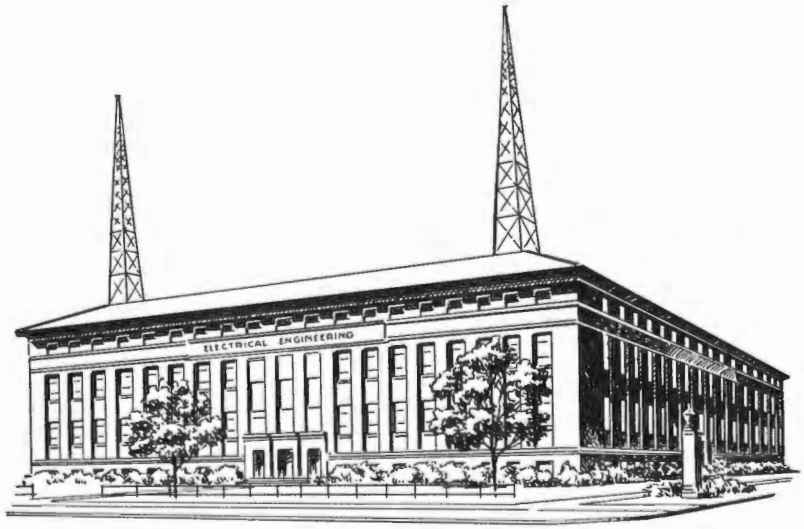
Outstanding students from both the honors and regular sophomore curricula are invited to participate in the electrical engineering honors program beginning with the first semester of their junior year. This program is offered to highly motivated students in the School of Electrical Engineering who wish to pursue a course of study specifically tailored to their individual needs and interests; the student progresses academically at a pace commensurate with his individual ability and ambition. This program permits (but does not require) the student to follow an integrated plan of study which leads to the simultaneous awarding of the B.S.E.E. and M.S.E.E. degrees.

Students who will be designated at graduation as graduating "With Honors" from the School of Electrical Engineering will be chosen from the participants in this program.

Students interested in this program should contact the head of the School of Electrical Engineering or his executive assistant for more details and information.

Library

The Electrical Engineering Library, located on the main floor of the Electrical Engineering Building, offers reference service to faculty and students



Electrical Engineering Building

approximately 78 hours per week. Its collection contains more than 9,200 volumes in the field of electrical engineering and related areas such as physics and mathematics. In addition, the library has more than 9,500 technical reports and subscriptions to more than 350 journals. The library staff includes a professional librarian, a junior professional assistant and one clerical assistant. A study room adjacent to the library is open 24 hours a day for students who wish to study but do not need to use library materials.

Laboratories

The School of Electrical Engineering maintains an integrated complex of well-equipped laboratories for undergraduate and graduate instruction. These laboratories are used for the five required undergraduate laboratory courses and for the elective senior- and graduate-laboratory courses.

The laboratories are located as a unit and are serviced by a common instrument storage and maintenance facility. Power and signal magnitude distribution systems are inter-connected and enable the performance of large-scale experiments in a wide variety of areas.

Equipment is available for elementary and advanced experiments in circuits, electronics, electromagnetic fields, signal transmission, energy conversion analog and digital computation, and electrical engineering materials. In addition general facilities are available for individual project work for qualified students.

A complete equipment calibration service is used to insure that all instruments are kept in their original operating condition. A continuing program of equipment purchase and replacement insures that the undergraduate laboratories are furnished with the latest models and the most versatile instruments available.

Other laboratories which are used for undergraduate and graduate elective courses and for undergraduate and graduate research include:

The **Servomechanisms Laboratory** is designed and equipped to complement the basic undergraduate and graduate courses in the analysis and design of servomechanisms. The experiments performed in the laboratory examine many of the familiar transducers, with particular attention to their characteristics which are important when the transducers are incorporated into a complete servomechanism. Simple positioning servomechanisms are assembled, tested, and modified consistent with the theoretical considerations in the course work.

Complete **Computer Facilities** are available in the School of Electrical Engineering for instruction at the undergraduate level, in addition to facilities for research and graduate study.

Five SIMULATOR 240 electronic analog computers including nonlinear and logic capability are used for routine laboratory instruction in the various courses beginning in the sophomore year. An Automatic Electronic Digital Computer (General Precision RPC-400) and several remote time shared terminals connected to the Computer Science Center's CDC-6500 and IBM-7094 computation facility are reserved for both undergraduate and graduate instruction and are also used in many of the courses.

A PDP-9 Digital Computer with a Digital Equipment Corporation 339 Graphic Display System is available as a teaching aid for use by the student in several undergraduate courses.

The **Purdue Hybrid Computation Laboratory** maintains a research computing facility including a high-speed digital computer (CDC-1700), and two large high-speed analog computers (EAI-680) with parallel digital logic and interface equipment for digital-analog simulation of highly sophisticated systems.

The **Communication Laboratories** consist of one large, well-equipped laboratory, several smaller laboratories, and a small shop, which provide excellent facilities for senior and graduate level instruction and for graduate research and development in the broad field of communication engineering. Available apparatus permits demonstration, measurements, and study of the performance and reception of information. The frequency range covered extends from audio and very low frequencies well into the super-high-frequency region.

The **Instrumentation Laboratories** perform two distinct functions: one, instruction in and application of the basic principles of the measurement of electrical and nonelectrical quantities as a basis for more advanced work in the field of instrumentation and control; two, standardization.

The laboratories that perform the first function are used primarily by undergraduate students.

The laboratory that performs the second function maintains primary standards and repairs and calibrates all kinds of electrical measuring instruments and devices not only for the other laboratories in the school but for the University as a whole.

The Control and Information Systems Laboratory was formed in 1961 in order to facilitate the increasing research activities in the general area of automatic control and information systems.

Naturally, the areas of emphasis in research continuously change, but within the last two-year period and at the present, major efforts are being made in such areas as (1) adaptive and learning systems, (2) estimation and identification, (3) nonlinear sampled data systems, (4) computer control, (5) hybrid computation, (6) artificial intelligence, (7) optimal and stochastic optimal control, (8) pattern recognition, (9) stability and response of nonautonomous nonlinear systems, and (10) theory of automata. The interests of students and staff control the initiation of new areas.

The **Materials Research Laboratories** provide facilities for theoretical and experimental studies of semiconducting, superconducting, dielectric, magnetic, and other materials. These facilities permit complete fabrication and analysis of devices and systems. Equipment available includes: electromagnets for medium- and high-field material studies; vacuum system for film deposition, environmental control, and device fabrication; environmental temperature apparatus for cryogenic work; ovens and furnaces necessary for diffusion, alloying, and annealing in controlled atmosphere; and a complete chemical laboratory for supporting chemical preparation of materials.

In addition there is a wide variety of electronic and optical apparatus used in analysis work. This includes programmed current-pulse generators, high-speed oscillographic equipment, a 3,000 Hz traveling-wave oscilloscope, microscopes for metallurgical analysis, and other related equipment.

The **Monolithic Integrated Circuits Laboratory** has available the facilities necessary for the design, fabrication, and evaluation of monolithic integrated circuits. The laboratory contains diffusion furnaces and the equipment necessary for photolithographic, photographic, vacuum evaporation, and bonding work. Laboratory training is provided in the techniques of solid-state device fabrication together with the capability required for solid-state device research.

The **Electroceramics Laboratory** provides facilities for experimental studies of the electrical behavior of nonmetallic inorganic materials. These facilities permit fabrication of materials by all conventional ceramic techniques; high precision measurements of electrical conductivity and dielectric loss over a wide frequency range, thermoelectric power, transference numbers, electric polarization, mass diffusivities, point defect concentrations, and microstructure; and control of the ambient during sample preparation and measurements including temperatures from 25° to 2300°C and oxygen partial pressures from 1 to 10^{-80} atmospheres. Basic studies as well as applied research on devices are conducted in the area of electroceramics.

In the **Speech Communications Laboratory**, problems concerning the analysis, synthesis, and transmission of speech are studied experimentally. Equipment is available for the examination and detailed measurement of speech spectra. An analog-to-digital multiplex conversion system connects with the adjacent Electrical Engineering Hybrid Computer Facility so that speech data may be processed digitally in real time or recorded on digital magnetic tape for subsequent use at the Central Computer Facility. A terminal-analog speech synthesizer in the lab is controlled by the multi-channel output of the Hybrid System.

Current work ranges from psychophysical testing of the perception of time-distorted speech to the programming of phoneme recognition procedures on the large-scale digital computer.

Neurobiology of Vision. Experimental and theoretical work on the processing of light information by the vertebrate retina is being done in cooperation with the Department of Biological Sciences. Transfer properties of slow potentials and patterns of firing of retinal ganglion cells are observed by means of microelectrode recordings in order to formulate linear and nonlinear models of the process by which stimulus parameters are encoded in neural activity.

Applied Speech Research Group at McClure Park. A group of scientists and engineers are applying programmed acoustical feature extractive and pattern recognition methods to the problem of identifying linguistic entities such as phonemes and words in connected speech. Vocal tract resonant frequencies, frequency of vocal cord vibration, and various statistical parameters, which reflex the linguistic information in an utterance as well as individual talker differences, are used as data available to classification routines.

The **Electronic Systems Research Laboratory** was formed in 1964 with the purpose of providing an organizational structure for coordinating and managing research progress in the areas and related systems of communication sciences, quantum electronics and millimeter waves, and nonlinear circuits. It currently encompasses the activities of the following laboratories:

A **Communication Science Research Laboratory** for graduate research is equipped with receivers, transmitters, various noise generators, and recording and correlating equipment for performing measurements on communication links. A 250-mile tropospheric scatter communication channel is also available for experimental work. Digital computer facilities provide opportunities to add adaptive and learning features to these systems.

The **Electromagnetic Wave Research Laboratory** offers opportunities for advanced research in electromagnetic wave theory and devices. Facilities are available for work in the interaction of fields with matter, low noise amplifiers, scattering, and optics. In addition to the usual microwave equipment which is available in this laboratory, arrangements may be made to share equipment with other Purdue laboratories so that many combinations of interdisciplinary work are possible.

The **Plasma Research Laboratory** is equipped to carry out a variety of experimental studies involving ionized gases. Plasma wave interaction phenomena, high voltage breakdown mechanisms, pulsed plasma acceleration processes, and plasma energy conversion techniques are examples of the types of programs under investigation. The objectives of these programs are both to advance the understanding of the plasma environment and to develop useful plasma applications. To obtain maximum progress in each objective, theoretical guidance and interpretation of experimental measurement is emphasized.

The **Quantum Electronics Laboratory** offers a program of research to investigate lasers and laser applications. This includes laser material research, nonlinear optics, laser modulation and deflection, etc. Special equipment includes ruby lasers, gas lasers, optical calorimeters and other optical instruments.

The **Laboratory for Application of Remote Sensing** is an inter-disciplinary research organization, established to develop systems for the timely automatic identification of vegetation, soils, hydrologic status, and general agricultural environment conditions from field, aircraft, and spacecraft platforms. The laboratory, housed at McClure Research Park includes in its facilities an IBM 360-44 computer, a tape-to-tape analog-to-digital conversation system, photographic processing rooms and equipment, spectroscopic and radiometric instrumentation laboratory, and an instrumented field van for ground truth data acquisition. Remote sensing aircraft flight services are provided by Manned Spacecraft Center, NASA, Houston, and include photographic, optical-mechanical scanner, spectral radiometer, and microwave radiometer sensor data. The program is sponsored jointly by the U. S. Department of Agriculture and the National Aeronautics and Space Administration.

(Total Credits—132 Semester Hours)

FRESHMAN YEAR

(See page 27)

SOPHOMORE YEAR

Third Semester

(3) EE 201 (Introduction to Electrical Engineering)
(1) EE 207 (Electrical Engineering Laboratory I)
(4) MA 261 (Mathematics for Engineering and the Physical Sciences III)
(4) PHYS 261 (Electricity and Optics)
(3) General Education Elective

(15)

Fourth Semester

(3) EE 202 (Linear Electronic Circuits)
(2) EE 208 (Electrical Engineering Laboratory II)
(3) EE 251 (Introduction to Nonlinear Circuits)
(4) MA 262 (Mathematics for Engineering and the Physical Sciences IV)
(3) General Education Elective

(15)

JUNIOR YEAR

Fifth Semester

(4) EE 301 (Signals and Systems)
(3) EE 302 (Probabilistic Methods in Electrical Engineering)
(1) EE 307 (Electrical Engineering Laboratory III)
(3) EE 311 (Electric and Magnetic Fields)
(4) ESC 306 (Basic Mechanics)
(3) General Education Elective

(18)

Sixth Semester

(1) EE 308 (Electrical Engineering Laboratory IV)
(3) EE 321 (Electromagnetic Energy Conversion Principles)
(3) EE 352 (Introduction to System Design)
(4) ME 308 (Thermophysics)
(3) PHYS 342 (Modern Physics)
(1) PHYS 342L (Modern Physics Laboratory)
(3) General Education Elective

(18)

SENIOR YEAR

Seventh Semester

(4) EE 402 (Materials and Circuit Models)
(1) EE 407 (Electrical Engineering Laboratory V)
(3) Elective*
(3) General Education Elective
(6) Electives†

(17)

Eighth Semester

(1) EE 400 (Modern Devices Seminar)
(3) General Education Elective
(13) Electives†‡

(17)

In addition to the restrictions placed on the use of the Pass/Not Pass Option by the University Senate and the engineering faculty, the following additional restriction applies to electrical engineering students: The option shall not be available for required courses (specifically designated by course number) in the Electrical Engineering Undergraduate Curriculum nor for electrical engineering electives to be used for undergraduate credit.

INDUSTRIAL ENGINEERING

The complexity of modern industrial organizations and the emphasis on increased productivity have led to a growing need for industrial engineering analysis and design and an increasing demand for industrial engineering graduates. The program is designed to prepare men and women for careers in all phases of industrial engineering and to enable them to perform other administrative and technical functions which require scientific and engineering backgrounds.

Industrial engineers are used by all types of industries to design, improve, and install systems, procedures, and methods involving the use of men, machines, and materials. For the most part they are concerned with production, although the analytic, fact-finding approach used by these engineers is applicable to almost any business or service enterprise. Among the common functions performed by industrial engineers are the following: the analysis of product design to determine the optimum manufacturing process; the selection of equipment and design of the equipment layout; the design and installation of systems for controlling production, inventory, quality, or costs; job design and methods improve-

* To be selected from: EE 409; INDM 457; 480, 583, 585.

† A minimum of ten hours of electives, including a senior laboratory, must be in electrical engineering. Substitutions may be made only with the approval of the head of the school or his designated representative.

‡ Upon satisfactory completion of four semesters of advanced ROTC or advanced band, six of these credits may be substituted for electives; however, credits of basic ROTC or basic band will not be used to satisfy graduation requirements. No substitution for the general education electives is permitted.

ment, design of materials handling systems, tool selection and design, manpower utilization, and work measurement; the design of job evaluation and wage incentive systems; and operations research. In all of these activities industrial engineers are highly concerned with the human and economic problems. Industrial engineers are frequently employed in the related fields of sales, product development and testing, and other engineering activities.

Two programs of study, the regular industrial engineering curriculum and the honors curriculum, are available to industrial engineering students. The course content in the two programs is identical during the first two years. Each curriculum provides the student with a broad scientific and engineering base, and contains a sequence of courses in mathematics, physics, chemistry, and the engineering sciences. These courses are either accompanied by or followed by industrial engineering courses covering the areas of manufacturing process and facilities design, engineering statistics, engineering cost analysis, work analysis and design, mathematical programming, process control, production control, computer utilization, systems analysis and design, and engineering administration. In the senior year several elective courses enable the student to study in those areas in which he has greatest interest. In addition, 15 to 21 hours of elective courses in the social sciences and humanities are included. The Pass/Not Pass Option may be used for any elective courses. The curriculum in industrial engineering is fully accredited by Engineers' Council for Professional Development.

The honors program is designed for the student of superior ability, who has demonstrated in his freshman and sophomore years a capacity and interest in more rapid and rigorous progress at the undergraduate level. The purpose of the program is to provide an opportunity for the qualified student to enhance his preparation for graduate work or for professional work in industry. The use of accelerated courses during the junior year permits more flexibility than is possible in the regular curriculum. Other features of this program enable the student to strengthen his mathematical base, to have additional electives, and to participate in a directed research or design activity.

The School of Industrial Engineering offers graduate work leading to the degrees of Master of Science, Master of Science in Industrial Engineering, and Doctor of Philosophy. Both undergraduate curricula provide an adequate foundation for graduate study, and students who complete either of the programs with appropriate academic records are encouraged to pursue graduate study.

Cooperative Program with Industry

A five-year cooperative educational program is offered which enables a limited number of qualified students to obtain industrial experience related to engineering with selected companies, while completing the requirements for the undergraduate degree. Such students are selected at the end of the freshman year, and begin the cooperative program in the sophomore year. Alternative periods, including summers, are spent in industry and at the University. In order to qualify for the program, students will be required to have a scholastic index which places them in the upper half of the freshman engineering class at the end of their first year.

Students desiring to participate, should file an application with the cooperative education coordinator for industrial engineering, following completion of the first semester of their freshman year. On the basis of the first semester's scholastic index, qualified students will be tentatively selected for the program. Upon completion of the year's work, with the required index and upon acceptance as a cooperative employee by a University-approved employer, students may formally enter the program. Upon completion of the program, the students receive the regular engineering degree and a certificate indicating their completion of the cooperative education program with industry.

Laboratories

The **Manufacturing Processes Laboratory** covers approximately 16,000 sq ft of floor space and includes over 165 different machine tools representative of most current industrial metal-cutting, forming, and inspection practices. The laboratory permits study of production processes, tooling, and equipment. In addition, service laboratories are available for tool development and research.

A separate **Gauge Laboratory** equipped with U. S. Navy property and housed in well-lighted and air-conditioned quarters includes an 80-in. measuring machine, comparators, toolmaker's microscope, electric gauges, supermicrometer, lead-check equipment, small instruments, and accessories.

The **Methods Engineering Laboratory** provides for supervised problem activity in the areas of work analysis and design, work measurement, and human factors engineering. The laboratory contains an Alden methods system production facility, methods simulation and demonstration units, and complete motion picture equipment. In addition, it contains physiological measuring and recording devices including a force platform, a Collins gasometer, an electrocardiograph, an Offner dynograph recorder, and an analog computer.

The **Instrumentation Laboratory** is equipped for laboratory investigations on the automatic control of manufacturing processes. It contains a Procter and Gamble F.L.I.T. automatic console, analog computers, Offner dynograph recorders, oscilloscopes, and various electronic, hydraulic, and pneumatic demonstration units.

The **Computation Laboratory** contains Monroe hand calculators and an IBM card punch.

The **Facilities Design Laboratory** contains drawing tables and other facilities for design work. Files of industrial equipment catalogues are maintained.

(Credit Hours Required for Graduation—132)

FRESHMAN YEAR

(See page 27)

(Common for all engineering students)

SOPHOMORE YEAR

(4)	MA 261 (Mathematics for Engineering and the Physical Sciences III)	(4)	MA 262 (Mathematics for Engineering and the Physical Sciences IV)
(3)	PHYS 241 (Electricity and Optics)	(3)	ESC 206 (Mechanics II)
(2)	ESC 221 (Basic Mechanics I)	(3)	ESC 223 (Mechanics of Materials)
(2)	IE 231 (Computers and Computer Methods)	(3)	IE 230 (Statistical Control I)
(1)	IE 283 (Industrial Engineering Seminar)	(3)	Elective*
(3)	Elective*		
(15)		(16)	

JUNIOR YEAR

(3)	EE 317 (Electrical Engineering)	(3)	EE 318 (Electrical Engineering)
(3)	ME 307 (Elements of Thermodynamics)	(3)	CHE 337 (Fluid Mechanics and Heat Transfer Operations)
(3)	IE 330 (Statistical Control II)	(3)	IE 331 (Measurements and Automatic Control Systems)
(3)	IE 343 (Engineering Cost Analysis)	(3)	IE 335 (Introduction to Mathematical Programming)
(3)	IE 385 (Manufacturing Process Design)	(3)	IE 386 (Work Analysis)
(3)	Elective*	(3)	Elective*
(18)		(18)	

SENIOR YEAR

(3)	IE 431 (Systems Analysis and Design)	(3)	IE 444 (Engineering Administration)
(3)	IE 470 (Materials Processing)	(3)	IE 484 (Facilities Design)
(3)	IE 483 (Production Control)	(9)	Electives*
(9)	Electives*		
(18)		(15)	

* The 30 credit hours of electives must be chosen in accord with the following:

a. 9 hours of technical electives must be selected from undergraduate or dual level courses in engineering, mathematics, or science.

b. 15 hours must consist of a six-hour sequence from either Group I or II of the General Education Program, and a nine-hour sequence from the remaining group.

c. 6 hours of electives may be chosen from (a) or (b) or, with the approval of the student's academic advisor, from other areas that might enhance his professional career.

HONORS PROGRAM

Sophomore Year

(Common for all industrial engineering students.)

JUNIOR YEAR

(3)	EE 317 (Electrical Engineering)	(3)	EE 318 (Electrical Engineering)
(3)	ME 307 (Elements of Thermodynamics)	(3)	CHE 337 (Fluid Mechanics and Heat Transfer Operations)
(3)	IE 330 (Statistical Control II)	(3)	IE 331 (Measurements and Automatic Control Systems)
(3)	IE 544 (Manufacturing Management)	(3)	IE 335 (Introduction to Mathematical Programming)
(3)	MA Elective	(3)	IE 543 (Manufacturing Analysis)
(3)	Elective*	(3)	Elective*
(18)		(18)	

SENIOR YEAR

(3)	IE 431 (Systems Analysis & Design)	(3)	IE 444 (Engineering Administration)
(3)	IE 499 (Research in Industrial Engineering)	(3)	IE 484 (Facilities Design)
(12)	Electives*	(2)	IE 499 (Research in Industrial Engineering)
		(9)	Electives*
(18)		(17)	

MATERIALS SCIENCE AND METALLURGICAL ENGINEERING

Materials science and metallurgical engineering comprise a wide spectrum of activities directed toward the design, development, and production of metals, alloys, ceramics, semiconductors, and other materials for engineering applications. The development of materials with outstanding combinations of mechanical, chemical, and electrical properties remains a problem of major importance for technological advances on every engineering frontier. The school's educational programs are designed to prepare engineers for positions of major responsibility in research, development, operations, and management in American industry.

* The 33 credit hours of electives must be chosen in accord with the following:

a. 12 hours of technical electives must be selected from undergraduate or dual level courses in engineering, mathematics, or science.

b. 15 hours must consist of a six-hour sequence from either Group I or II of the General Education Program, and a nine-hour sequence from the remaining group.

c. 6 hours of electives may be chosen from (a) or (b) or, with the approval of the student's academic advisor, from other areas that might enhance his professional career.

Many engineers are engaged in research and development aimed at the solution of problems involved in production and design of new refractory alloys and ceramics. Others are involved in specific applications in fabrication or in semiconductors. Still other engineers face the challenging problems of production control in the large scale and high temperature processes common in metal production and refining. In all of these areas, the successful engineer has a basic understanding of the physics and chemistry of materials, combined with the desire and ability to use this background to solve engineering problems.

The School of Materials Science and Metallurgical Engineering offers undergraduate programs for the B.S. in Engineering, and the B.S. in Metallurgical Engineering, as well as graduate programs for the M.S. and Ph.D. degrees. Scholarships, fellowships, and traineeships are available for qualified undergraduate and graduate students.

The undergraduate programs are as follows:

I. Cooperative Program with Industry

II. Honors Program

III. Interdisciplinary Program in Materials Science and Engineering, leading to the B.S.E. degree.

IV. Curriculum in Metallurgical Engineering, leading to the B.S.Met.E. degree

V. Curriculum in Materials Sciences, leading to the B.S.Met.E. degree.

The first two years of each program are devoted principally to basic courses in mathematics, physics, chemistry, and general education. Introductory engineering courses are offered in the second year, and transfer between programs is not difficult. Materials science and metallurgical engineering courses cover the fundamentals of both physical metallurgy and materials processing in an integrated sequence, so that the graduate is broadly prepared to enter any part of the field or to undertake graduate study. The materials and processing design courses in the senior year, offer the opportunity of carrying through an original experimental and theoretical investigation of a creative design problem.

Information about Pass/Not Pass Option for undergraduate courses is available in the Undergraduate Office.

The curriculum leading to the B.S.Met.E. degree is fully accredited by the Engineers' Council for Professional Development.

Laboratories

The laboratories of the School of Materials Science and Metallurgical Engineering are well-equipped for instruction and research in several areas of physical metallurgy, ceramics, and materials processing. Some of the more important items of equipment are the electron probe microanalyzer, electron microscopy facilities, ultra-high vacuum facility, vacuum melting and pouring equipment, and the radioactive tracer facility.

The **Physical Metallurgy Laboratories** provide for experimental work which emphasizes structures of materials, and the relationships between structure and properties. These laboratories are flexibly designed to serve not only for instruction, but also for individual graduate and undergraduate research. Equipment is available for optical and electron microscopy, electron diffraction, electron microprobe analysis, dilatometry, controlled heat treatment, and measurement of physical and mechanical properties.

The **Electroceramics Laboratory,** developed jointly with the School of Electrical Engineering, provides facilities for experimental studies of the electrical behavior of nonmetallic inorganic materials. These facilities permit fabrication of materials by all conventional ceramic techniques; high precision measurements of electrical conductivity and dielectric loss over a wide frequency range, thermoelectric power, transference numbers, electric polarization, mass diffusivities, point defect concentrations, and microstructure; and control of the ambient during sample preparation and measurements including temperatures from 25° to 2300°C and oxygen partial pressures from 1 to 10^{-30} atmospheres. Basic studies as well as applied research on devices are conducted in the area of electroceramics.

The **X-ray Diffraction Laboratories** provide facilities necessary for X-ray fluorescence and for diffraction studies of materials by the usual single crystal and powder methods. The equipment consists of diffraction units with accessory tubes, goniometers, monochromators, electronic scaling circuits, and several cameras.

The **Chemical Metallurgy Laboratories** are equipped primarily with bench scale apparatus for studies of the high temperature unit processes of extracting metals. Three high frequency converters are available for induction furnaces. Specialized research facilities include a high precision Sieverts apparatus for measuring gas solubilities in metals, a radiotracer laboratory, and vacuum melting furnaces.

Several **Materials Research Laboratories** provide space and flexible equipment for undergraduate research projects and graduate thesis investigations.

The **Metal Processing Laboratories,** located in Michael Golden Engineering Laboratories, are large laboratories, well-equipped for both small and medium scale work in casting metals, gas and electric welding, heat treating, and working.

Machine Shop. A complete service shop with a skilled machinist in charge is available for building new equipment and keeping existing equipment in good operating condition.

Student Shop. A shop supervised by a full-time mechanic is available for the student to construct special apparatus when needed in his laboratory work.

Library

A departmental library contains over 6,000 volumes in materials science and metallurgical engineering and related areas of science and engineering. Journals, foreign books, theses, special bibliographies, and services are available for advanced study and research.

Cooperative Program with Industry

A five-year cooperative educational program is offered, which enables a limited number of qualified students to obtain industrial employment related

to engineering with selected industries while completing the requirements for an engineering degree. To qualify for the program, students will be required to have a scholastic index which places them in the upper half of the freshman engineering class at the end of their first year.

Students desiring to participate should contact the cooperative education coordinator in materials science and metallurgical engineering following the first semester of their freshman year. On the basis of the first semester's scholastic index, qualified students will be selected tentatively for the program. Upon completion of the year's work with the required index, and upon acceptance as a cooperative employee by a University-approved employer, students may enter the program formally. Upon completion of the program, students receive their regular engineering degree and a certificate indicating their completion of the cooperative education program with industry.

Honors Program

An honors program is offered for superior students in the School of Materials Science and Metallurgical Engineering who wish to pursue individual programs with more time for self-study in areas or problems of special interest to them and relevant to the science and engineering of materials. Such programs typically might involve substitution for approximately one-fourth of the usual formal requirements in the junior and senior years. The two-year program of honors substitutions is proposed by the student before registration for the junior year and is subject to approval by the school faculty.

The honors studies may comprise a special individual or group investigation under the guidance of a staff member (for example, laboratory and/or library research on a significant scientific or engineering-design problem). Another kind of acceptable program might involve supplementary study and readings in one of the major areas of the curriculum (for example, thermodynamics of solutions, electrical and magnetic properties of materials, metal processing, physical ceramics, etc.). Students expecting eventually to undertake doctoral studies emphasizing solid-state science may well wish to request the curriculum in materials science, which provides for greater depth in solid state physics, introductory quantum mechanics, and associated higher mathematics.

Admission into the honors program is based on a written application submitted by the student and approved by the school faculty. This application should provide a brief statement of the objectives and content of the proposed program, and should be transmitted to the head of the school before the beginning of the second semester of the sophomore year. To enter and remain in the honors program, the student must maintain at least a 4.8 graduation index in his course work, and must show a reasonable rate of progress toward his honors objectives. All honors students may participate in a weekly 1-hour seminar (MSE 497). Successful completion of an honors program will be recognized by the award of an honors certificate at graduation.

Interdisciplinary Program in Materials Science and Metallurgical Engineering

The School of Materials Science and Metallurgical Engineering, has created a unique opportunity for the undergraduate student to design his own program of study in preparation for a professional career in the field of engineering

materials. Students are helped to design interdepartmental programs aimed to meet the challenging needs for new and improved materials in solid state electronics, energy conversion, nuclear reactors, chemical processing plants, and many types of aerospace vehicles.

Each student plans approximately 75 percent of his course work to meet his own personal educational objectives, choosing key courses from several of the Schools of Engineering. In keeping with the interdisciplinary character of the program, the degree of Bachelor of Science in Engineering is awarded to those who successfully complete the requirements described below.

A. The common requirements with other degree granting units of the University are as follows:
   1. Satisfaction of minimum scholastic index requirements as established by the faculty;
   2. Satisfaction of general University requirements for residence, payment of fees, etc.

B. Academic requirements for the Bachelor of Science in Engineering degree are as follows:
   1. Completion of the engineering core requirements;
   2. Completion of the area requirements;
   3. Completion of 124 semester hours of credit.

	Semester Hours of Credit in Approved Courses
C. The engineering core requirements are as follows:	
1. Academic requirements of the freshman engineering program;	32
2. Physics for engineers and scientists;	7
3. Mathematics for engineers and scientists;	10
4. Engineering and supporting sciences as follows:	21
a. Mechanics (statics, dynamics, strength of materials, continuum mechanics);	
b. Thermodynamics;	
c. Transport processes and mechanisms;	
d. Electrical theory (fields, circuits, and electronics);	
e. Numerical techniques (computer programming, numerical analysis);	
f. Statistics and probability;	
g. Physical chemistry;	
h. Modern and solid state physics.	
One three-course sequence of at least 8 semester hours must be selected from one of the above headings.	
5. Social science and humanities (General Education Program of the Schools of Engineering).	18
	88

D. The area requirements are as follows:

1. The identification and clear definition of an objective or set of related objectives principally in the field of materials science and engineering.

2. The formulation of a program of courses which has a minimum of 36* semester hours of credit and which is directed toward the objective(s) defined above. This program must contain courses directly concerned with the science and engineering of materials which total to 18 semester hours of credit, including a senior-level, design-oriented course.

3. The approval of the objective(s) and program by the head of the School of Materials Science and Metallurgical Engineering or his designated representative. This approval is required to attain junior class standing.

4. The successful completion of this program by the student.

The purpose of the area requirements is to provide the student with the opportunity to develop his capabilities in an area in materials science and engineering and to develop supporting or peripheral capabilities. The primary objective must be concerned with the behavior and/or processing of materials. A secondary objective may be in a supporting science or a peripheral professional field (e.g., production control and design, management, prelaw, etc.). The various combinations of primary and secondary objectives may produce significant differences in the programs. For example, a student whose objectives include research and design in electrical properties of materials might develop a strong area of physics to support his materials program; whereas, a student whose objectives include production of electrical materials might develop an area of industrial engineering to support his materials program. The range of choice of objectives of materials programs is illustrated by the following examples: chemical properties of inorganic materials; electronic materials and prelaw; materials fabrication management; materials in nuclear engineering; mechanical properties of materials; metals processing control; physical chemistry of metals; or processing of metallic and ceramic materials.

* Students who satisfactorily complete four semesters of advanced military or advanced band may substitute these for six credits in the area requirements.

Curriculum in Metallurgical Engineering

(Total Credits—129 Semester Hours)

FRESHMAN YEAR

(See page 27)

SOPHOMORE YEAR

Third Semester

(3) MSE 201 (Engineering Problems in Materials Processing and Metallurgical Engineering)
(4) MA 261 (Mathematics for Engineering and the Physical Sciences III)
(5) PHYS 251 (Heat, Electricity, and Optics)
(3) General Education Elective

(15)

Fourth Semester

(3) MSE 202 (Microstructure of Solids)
(4) MA 262 (Mathematics for Engineering and the Physical Sciences IV)
(3) PHYS 342 (Modern Physics)
(3) CHM 373 (Physical Chemistry)
(3) General Education Elective

(16)

JUNIOR YEAR

Fifth Semester

(4) MSE 353 (Introduction to Structure and Diffraction)
(2) ESC 221 (Basic Mechanics I)
(3) CHM 374 (Physical Chemistry)
(2) CHM 374L (Physical Chemistry Laboratory)
(3) Mathematics Elective
(3) General Education Elective

(17)

Sixth Semester

(3) MSE 360 (Metallurgical Thermodynamics)
(3) MSE 365 (Kinetics in Condensed Systems)
(3) ESC 223 (Mechanics of Materials)
(6) General Education Elective
(3) Elective*

(18)

SENIOR YEAR

Seventh Semester

(1) MSE 430 (Materials and Processing Design I)
(4) MSE 448 (Physical Metallurgy)
(4) MSE 470 (Chemical Metallurgy)
(3) CHE 337M (Transfer Operations)
(3) Elective*

(15)

Eighth Semester

(4) MSE 431 (Materials and Processing Design II) or
MSE 497 (Selected Topics in Materials Science and Metallurgical Engineering)
(9) Elective*
(3) General Education Elective

(16)

* Electives must be selected with the student's faculty adviser. Students who satisfactorily complete four semesters of advanced military or advanced band may substitute these for six hours of electives.

Curriculum in Materials Sciences

(Total Credits—127 Semester Hours)

FRESHMAN YEAR

(See page 27)

SOPHOMORE YEAR

Third Semester

(3) CHM 373 (Physical Chemistry)
(4) MA 261 (Mathematics for Engineering and the Physical Sciences III)
(5) PHYS 271 (Electricity and Magnetism)
(1) PHYS 271L (Electricity and Magnetism Laboratory)
(3) General Education Elective

(16)

Fourth Semester

(3) CHM 374 (Physical Chemistry)
(2) CHM 374L (Physical Chemistry Laboratory)
(4) MA 262 (Mathematics for Engineering and the Physical Sciences IV)
(3) PHYS 342 (Modern Physics)
(3) General Education Elective

(15)

JUNIOR YEAR

Fifth Semester

(4) MSE 353 (Introduction to Structure and Diffraction)
(5) PHYS 410 (Introduction to Physical Mechanics)
(4) MA 410 (Elements of Advanced Calculus)
(3) General Education Elective

(16)

Sixth Semester

(4) PHYS 430 (Electricity and Magnetism)
(3) MSE 360 (Metallurgical Thermodynamics)
(5) PHYS 417 (Introduction to Statistical Physics)
(4) MA 425 (Elements of Complex Analysis)

(16)

SENIOR YEAR

Seventh Semester

(1) MSE 430 (Materials and Processing Design I)
(4) MSE 448 (Physical Metallurgy)
(5) PHYS 552 (Introduction to Quantum Mechanics and Atomic Physics)
(3) General Education Elective
(3) Elective*

(16)

Eighth Semester

(4) MSE 431 (Materials and Processing Design II) or
MSE 497 (Selected Topics in Materials Science and Metallurgical Engineering)
(3) PHYS 545 (Solid State Physics)
(6) General Education Elective
(3) Elective*

(16)

* Electives must be selected with the student's faculty adviser. Students who satisfactorily complete four semesters of advanced military or advanced band may substitute these for six hours of elective.

MECHANICAL ENGINEERING

Mechanical engineering comprises a wide range of activities covering research, development, design, manufacture, management, and the control of engineering systems, subsystems, and their components. Some of the many systems with which mechanical engineers are concerned include space vehicles, rocket systems, automatic controls, nuclear power, energy converters, and all the various manufacturing complexes necessary to build these systems and their component parts.

The School of Mechanical Engineering offers course work leading to the Bachelor of Science in Mechanical Engineering, the Master of Science in Mechanical Engineering, and the Doctor of Philosophy degrees. Many teaching and research assistantships and free-grant fellowships are available to qualified graduate students.

The faculty of the School of Mechanical Engineering has developed a curriculum to provide the student with a broad base upon which to build an engineering career. The sequence is built upon a foundation of basic sciences including physics, chemistry, and mathematics and the communication arts. To this is added a substructure of engineering science including mechanics, materials, electric circuits and electronics, thermodynamics, fluid mechanics, heat and mass transfer, and automatic controls. Recognizing that the sciences are a means to an end, but not an end in themselves, the faculty has provided design courses throughout the four years to help draw together the sciences, and to provide guidance and experience in the synthesis of components and systems and their application to the needs of society.

A major feature of the curriculum is the flexible 33 credit hour elective program, of which 21 credit hours are in the senior year. This allows for a program with more breadth while also allowing the depth and specialization in an area of the student's technical interests.

Because of the wide scope of activities in which the mechanical engineer is engaged and because of the broad spectrum of student interests, mechanical engineering graduates may choose either to enter the profession immediately after receiving their bachelor's degree or to go directly to graduate school. No matter which the student chooses, the curriculum provides a firm foundation for continuing education, a necessity in today's changing world, whether it be as a member of the engineering professions, through formal graduate work, or through independent study.

A number of part-time jobs are available to the high-ranking undergraduate student in connection with research conducted in the School of Mechanical Engineering. The experience provided by such part-time work supplements the student's course work and is particularly valuable to those who later undertake graduate study.

The curriculum in mechanical engineering is fully accredited by the Engineers' Council for Professional Development.

Honor Student Counseling Program

In the School of Mechanical Engineering honor students qualify for an exceptional plan of study specifically tailored to the individual student. With advance approval, an exceptional program may be arranged permitting more

depth, breadth, speed, self-study, and/or research than is possible within the regular curriculum. This special counseling is generally initiated early in the sophomore year and is continued throughout the student's academic career.

Some of the special opportunities available under the honor student counseling program are:

1. An individual plan of study to fulfill the student's personal interests and goals.
2. Special design and research projects.
3. Special summer employment opportunities.
4. Continuing education orientation.

All students having a graduation index of 5.2 or above are considered eligible for this special counseling program. Other students can apply for this program if they have exceptional academic interests, or if they are significantly ahead of the standard curriculum. The program is optional.

Students interested in this program should contact the head of the School of Mechanical Engineering or his executive assistant who will arrange for special counseling.

Cooperative Program with Industry

A five-year cooperative education program is offered that enables students to obtain engineering experience with selected industries, government installations, and consulting engineering firms. The student acquires the experience while completing the requirements for an engineering degree.

In the cooperative program, the student integrates his university studies with practical engineering experience through well-planned and varied work assignments. The student serves an engineering "internship" while qualifying for a Bachelor of Science in Mechanical Engineering.

Students make application for the program three months before the end of their freshman year; qualified students are tentatively selected for the program at that time. Upon completion of the year's work and acceptance by a University-approved employer, students begin their first work period.

Some of the reasons for pursuing a cooperative program are:

First: the student receives an engineering degree together with three semesters and two summers of industrial experience. This helps to make the student's academic work more meaningful, provides him with the opportunity to work with others in an engineering environment, and helps him to discover the area of mechanical engineering in which he might like to work. These experiences also help the student choose more wisely his engineering elective courses.

Second: the student can earn all or a good part of his financial way through school. This is especially true for a student working within commuting distance of his home.

Third: during their work periods many co-op students take a course at a Purdue University regional campus or another university. If these courses are carefully selected, the credits can be transferred to Purdue University, and they will apply toward the student's degree. The student then has three choices: he can elect additional courses during his last year on campus; he can graduate in less than five years; or, he can begin work on a graduate degree while still a co-op student.

Fourth: a co-op student earns a Bachelor of Science degree and has nearly 100 weeks of practical engineering-related experience upon graduation. Employers start the co-op graduate in more responsible and better paying positions.

The fall and spring work periods are 25 and 20 weeks and the summer, 13 weeks. Arrangements have been made with the military departments so a co-op student may elect an advanced course in ROTC.

Students who complete the program receive a regular degree, Bachelor of Science in Mechanical Engineering, and a certificate indicating their completion of the cooperative education program with industry.

Laboratories

Laboratory facilities in mechanical engineering for undergraduate instruction include: the Measurements Laboratory, Heat and Mass Transfer Laboratory, Automatic Control Laboratory, Fluid Mechanics Laboratory, and Systems Design Laboratory. A number of other laboratories are used for research work and graduate instruction.

The **Measurement Laboratory** is equipped with modern electronic instrumentation for the measurement of static and dynamic forces, pressures, temperatures, strain, and flow. Versatile apparatus also has been constructed primarily for illustration of the basic principles of dynamic measurements in the various fields of mechanical engineering. Small electronic analog computers are available for instruction in their use in engineering calculations.

The **Heat Transfer Laboratory** provides facilities for studying heat transfer, mass transfer and fluid flow phenomena. These facilities include cryogenic and vacuum equipment, radiation detectors and a spectrometer for infrared experiments, and instrumentation appropriate for analog, digital and optical recording of various dynamic and steady state measurements. A complete electrodynamic vibrational system is also available for research associated with flow and transport processes which are exposed to vibratory environments.

The **Heat and Mass Transfer Instructional Laboratory** contains analog equipment, heat exchangers, subsonic and supersonic wind tunnels, schlieren and interferometric devices, and other apparatus and instrumentation for studying heat and mass transfer phenomena.

The **Automatic Control Laboratory** is divided into two sections: an undergraduate laboratory used in conjunction with undergraduate courses in control and dynamics, and a graduate laboratory devoted primarily to research concerned with advanced automatic control systems. The undergraduate laboratory contains a large electro-hydraulic position control, a small electromechanical instrument servomechanism, and ten electronic analog computers with associated readout equipment. The graduate laboratory contains equipment for making frequency and transient response runs, as well as other tests, on control systems and components. Transducers and recording instruments are available for steady state and dynamic measurement of pressure, flow, displacement, strain, and other physical variables. A hydraulic test stand and a pump-motor unit are available for a variety of fluid power applications. The laboratory is housed in an air-conditioned room, so that experiments may be made at controlled ambient conditions. Extensive analog computer facilities are available for study of both linear and nonlinear systems. In addition, a complete hybrid computer facility is available for research and instructional uses.

The **Fluid Mechanics Instructional Laboratory** contains subsonic wind tunnels, smoke tunnels, a water table, a towing tank, flux plotters, viscometers, and other apparatus for studying fluid flow phenomena. New apparatus is being developed continually to provide new laboratory experiments and demonstrations each semester.

Equipment and apparatus for studies of boundary layers, diffuser flows, jets, fluidics, pulsatile flows, turbulence, and acoustics are available in the Fluid Mechanics Research Laboratory. Available equipment includes: hot wire and hot film anemometers, laser velocimeter, spectral analyzers, digital voltmeters, oscilloscopes, acoustic field generators, and other supporting instrumentation.

The **Combustion Laboratory** is equipped with spectrographic apparatus for the visible and infrared spectral regions, a gas chromatograph for gas mixture analysis, and a Bendix Time-of-Flight Mass Spectrometer. Fundamental chemical kinetic phenomena may be studied in a fifteen meter shock tube. Facilities are available for the study of combustion-generated air pollution from diesel and gas turbine engines.

The **Applied Optics Laboratory** provides facilities for both research and instruction. The emphasis is on studies related to engineering applications of optics, particularly in the area of engineering measurements. Equipment available includes a large Mach-Zehnder interferometer, several lasers, various types of electronic instrumentation, and numerous optical components.

The **Thermodynamics Laboratory** is equipped with facilities to determine P-v-T properties of vapors and gases, vapor pressure of liquids; calorimeters for the measurements of specific heats at constant pressure and constant temperature and instrumentation for the measurements of transport and optical properties. All the data are measured absolutely and are, therefore, of high accuracy. The ranges are as wide as feasible for precise measurements, and the values of the properties obtained provide information for theoretical studies and for the derivation of thermal-dynamic functions and/or other properties. The laboratory is equipped with NBS standards for the measurements of temperature and pressure and electrical quantities.

The **Ray W. Herrick Laboratories** is a graduate research facility which operates in the area of industrial research. Much of the research is in the area of climate control. Included in the laboratories are various heat transfer loops, wind tunnels, vacuum systems, controlled temperature rooms, chemistry and biological laboratories, and complete shop facilities. Precision instrumentation for studies in energy and mass transport, stress analysis, vibration, acoustics, fluid flow, and thermodynamic properties is available. There are two chambers 3,500 cu ft each in volume in which all aspects of climate can be controlled over the range 130F to –30F. These chambers are primarily for the study of the effects of climate on life processes. Th Acoustics Laboratory consists of an 8,000 cu ft reverberation chamber and a 5,000 cu ft anechoic chamber and are available for noise control research, principally in mechanical areas.

The research facilities of the **Jet Propulsion Center** comprise the following buildings: Chaffee Hall, the Propulsion Sciences Laboratory, the Solid Propellant Rocket Research Laboratory, the Gas Dynamic Laboratory, and the Combustion Research Laboratory. At the Combustion Research Laboratory studies currently are being conducted on the combustion characteristics of propellants at high combustion pressures, on supersonic combustion, and on air augmented rocket problems. The Laboratories are equipped for the investigation of a wide range of research problems that are pertinent to such types of propulsion systems as chemical rocket engines, air-breathing engines, electrical rocket engines, nuclear rocket engines, and space power plants. In addition to the main laboratories listed above there are several support buildings, including a magazine for storing propellants and explosives and a building for conditioning solid propellants at temperatures ranging from –60F to 160F.

Library

The Mechanical Engineering Library, located in the Mechanical Engineering Building, consists of reference works, periodicals, reports, and texts which are of current interest to the engineering student, undergraduate, and graduate. The collection includes 300 periodical subscriptions and more than 12,000 books readily accessible to the student to meet his needs in the broad field of mechanical engineering.

(Total Credits—133 Semester Hours)

FRESHMAN YEAR

(See page 27)

SOPHOMORE YEAR

Third Semester

(4) MA 261 (Mathematics for Engineering and the Physical Sciences III)
(3) ME 261 (Introduction to Engineering Design)
(3) PHYS 241 (Electricity and Optics)
(2) ESC 221 (Basic Mechanics I)
(3) Elective*

(15)

Fourth Semester

(4) MA 262 (Mathematics for Engineering and the Physical Sciences IV)
(3) ME 200 (Thermodynamics I)
(3) ESC 206 (Basic Mechanics II)
(3) EE 231 (Electrical Engineering)
(3) Elective*

(16)

JUNIOR YEAR

Fifth Semester

(3) ME 302 (Thermodynamics II)
(4) ME 310 (Fluid Mechanics)
(3) ME 340 (Measurements and Computers)
(2) EE 342 (Electrical Engineering)
(3) Math Elective†
(3) Elective*

(18)

Sixth Semester

(4) ME 315 (Heat and Mass Transfer)
(4) ME 370 (Machine Analysis and Design)
(4) EE 353 (Electronics)
(3) ESC 223 (Mechanics of Materials)
(3) Elective*

(18)

SENIOR YEAR

Seventh Semester

(3) ME 463 (Engineering Design I)
(2) ME 465 (Design Project I)
(3) ME 475 (System Analysis and Control)
(9) Elective*

(17)

Eighth Semester

(2) ME 464 (Engineering Design II)
(3) ME 466 (Design Project II)
(12) Elective*

(17)

* The 33 credit hours of electives must be chosen in accordance with the following conditions:

1. Fifteen credit hours of general education electives must be chosen consisting of a six-hour sequence from either Group I or Group II of the General Education Program and a nine-hour sequence from the other group.
2. Six hours must be selected from A&ES 361, IE 470, EE 452, MA 410, MSE 411, PHYS 342.
3. Six hours of technical electives from 400 or 500 level courses in engineering, mathematics, physics, or chemistry.
4. Six hours of the electives may be chosen from 1, 2, or 3 above, or with the approval of the student's faculty adviser, from other areas.

† MA 302, 422, 501, 502, STAT 311 (Credit will not be given for both A&ES 361 and STAT 311), or CS 414; or with the approval of the student's faculty adviser, another course in mathematics, statistics, or computer sciences.

The Pass/Not Pass option (see page 24) may, in mechanical engineering, be applied only to elective courses.

NUCLEAR ENGINEERING

The design and operation of nuclear systems and equipment depend upon a wide spectrum of knowledge from all of the more traditional fields of engineering as well as from nuclear physics and mathematics. Students with majors in any of these fields may, therefore, wish to include in their program some of the specialized course work offered by the Department of Nuclear Engineering.

Interdisciplinary Program in Nuclear Engineering

The department, through the Division of Interdisciplinary Engineering Studies, offers a very flexible undergraduate program for those students planning to make a career in nuclear engineering.

A selection of courses to best meet his own objectives is worked out by each student in consultation with his advisory committee. These objectives generally include:

1. A working knowledge of nuclear engineering.
2. A basic knowledge of a science, technology, or some other branch of engineering related to nuclear engineering.
3. An understanding of the social implications of engineering decisions.

Other Programs

A variety of elective courses are available for students desiring only an introduction to nuclear engineering. Of particular interest is a two-course sequence consisting of NUCL 500 (Nuclear Engineering) and NUCL 504 (Nuclear Engineering Experiments) designed to provide such an introduction to both the theoretical and applied aspects of nuclear engineering.

Areas for graduate research and study include (1) nuclear reactor theory and analysis, including computer use; (2) reactor kinetics, including stability and control of nuclear system; (3) fast reactor analysis; (4) shielding of nuclear systems; (5) liquid metals technology; (6) design of nuclear systems; (7) fuel systems analysis; (8) the characteristics of the PUR-I; (9) radiation effects; and (10) reactor materials.

Facilities

The PUR-I, a swimming pool reactor licensed for operation at 10 kw, is specifically designed for instructional purposes. The reactor, of unique design with a graphite reflector, is used for a variety of thesis research problems in addition to serving students in the instructional laboratories.

A natural uranium graphite moderated subcritical assembly with supporting instrumentation is also used for the study of reactor behavior.

The Nuclear Instrumentation Laboratory is completely equipped with a variety of scalers, counters, and various detectors as well as an assortment of radioactive sources. Also available are a 400 channel analyzer, an X-Y plotter, and other major equipment.

CDC 6500 and IBM 7094 computer systems, as well as a variety of standard tabulating equipment are available through the Purdue Computer Sciences Center. In addition, a small digital computer and an analog computer are lo-

cated in the Nuclear Engineering Laboratories. Students in the Department of Nuclear Engineering also have access to extensive analog computer facilities in other schools of engineering.

The Nuclear Engineering Library contains an excellent collection of books and periodicals in the field.

In addition, many of the extensive facilities of the Argonne National Laboratory are used in connection with the graduate education and research program of the Department of Nuclear Engineering.

Description of Courses

THE COURSES listed on the following pages will, for the most part, be offered during the academic year 1970-71. In many cases the session in which a course will be offered is indicated thus: Sem. 1 and 2. SS. (summer session). In some cases it is impossible to specify in advance whether or not a course will be offered in any given session. Information on this point may sometimes be obtained from the head of the department.

For each course the description should be interpreted as follows: first, the official number of the course; second, its special title; third, the semester(s) in which the course is offered; fourth, the number of hours a week of recitation, laboratory, or practice, and credit hours; and fifth, the class of students for whom the course is required. Under "Engineering Graphics," for example, the following:

> 118. **ENGINEERING GRAPHICS.** Sem. 1 and 2. SS. Class 1, Lab. 6, cr. 3. (1 or 2 ENGR, el.).

indicates that the course Engineering Graphics 118 is titled Engineering Graphics, is offered during the first and second semesters and summer session, meets for one recitation hour and six laboratory hours per week and gives three semester-hours of credit, is required for all first- or -second-semester engineering students, and is an elective for students in other schools. Parenthetical information gives the class semester during which students will take the course, the initials of the schools that require it, and the abbreviations "el." or "op.", indicating that the course is elective or optional for students in the school listed after these abbreviations. The following abbreviations are used for schools and departments when listed parenthetically:

A—Agriculture
A&ES—Aeronautics, Astronautics, and Engineering Sciences
AE—Aeronautical Engineering
AGE—Agricultural Engineering
CE—Civil Engineering
CHE—Chemical Engineering
EE—Electrical Engineering
ENGR—Engineering
H—Humanities, Social Science, and Education
IE—Industrial Engineering
IED—Industrial Education
ME—Mechanical Engineering
MSE—Materials Science and Metallurgical Engineering
S—Science

The numbering system for courses reflects the level of instruction. The course number in this system indicates the following:

1 through 49—Precollege and deficiency courses

100 through 299—Lower-division courses normally scheduled for freshmen and sophomores

300 through 499—Upper-division courses formally scheduled for juniors and seniors

500 through 599—Dual-level courses that may be scheduled by juniors and seniors, and by graduate students for graduate credits

600 through 699—Graduate-level courses restricted to graduate students.

Description of courses in the 600 series will be found in the *Graduate School Bulletin.*

FRESHMAN ENGINEERING

C. S. Gerde, Head of the Department

R. W. McDowell, Executive Assistant to Head and Director of Academic Counseling

Professors: C. S. Gerde, S.M.; W. K. LeBold, Ph.D.; F. Sandgren, M.S.B.A.
Professor Emeritus: W. W. Briggs, M.S.
Associate Professors: T. A. Boyle, Ph.D.; R. W. McDowell, M.S.I.E.; C. P. Smith, M.S.I.E.
Assistant Professor: J. Bruyn, M.S.E. (Indianapolis Campus).

UNDERGRADUATE LEVEL

Lower-Division Courses

100. FRESHMAN ENGINEERING LECTURES. Sem. 1 and 2. Class 1, cr. 1. (1 ENGR).

An introduction to the engineering profession. Professor McDowell and engineering staff.

110. INTRODUCTION TO DIGITAL COMPUTERS. Sem. 1. Class 2, Lab. 3, cr. 3. (1 ENGR).

An introduction to numerical analysis and digital computers.

111. INTRODUCTION TO NUCLEAR ENGINEERING. Sem. 1. Class 3, cr. 3. (1 ENGR).

An introduction to nuclear energy, nuclear reactor principles, and nuclear power plants.

178. FRESHMAN ENGINEERING LECTURES. Sem. 1 and 2. Class 1, cr. 0. (1 ENGR).

An introduction to the engineering profession. Professor McDowell and engineering staff.

179. FRESHMAN ENGINEERING LECTURES. Sem. 1 and 2. Class 1, cr. 1. (2 ENGR).

An introduction to the engineering profession. Professor McDowell and engineering staff.

190. ELEMENTARY ENGINEERING DESIGN. Sem. 1 and 2. Class 2, Lab. 3, cr. 3. (1 or 2 ENGR).

An introduction to engineering design.

AERONAUTICS, ASTRONAUTICS, AND ENGINEERING SCIENCES

Hsu Lo, Head of the School
J. L. Bogdanoff, Associate Head
T. J. Herrick, Executive Assistant to the Head

Professors: J. L. Bogdanoff, Ph.D.; S. J. Citron, Ph.D.; P. B. Feuer, Ph.D.; J. Genin, Ph.D.; R. Goulard, Ph.D.; W. A. Gustafson, Ph.D.; G. Lianis, Ph.D.; J. Liston, M.E.; Hsu Lo, Ph.D.; P. S. Lykoudis, Ph.D.; S. S. Shu, Ph.D.; M. M. Stanisic, Ph.D.; P. E. Stanley, Ph.D.; E. O. Stitz, M.S.E.
Professors Emeriti: E. F. Bruhn, C.E.; S. D. Chambers, C.E.; C. S. Cutshall, M.S.Ch.E.; N. Little, A.B.
Associate Professors: D. W. Alspaugh, Ph.D.; R. L. Anderson, M.S.E.; L. T. Cargnino, M.S.Ed.; W. M. Gersch*, D.Eng.Sc.; M. Goulard, Ph.D.; J. O. Hancock, Ph.D.; T. J. Herrick, M.S.; C. P. Kentzer, Ph.D.; S. L. Koh, Ph.D.; F. J. Marshall, Sc. Engr.Dr.; A. K. Naghdi, Ph.D. (Indianapolis Campus); G. M. Palmer, Jr., Ae.E.; J. F. Radavich, Ph.D.; R. L. Swaim, Ph.D.; A. L. Sweet, Ph.D.
Assistant Professors: R. F. Curtain, Ph.D.; R. A. Curtis, Ph.D.; J. H. Ginsberg, Ph.D.; D. W. Malone, Ph.D.; A. A. Ranger, Ph.D.; A. J. Schiff, Ph.D.; C-T. Sun, Ph.D.; E. C. Ting, Ph.D.; H. T. Y. Yang, Ph.D.
Instructor: N. H. Shen, M.S.

Engineering Sciences

UNDERGRADUATE LEVEL
Lower-Division Courses

205. **BASIC MECHANICS I.** SS only. Class 3, cr. 3. Prerequisite: PHYS 152. Prerequisite or corequisite: MA 261.

Fundamental concepts, force systems, graphical representation of force systems, equilibrium, distributed forces, hydrostatics, virtual work, static stability, friction. First and second moments of areas, volumes, and masses, center of gravity. Application to structural and machine elements, such as bars, beams, trusses, cables, and friction devices.

206. **BASIC MECHANICS II.** Sem. 1 and 2 and SS. Class 3, cr. 3. (4 IE, 4 ME, 4 CE, 4 AGE). Prerequisites: ESC 205 or ESC 221 and MA 261.

Fundamental concepts, kinematics, translation, and rotation. Kinetics, impulse, momentum, work, energy. Rectilinear and curvilinear translation of point masses. Plane motion of rigid bodies and vibration. Application to projectiles, gyroscopes, machine elements, and other engineering systems.

221. **BASIC MECHANICS I.** Sem. 1 and 2. Class 3†, cr. 2. (3 AGE, 3 CE, 3 IE, 3 ME, 5 MSE). Prerequisite: PHYS 152; prerequisite or corequisite: MA 261 or equivalent.

Review of vector algebra; resultants and equilibrium of force systems; applications involving structures, machine elements, hydrostatics, friction, etc.; virtual work, potential energy and static stability; first and second moments of areas, volumes and masses.

223. **MECHANICS OF MATERIALS.** Sem. 1 and 2 and SS. Class 3, cr. 3. (5 AGE, 4 CE, 5 IE, 6 ME, 6 MSE). Prerequisite: ESC 221 or equivalent.

Analysis of stress and strain; equations of equilibrium and compatibility; stress-strain laws; extension, torsion, and bending of bars; membrane theory of pressure vessels; elastic stability; selected topics.

UNDERGRADUATE LEVEL
Upper-Division Courses

306. **BASIC MECHANICS.** Sem. 1 and 2. Class 4, cr. 4. (5 EE). Prerequisites: PHYS 152 and MA 262.

Review of fundamental concepts of statics; kinematics; Newton's laws; energy principles; mechanics of systems of particles; rigid body motion. Applications to problems in current electrical engineering practice.

499. **RESEARCH IN ENGINEERING SCIENCES.**

* On leave 1970-71.

† Of the three classes per week, attendance will be required at two. The third will be a scheduled help session.

Aeronautics, Astronautics, and Engineering Sciences

207. **BASIC MECHANICS I.** Sem. 1 and 2. Class 3, cr. 3. (3 A&ES). Prerequisite: PHYS 152. Prerequisite or corequisite: MA 261.

Review of vector algebra and equilibrium. Hydrostatics, virtual work, static stability, friction. First and second moments of areas, volumes, and masses, center of gravity. Application to structural and machine elements in field of aeronautics and astronautics.

208. **BASIC MECHANICS II.** Sem. 1 and 2. Class 3, cr. 3. (4 A&ES). Prerequisites: MA 261 and A&ES 207 or ESC 221.

Fundamental concepts, kinematics, translation and rotation. Kinematics impulse, momentum, work, energy. Rectilinear and curvilinear translation of point masses. Plane motion of rigid bodies and vibration. Application to gyroscopes and other elements in field of aeronautics and astronautics.

232. **INTRODUCTION TO MECHANICS OF SOLIDS.** Sem. 1 and 2. Class 3, cr. 3. (4 A&ES). Prerequisite: A&ES 207 or 221; prerequisite or corequisite: A&ES 208 or equivalent.

Deformation, strain, stress, equations of equilibrium. Elastic stress-strain relation. Theory of tension, bending, torsion. Plastic deformation, yield criterion. Stress-strain relation of plasticity. Application to bending and torsion. Elements of limit analysis, viscoelastic bodies, simple models, nonlinear creep.

241. **INDUSTRIAL PRACTICE I** .Sem. 1 and 2 and SS. cr. 0. For cooperative program students only.

Practice in industry and comprehensive written reports of this practice.

242. **INDUSTRIAL PRACTICE II.** Sem. 1 and 2 and SS. cr. 0. For cooperative program students only. Prerequisite: A&ES 241.

Practice in industry and comprehensive written reports of this practice.

290. **INTRODUCTION TO ENGINEERING SCIENCES.** Sem. 1. Class 1, cr. 1. (3 A&ES).

Lectures and laboratory demonstrations designed to acquaint students with the field of engineering sciences and with current research work being done.

UNDERGRADUATE LEVEL
Upper-Division Courses

307. **ADVANCED DYNAMICS.** Class 3, cr. 3. (6 A&ES). Prerequisites: A&ES 208 and MA 422. Credit will not be granted for both A&ES 307 and A&ES 507.

Kinematics, fundamental laws of mechanics, constraints and generalized coordinates. Lagrange equations, virtual work. Applications to particle dynamics, rigid body motion, theory of small oscillations, and stability of motion.

309. **STATISTICAL MECHANICS.** Class 3, cr. 3. (6 A&ES). Prerequisite: A&ES 361.

A simple kinetic theory of gases; equilibrium properties of a monatomic ideal gas; the concept of mean free path; transport coefficients; fluctuations. Statistical mechanics of weakly interacting particles; gases; simple dielectrics; paramagnetism; the Einstein solid. An introduction to ensemble theory; stochastic phenomena; cooperative phenomena.

333. **FLUID MECHANICS.** Sem. 1 and 2. Class 3, cr. 3. (6 A&ES).

Review of thermostatics and thermodynamics. The earth's atmosphere. Transport properties for mass, momentum and energy. Conservation equations for mass, momentum and energy. Nondimensional analysis. Flow problems with friction forces negligible. Flow problems with friction. Discussion and simple examples of compressibility, turbulence, and rarefied gases.

334. **APPLIED AERODYNAMICS AND PERFORMANCE.** Sem. 1 and 2. Class 3, cr. 3. Prerequisite or corequisite: A&ES 333.

General conservation principles in fluid mechanics. Bernoulli's equation and vectoral impulse function. Isentropic expansion and shocks. Elements of propulsion, efficiencies, and performance of power plants. Lift, drag and moments of airfoils, wings, and aircraft. Optimization of range and flight time. Elements of stability.

340. DYNAMICS AND VIBRATIONS. Sem. 1 and 2. Class 3, cr. 3. (6 A&ES). Prerequisite: A&ES 208.

Review in depth of kinematics and kinetics of particles and rigid bodies. Lagrange's equations of motion. Gyroscopic motion. Small vibrations of conservative and nonconservative systems.

341. INDUSTRIAL PRACTICE III. Sem. 1 and 2 and SS. cr. 0. For cooperative program students only. Prerequisite: A&ES 242.

Practice in industry and comprehensive written reports of this practice.

342. INDUSTRIAL PRACTICE IV. Sem. 1 and 2 and SS. cr. 0. For cooperative program students only. Prerequisite: A&ES 341.

Practice in industry and comprehensive written reports of this practice.

351. DIGITAL COMPUTERS. (For A&ES students only.) Sem. 1 and 2. Class 1, Lab. 2, cr. 2. (4 A&ES). Prerequisite: MA 261 or consent of instructor.

An introduction to numerical analysis applicable to digital computation and to programming and operations of digital computers.

352. STRUCTURAL ANALYSIS I. Sem. 1 and 2. Class 3, cr. 3. (6 A&ES). Prerequisite: A&ES 232.

Fundamental equations of elasticity, stress functions, introduction to elastic energy principles. Two dimensional problems, stresses and deformations in simple beams, analysis of cylinders, curved bars, and stress concentrations due to holes. Beam instability and beam columns. Redundant truss analysis, energy methods. Theory of torsion, membrane analogy, thermal stress.

361. INTRODUCTION TO RANDOM VARIABLES IN ENGINEERING. Sem. 1 and 2. Class 3, cr. 3. Prerequisite: MA 262.

Events, sample space, probability, conditional probability, independence, random variables. Probability mass functions, density functions, and cumulative distribution functions. Derived probability density functions. Expectation and generating functions. Bernoulli, Poisson and normal processes. Applications to engineering problems. Some fundamental limit theorems.

372. PROPULSION I. Sem. 1 and 2. Class 3, cr. 3. (6 A&ES).

Principles of jet propulsion (air breathing and rocket). Basic types and cycle analysis in dimensional analysis and matching of components. Engine performance, control and installation, solid and liquid propellant, atomic power.

381. MODELING TECHNIQUES FOR COMPLEX SYSTEMS I. Sem. 2. Class 3, cr. 3. (6 A&ES). Prerequisite: A&ES 351 or equivalent.

Parametric analysis and models. Deterministic, statistical and human factors. Desirable model features. Systems and sub-systems. The modeling process in design, research and identification. Analysis vs. synthesis. The process of iteration. Psychology of creativity: imagination vs. rigor, team work, and planning vs. testing.

An introduction to the use of computers in the modeling of systems. Capabilities and limitation of computers. Computercentric design. Computer hardware and software. Survey of advanced coding techniques.

Introduction to the optimization of discrete systems. Direct and indirect methods. Linear programming theory. The Simplex algorithm. Dynamical programming. Application to large scale systems.

400. MODELING TECHNIQUES FOR COMPLEX SYSTEMS II. Sem. 1. Class 3, cr. 3. (7 A&ES). Prerequisites: A&ES 381 and A&ES 361.

Modeling of systems with random elements. Examples from structural and dynamical application. Discrete systems. Poisson processes, Markov chains, queues, generation of random numbers, simulation, Monte Carlo techniques.

Decision theory. Elements of game theory. Statistical decision theory. Estimation.

The validation of mathematical models will be considered with engineering examples taken from various fields which may contain economic, social or political elements.

402. AEROSPACE ENGINEERING LABORATORY. Class 1, Lab. 3, cr. 3. Prerequisites: A&ES 372, 416, and 453.

The theory of and experimentation with selected aerospace diagnostic techniques.

416. AERODYNAMICS II. Sem. 1 and 2. Class 3, cr. 3. (7 A&ES).

Thermodynamic properties of high temperature gases, one-dimensional gas dynamics, isentropic flow, normal shocks, nozzle and duct flows. Small perturbation theory, high subsonic and supersonic linearized flows. Oblique and detached shocks. The theory of characteristics. Introduction to hypersonic flow. Axially symmetric models and wing configurations.

421. STABILITY AND CONTROL. Sem. 2. Class 3, cr. 3. Prerequisite: A&ES 333 and 334 or equivalent.

Stability derivatives of wings and bodies; dynamic stability; control; modern airplane requirements; operational methods.

431. AEROMECHANICS I. Sem. 1 and 2. Class 3, cr. 3. (7 A&ES).

Aerodynamic loads on a flexible surface, divergence, control effectiveness, and reversal, introduction to flutter theory.

442. INDUSTRIAL PRACTICE V. Sem. 1 and 2 and SS. cr. 0. For cooperative program students only. Prerequisite: A&ES 342.

Practice in industry and comprehensive written reports of this practice.

451. DESIGN I. Sem. 1 and 2. Class 2, Lab. 3, cr. 3. (7 A&ES). Prerequisites: A&ES 334, 351, 352, and 372.

Lectures on the philosophy of design. Laboratory work on the synthesis of preliminary design of one of the following: flight vehicle (airplane, missile, or space vehicle), creative product, or experimental research study.

452. DESIGN II. Sem. 1 and 2. Class 2, Lab. 3, cr. 3. (8 A&ES). Prerequisite: A&ES 451.

Continuation of A&ES 451, with the laboratory a continuation of projects started in Design I. Work is to emphasize analysis and development in order to bring projects to an acceptable level of completion.

453. STRUCTURAL ANALYSIS II. Sem. 1 and 2. Class 3, cr. 3. (7 A&ES). Prerequisite: A&ES 352.

Review of formulation of isothermal elastic boundary value problem. Thin wall structures. Torsion of multicell, open and closed tubes, torsion buckling. Bending and instability of thin plates. Energy theorems. Formulation of variational principle of minimum potential energy and complementary strain energy. Highly redundant structures. Elements of matrix analysis.

461. CONTINUUM MECHANICS I. Sem. 1. Class 3, cr. 3. (7 A&ES). Prerequisite: A&ES 232.

Basic principles of continuum mechanics, concepts of deformation, motion, stress, conservation of mass, balance of momenta, continuum thermodynamics, and constitutive equations. Illustrative applications taken from elasticity and fluid flow.

462. CONTINUUM MECHANICS II. Sem. 2. Class 3, cr. 3. (8 A&ES). Prerequisite: A&ES 461.

Application of the theory developed in A&ES 461 to some problems in plasticity, wave motion, fluid motion, and basic equations of and their applications to viscoelastic materials and thermal problems.

463. SYSTEMS ANALYSIS. Class 3, cr. 3. (7 A&ES). Prerequisite: MA 525 or equivalent. Credit will not be granted for both A&ES 463 and A&ES 464.

Analysis of systems for applications to dynamic response and control. Mechanical and electrical models. Transfer function, weighting function, frequency response. General dynamic response. Stability and performances. Continuous systems, approximation by lumped parameters and finite number of modes. Energy methods. Nonlinear systems. Optimization problems.

464. CONTROL SYSTEMS ANALYSIS. Class 3, cr. 3. (7 A&ES). Prerequisite: MA 302. Credit will not be granted for both A&ES 463 and A&ES 464.

Similar to A&ES 463 with applications to aerospace control systems.

472. AIRCRAFT POWER PLANTS II. Sem. 1. Class 3, cr. 3. Prerequisite: A&ES 372 or equivalent.

Continuation of A&ES 372, with emphasis on the newer types of aircraft and missile propulsion systems.

475. PHYSICAL MEASUREMENTS LABORATORY. Sem. 1. Lab. 3, cr. 1. (7 A&ES).

Experiments using transducers and associated recording instrumentation to measure magnitudes of physical quantities such as force, displacement, acceleration, etc. Consideration of standards and errors.

476. PHYSICAL MEASUREMENTS LABORATORY. Sem. 2. Lab. 3, cr. 1. (8 A&ES). Prerequisite: A&ES 475.

Additional experimental work of same nature as performed in A&ES 475.

483. PROBLEMS IN LARGE SCALE SYSTEMS. I. Sem. 1. Class 3, cr. 3. Prerequisites: A&ES 381 and consent of instructor; corequisite: A&ES 400.

Problems involving large scale systems will be selected from technical and/or socio-economic areas. The main emphasis will be on the modeling and validation of the model selected for prediction purposes. Team effort and interdisciplinary cooperation with other schools will be employed.

484. PROBLEMS IN LARGE SCALE SYSTEMS II. Sem. 2. Class 3, cr. 3. Prerequisite: A&ES 483 and consent of instructor.

A continuation of A&ES 483.

486. AIRCRAFT POWER PLANT EVOLVEMENT. Sem. 2. Class 1, Lab. 6, cr. 3. Prerequisites: A&ES 372 and 453; prerequisite or corequisite: AE 472 or equivalent.

Proposal design for a prime mover to satisfy a selected aircraft or missile need. The creative engineering design and development team methods of industry are utilized.

490. SPECIAL PROBLEMS IN AERONAUTICAL ENGINEERING. Sem. 1 and 2. Hours and credits to be arranged.

DUAL LEVEL—UNDERGRADUATE AND GRADUATE

507. BASIC MECHANICS III. Class 3, cr. 3. Prerequisite: ESC 206 or A&ES 208. Knowledge of differential equations assumed.

Kinematics, fundamental laws of mechanics, constraints and generalized coordinates, Lagrange equations, virtual work. Applications to particle dynamics, rigid body motion, theory of small oscillations, and stability of motion.

508. SYSTEM OPTIMIZATION TECHNIQUES I. Sem. 1, Class 3, cr. 3.

Development of elements of the theory of the minima of functions, the calculus of variations, Pontryagin's maximum principle, steepest descent techniques and dynamic programming. Computational solution of engineering problems. Professors Citron and Alspaugh.

511. INTRODUCTION TO FLUID MECHANICS. Sem. 1, Class 3, cr. 3. Prerequisite: B.S. degree in engineering, physics or mathematics. May be taken concurrently with A&ES 611.

This course is intended for graduate students whose background in fluid mechanics is limited. The basic conservation equations are derived for a compressible viscous fluid, and then specialized for applications in potential flow, viscous flow, and gas dynamics. Staff.

519. INTRODUCTION TO HYPERSONIC AERODYNAMICS. Sem. 2. Class 3, cr. 3. Prerequisite: A&ES 416 or equivalent.

Fundamental physical chemistry of high temperature gases; chemical equilibrium properties, electrical properties, radiation processes and chemical kinetics. Their inclusion in the fluid dynamic study of reacting gases, viscous and inviscid; application to hypersonic, propulsion and space cases. Professors R. Goulard and Gustafson.

523. INTRODUCTION TO ASTROPHYSICS. Sem. 1. Class 3, cr. 3.

Observational data concerning stars and galaxies, luminosity, mass, temperature and spectra of stars, motion and distances, the Hertzsprung-Russel diagram; physical principles and mathematical techniques for the study of stellar interiors and stellar evolution, double and pulsating stars; magnetic fields associated with galaxies, interstellar space and stars, with particu lar emphasis on phenomena associated with the sun and earth, such as solar flares, solar wind, radiation belts, origin of earth's magnetic field, etc. Professors Lykoudis and Lo.

525. PHYSICAL OPTICS AND RADIATION TRANSFER. Sem. 2. Class 3, cr. 3. A knowledge of electromagnetism and modern physics is desirable.

Physical phenomena governing the emission, absorption and scattering of electromagnetic radiation. Classical and quantum elements of line, band and continuum radiation. Nonequilibrium and broadening effects, lasers. Radiation as an energy transfer mechanism, the integro-differential equation problem. Applications to remote sensing and to high temperature energy exchanges. Prof. R. Goulard.

531. FLIGHT MECHANICS. Sem. 1. Class 3, cr. 3. Must be preceded by A&ES 208, or equivalent. Undergraduates must have a 4.8 or higher graduation index or consent of instructor.

Dynamics of variable mass systems. Application to missiles and space-carrier vehicles. Systems considerations. Flight within the atmosphere and in vacuum. Trajectory optimization, numerical techniques, gradient method, application to guidance and control. Professors Lo and Alspaugh.

532. ORBIT MECHANICS. Sem. 1. Class 3, cr. 3. Admission by consent of instructor. Undergraduates must have a 4.8 or higher graduation index or consent of instructor.

Orbit determination of near-earth satellites and various perturbations; liberation and attitude control; orbit transfer and interception; lunar theory and interplanetary orbits; ascending mechanics and reentry. Professors Lo and Alspaugh.

533. THEORY OF MATERIALS I. Class 2, cr. 2. (7 A&ES). Corequisite: CHM 584.

A&ES 533 and 534 are part of an integrated sequence of courses involving chemistry courses, CHM 584 and 585.

The courses begin with a series of several lectures on quantum phenomena, leading up to the formulation of the Schroedinger equation and the interpretation of the wave function. Properties of atoms and molecules are considered, then equilibrium properties of simple materials and then materials of increasing complexity. Finally nonequilibrium and transport properties are discussed.

534. THEORY OF MATERIALS II. Class 2, cr. 2. (8 A&ES). Prerequisite: A&ES 533; corequisite: CHM 585.

Continuation of A&ES 533.

535. THEORY OF MATERIAL PROPERTIES. Class 3, cr. 3. Prerequisites: Must be preceded by A&ES 232 and ME 306 or equivalent.

Kinetic theory. Atomic structure; the periodic table. Microscopic structure of gases, liquids, and solids. Microscopic models to describe such properties as cohesive energy, elasticity, viscosity, slip, thermal conductivity, diffusion, specific heat, and electrical conductivity. Relations between the mechanical, thermal, and electrical properties of materials. Mechanical models of solids, anelasticity, internal friction. Professor Feuer.

546. STRENGTH OF MATERIALS. Sem. 1 or 2. SS. Class 3, cr. 3. Must be preceded by an undergraduate course in mechanics of materials.

An in-depth review of elementary mechanics of materials; theories of strength; impact; fatigue; creep; introduction to theory of elasticity.

547. EXPERIMENTAL STRESS ANALYSIS. Sem. 1 and 2. SS. Class 2, Lab. 3, cr. 3. Admission by consent of instructor.

Theory and application of photoelastic, electric strain gage, and brittle lacquer methods of experimental stress analysis for static and dynamic loadings. Strain gage work will include strain rosettes. Professor Stitz.

553. ELASTICITY IN AEROSPACE ENGINEERING. Sem. 1. Class 3, cr. 3. Knowledge of ordinary and partial differential equations assumed. Undergraduates must have a 4.8 or higher graduation index or consent of instructor.

A basic course in elasticity with applications directed toward needs of the aerospace engineer. Tensor index notation and summation convention. Three-dimensional equations of linear elasticity; orthotropic and isotropic solids. Two- and three-dimensional applications include turbines, orthotropic sandwich panels, and torsion and bending of multiple-cell aircraft structural sections. Yield and brittle fracture criteria; fatigue crack propagation. Professor Genin.

554. ELASTICITY IN AEROSPACE ENGINEERING II. Sem. 2. Class 3, cr. 3. Prerequisite: A&ES 553 or equivalent.

Continuation of A&ES 553. Thermoelasticity. Energy principles and variational methods of approximate analysis. Theory of thin plates and shells. Applications include torsion of wings with root constraint; thermal and mechanical loading of turbines, stiffened panels, and pressure vessels. Buckling of beams, plates, and cylinders; ultimate loads of stiffened panels. Professor Genin.

563. PROBABILITY FOR ENGINEERING SCIENCES. Class 3, cr. 3. Prerequisite: MA 262, or consent of instructor.

Foundations, combinations, conditional probability, expectations, and application to discrete sample spaces; random variables in one and more dimensions, various continuum distribution, characteristic functions; application to engineering problems.

The purpose of this course is to discuss applications of probability to problems of engineering interest. Professor Bogdanoff.

[illegible] SYSTEMS ANALYSIS AND SYNTHESIS. [illegible] Class 3, cr. 3. Must be preceded by A&ES 402 or 404 or equivalent.

[illegible] differential equations. [illegible] methods of analysis for continuous and discrete-data systems. Stability analysis by Liapunov's second method. Optimal control. Deterministic systems with random inputs. Wiener and Kalman filtering for data smoothing and prediction. Parameter estimation and system identification. Professor Swaim.

565. GUIDANCE AND CONTROL OF AEROSPACE VEHICLES. Sem. 2. Class 3, cr. 3. Must be preceded by A&ES 464 or 564 or equivalent.

Inertial sensors. Tracking and navigation systems. Guidance of rocket vehicles. Satellite attitude control. Aircraft and lifting entry vehicle handling qualities; stability augmentation; autopilots. Launch vehicle and ballistic missile attitude control. Professors M. Goulard and Swaim.

567. INTRODUCTION TO APPLIED STOCHASTIC PROCESSES. Class 3, cr. 3. Prerequisite: A&ES 563 or equivalent.

An introductory course in the concept of a discrete stochastic process, based upon the physical phenomena that originally give rise to the specific stochastic models that are studied.

Branching processes, recurrent events, queuing theory, random walks, ruin and absorbing states, Markov chains, simple time dependent stochastic processes. Professor Bogdanoff.

568. STOCHASTICS LABORATORY. Sem. 2. Class 2, Lab. 3, cr. 3. An elementary knowledge of probability is required.

Laboratory generation of stochastic processes; analog and digital techniques for the analysis of stochastic processes; analysis and simulation of stochastic systems and their responses; stability. Professor Schiff.

572. AERODYNAMICS OF PROPULSION. Class 3, cr. 3. Prerequisites: A&ES 372 and 416. Undergraduates must have a 4.8 or higher graduation index or consent of instructor.

Trajectories, orbits, and space flight paths; principles of multistage rockets; air breathing propulsive devices; chemical rockets; principles of electromagnetic propulsion methods; nuclear methods and possibilities, fission system requirements. Professor Palmer.

590. PROJECTS IN AERONAUTICAL ENGINEERING. Sem. 1 and 2. cr. 1-6. Undergraduates must have a 4.8 or higher graduation index or consent of instructor.

597. PROJECTS IN ENGINEERING SCIENCES. Hours and credits to be arranged.

GRADUATE LEVEL

603. THEORETICAL METHODS IN ENGINEERING SCIENCES I. Class 3, cr. 3.

604. THEORETICAL METHODS IN ENGINEERING SCIENCES II. Class 3, cr. 3.

608. SYSTEM OPTIMIZATION TECHNIQUES II. Class 3, cr. 3.

610. ANALYTICAL MECHANICS AND ELECTROMAGNETIC THEORY. Class 3, cr. 3.

611. PRINCIPLES OF FLUID DYNAMICS. Sem. 1. Class 3, cr. 3.

612. AEROTHERMOCHEMISTRY. Sem. 2. Class 3, cr. 3.

613. VISCOUS FLOW THEORY. Sem. 1. Class 3, cr. 3.

614. INVISCID GAS DYNAMICS. Sem. 2. Class 3, cr. 3.

615. RAREFIED GAS DYNAMICS. Sem. 2. Class 3, cr. 3.

616. APPROXIMATE METHODS OF FLUID MECHANICS. Sem. 1. Class 3, cr. 3.

618. APPLIED AERODYNAMICS. Class 3, cr. 3.

621. INTRODUCTION TO MAGNETO FLUID MECHANICS AND PLASMA PHYSICS. Sem. 2. Class 3, cr. 3.

623. ADVANCED SEMINAR IN ASTROPHYSICS. Sem. 2. Class 3, cr. 3.

625. RADIATIVE ENERGY TRANSFER. Sem. 1. Class 3, cr. 3.

626. MATHEMATICAL THEORY OF TURBULENCE. Class 3, cr. 3.

627. INTRODUCTION TO DYNAMICS OF THE OCEAN. Sem. 2. Class 3, cr. 3.

634. AEROSPACE SCIENCE DIAGNOSTIC TECHNIQUES. Class 2, Lab. 1, cr. 3.

641. THEORY OF NONLINEAR ELASTICITY. Sem. 2. Class 3, cr. 3.

642. RHEOLOGY. Sem. 1. Class 3, cr. 3.

643. THEORY OF CONTINUOUS MEDIA I. Class 3, cr. 3.

644. THEORY OF CONTINUOUS MEDIA II. Class 3, cr. 3.

645. DYNAMIC STABILITY OF ELASTIC SYSTEMS. Class 3, cr. 3.

646. ELASTIC WAVE PROPAGATION. Class 3, cr. 3.

647. EXPERIMENTAL STRESS ANALYSIS. Class 2, Lab. 3, cr. 3.

650. PLASTIC BEHAVIOR OF MATERIALS AND STRUCTURES. Sem. 2. Class 3, cr. 3.

651. VISCOELASTICITY. Class 3, cr. 3.

652. THEORY OF PLATES AND SHELLS. Class 3, cr. 3.

653. NONLINEAR MECHANICS. Sem. 1. Class 3, cr. 3.

664. APPLICATIONS OF STOCHASTIC ANALYSIS TO THE ENGINEERING SCIENCES I. Class 3, cr. 3.

665. APPLICATIONS OF STOCHASTIC ANALYSIS TO THE ENGINEERING SCIENCES II. Class 3, cr. 3.

666. SELECTED TOPICS IN APPLICATIONS OF STOCHASTIC ANALYSIS TO THE ENGINEERING SCIENCES. Class 3, cr. 3.

667. OPTIMAL DESIGN OF STOCHASTIC SYSTEMS, FOUNDATIONS AND APPLICATIONS. Class 3, cr. 3.

668. METHODS AND APPLICATIONS OF TIME SERIES ANALYSIS. Class 3, cr. 3.

690. ADVANCED AERONAUTICAL ENGINEERING PROJECTS. Sem. 1 and 2. cr. 0-6.

691. AERONAUTICAL ENGINEERING SEMINAR. Sem. 1 and 2, cr. 1-6.

697. ADVANCED ENGINEERING SCIENCES PROJECTS. Hours and credits to be arranged.

698. RESEARCH. M.S. Thesis.

699. RESEARCH. Ph.D. Thesis.

AGRICULTURAL ENGINEERING

Professor Isaacs in charge

Professors: A. C. Dale, Ph.D.; C. N. Hinkle, Ph.D.; G. W. Isaacs, Ph.D.; J. B. Liljedahl, Ph.D.; E. J. Monke, Ph.D.; R. M. Peart, Ph.D.
Professor in Extension: B. A. McKenzie, M.S.Ag.E.
Associate Professors: D. F. Bline, M.S.F.; A. D. Brown, M.S.Ed.; W. R. DeTar, Ph.D.; G. H. Foster, M.S.; C. G. Haugh, Ph.D.; L. F. Huggins, Ph.D.; R. M. Lien, M.S.Ag.E.; L. D. Meyer, Ph.D.; W. H. Wischmeier, M.S.; G. L. Zachariah, Ph.D.
Associate Professor in Extension: R. Z. Wheaton, D. Eng.
Assistant Professor: W. H. Friday, M.S.Ag.E.
Assistant Professors in Extension: J. R. Foley, M.Ag.; P. E. Johnson, M.S.; J. E. Mentzer, M.S.Ag. E.; S. D. Parsons, M.S.; F. R. Willsey, Ed.D.
Instructors in Research: J. R. Barrett, M.S.; R. A. Thompson, B.S.

UNDERGRADUATE LEVEL
Lower-Division Courses

108. INTRODUCTION TO ANALYSIS AND DESIGN. Sem. 1 and 2. Class 1, Lab. 2, cr. 2. (el. 2 AGE).

Introduction by case studies to analysis and design procedures used by agricultural engineers in developing agricultural machines, buildings, water control practices, and processes. Practice in using special instrumentation, such as analog and digital computers, spectrophotometers, and rheological testing machines for biological materials. Staff.

200. INTRODUCTION TO AGRICULTURAL ENGINEERING DESIGN. Sem. 1. Lab. 2, cr. 1. (3 AGE).

Basic concepts of engineering design with applications to typical agricultural engineering design problems. Professor Isaacs and staff.

280. AGRICULTURAL ENGINEERING PRACTICE I. Sem. 1 and 2. SS. cr. 0. For Cooperative Engineering Education Program students. Must be accepted into program by department coordinator.

Practice in industry and written reports of this practice.

285. AGRICULTURAL ENGINEERING PRACTICE II. Sem. 1 and 2. SS. cr. 0. Prerequisite: AGEN 280.

Practice in industry and written reports of this practice.

UNDERGRADUATE LEVEL
Upper-Division Courses

305. PHYSICAL PROPERTIES OF BIOLOGICAL MATERIALS. Sem. 1. Class 2, Lab. 2, cr. 3. (5 AGE). Prerequisite or corequisite: ESC 223.

Physical properties important to the design of harvesting, storage and processing systems for agricultural crops; principles and techniques for measurement and definition of properties. Professor Haugh.

310. **ENVIRONMENTAL RELATIONSHIPS.** Sem. 2. Class 2, Lab. 2, cr. 3. (6 AGE). Prerequisites: ANSC 431 and AGRY 410; prerequisite or corequisite: ME 315.

The relation and response of animals, plants, and their products to the environment in which they are produced or stored; basis for the synthesis of systems for optimal response with special emphasis on confined housing of animals, controlled environments for plants, and storage facilities for plant and animal products. Professor Hinkle.

380. **AGRICULTURAL ENGINEERING PRACTICE III.** Sem. 1 and 2. SS. cr. 0. Prerequisite: AGEN 285.

Practice in industry and written reports of this practice.

385. **AGRICULTURAL ENGINEERING PRACTICE IV.** Sem. 1 and 2. SS. cr. 0. Prerequisite: AGEN 380.

Practice in industry and written reports of this practice.

425. **SOIL-WATER-PLANT SYSTEMS DESIGN.** Sem. 1. Class 2, Lab. 3, cr. 3. (7 AGE). Prerequisites: AGEN 310 and CE 342 or ME 310.

Interrelationships of water, air, and soil and their utilization by plants; plant tolerances and optimization of soil moisture; design of subsurface and overland flow systems; irrigation systems analysis. Professor Monke.

430. **DESIGN OF CROP PRODUCTION AND HARVESTING MACHINES.** Sem. 1. Class 2, Lab. 2, cr. 3. (7 AGE). Prerequisites: AGEN 305 and 310.

Design of selected machines and machine components for crop production and harvesting; use of physical properties of soils and agricultural products in the design of machines; analytical, computer, and experimental methods. Professor Liljedahl.

455. **AGRICULTURAL PROCESSING I.** Sem. 2. Class 2, Lab. 2, cr. 3. (el. 7 or 8 AGE).

Design of systems for processing agricultural materials; analysis of drying, conditioning and cooling processes; size reduction, metering, mixing, and conveying; sorting of food products; introduction to automatic control. Professors Peart and Zachariah.

475. **DESIGN OF FACILITIES FOR ANIMAL PRODUCTION AND CROP STORAGE.** Sem. 1. Class 2, Lab. 2, cr. 3. (7 AGE). Prerequisites: ESC 223 and AGEN 310.

Fundamentals of light-frame structure design including structural analysis, estimating loads, properties of materials, fabrication and construction procedures; facilities for animal production and crop storage including layouts, space requirements, materials flow, waste disposal, and storage. Professors Dale and Friday.

480. **AGRICULTURAL ENGINEERING PRACTICE V.** Sem. 1 and 2. SS. cr. 0. Prerequisite: AGEN 385.

Practice in industry and written reports of this practice.

490. **PROFESSIONAL PRACTICE IN AGRICULTURAL ENGINEERING.** Sem. 2. Class 2, cr. 1. (8 AGE).

Professional attitudes and ethics; research and development; patents; contracts and specifications; reports of summer experience requirement. Professor Isaacs.

DUAL LEVEL—UNDERGRADUATE AND GRADUATE

519. **MECHANICS AND RHEOLOGY OF FIBROUS MATERIALS.** Sem. 1. Class 2, Lab. 3, cr. 3. (el. 7 AGE). Prerequisites: MA 262 and ESC 223. (Same as FOR 519).

Stress and strain tensor relationships in anistropic fibrous materials; mechanical properties as functions of time. Professor Suddarth.

526. **WATERSHED SYSTEMS DESIGN.** Sem. 2. Class 3, cr. 3. (el. 8 AGE). Prerequisite: AGEN 425.

Hydrologic design of upland water management systems for erosion control, water utilization, and runoff control; examination of economic and legal factors; analysis and design of composite systems for agricultural watersheds. Professor Huggins.

545. **DESIGN OF OFF-HIGHWAY VEHICLES.** Sem. 2. Class 2, Lab. 2, cr. 3. (el.). Prerequisite: AGEN 430 or consent of instructor.

Problems associated with the design of off-highway vehicles, with special emphasis upon farm and industrial tractors, and self-propelled machines; application of soil mechanics to traction; dynamic behavior of the tractor chassis; power transmission, control systems; human factors; testing and evaluation of performance. Professor Liljedahl.

556. **AGRICULTURAL PROCESSING II.** Sem. 1. Class 2, Lab. 2, cr. 3. (el. 8 AGE). Prerequisite: AGEN 455.

Heat and mass transfer in biological materials during cooling, heating, drying, and wetting processes; thin-layer and deep-bed grain drying theories; electromagnetic radiation; digital and analog simulation of process dynamics and control systems. Professors Haugh and Zachariah.

565. **AGRICULTURAL SYSTEMS ENGINEERING.** Sem. 1. Class 3, cr. 3.

Analysis and optimization of systems for agricultural production and processes; switching algebra, Karnaugh maps, and sequence charts for switching circuit design; simulation by mathematical models of discrete and of continuous biological and bio-chemical systems; single-server queueing, linear programming, and search techniques for agricultural processes. Professor Peart.

576. **AGRICULTURAL STRUCTURES DESIGN.** Sem. 2. Class 2, Lab. 3, cr. 3. (el. 8 AGE). Prerequisite: AGEN 475.

Advanced structural design including indeterminant analysis and environmental control. Professors Dale and Friday.

590. **SPECIAL PROBLEMS.** Sem. 1 and 2. SS. cr. 1-6. (el. 7 and 8 AGE).

Assignment by permission of the instructor in the field of selected study. Laboratory, field, and library studies and reports on special problems related to agricultural engineering not covered in regular course work.

GRADUATE LEVEL

627. **THEORY OF WATER MANAGEMENT.** Sem. 2. Class 3, cr. 3.

645. **SOIL-VEHICLE MECHANICS.** Sem. 1. Class 2, Lab. 3, cr. 3.

677. **FARM STRUCTURES PROBLEMS.** Class 3, cr. 3.

690. **AUTOMATIC DATA ACQUISITION AND ANALYSIS.** Sem. 1. Class 3, cr. 3.

697. **SEMINAR.** Sem. 1 and 2. Class 1, cr. 0.

698. **RESEARCH.** M.S. Thesis.

699. **RESEARCH.** Ph.D. Thesis.

CHEMICAL ENGINEERING

R. A. Greenkorn, Head of the School

R. E. Eckert, Assistant Head of the School

Professors: L. F. Albright, Ph.D.; K-C. Chao, Ph.D.; A. H. Emery, Ph.D.; R. A. Greenkorn, Ph.D.; L. B. Koppel, Ph.D.; J. H. Rushton, Ph.D.; A. Sesonske, Ph.D.; T. J. Williams, Ph.D.

Visiting Professor: R. E. Hannemann, M.D.

Associate Professors: R. E. Eckert, Ph.D.; J. Pinzelik, M.A.; R. G. Squires, Ph.D.; J. M. Woods, Ph.D.

Assistant Professors: R. G. Barile, Ph.D.; N. R. Houze, Ph.D.; H. C. Lim, Ph.D.; D. R. Schneider, Ph.D.; T. G. Theofanous, Ph.D.; W. A. Weigand, Ph.D.

Visiting Assistant Professor: J. A. Guin, Ph.D.

UNDERGRADUATE LEVEL

Lower-Division Courses

205. **CHEMICAL ENGINEERING CALCULATIONS.** Sem. 1 and 2. SS. Class 3, cr. 3. (3 CHE). Prerequisite: CHM 116 or 117, MA 161, PHYS 152, or equivalent.

Quantitative applications of material and energy balances to the chemical process industries. The use of chemical equations, yield of a chemical process; handling of multiple, by-pass, and recycle streams; and introduction to the first law of thermodynamics.

206. STAGEWISE OPERATIONS. Sem. 1 and 2. SS. Class 2, cr. 2 (4 CHE). Prerequisites: CHE 205, PHYS 251, or equivalent.

The application of equilibria and heat and material balances for the design of separation processes. Use of Dalton's, Raoult's, and distribution laws in development of equipment for distillation, absorption, and extraction. Stagewise successive separations and graphical methods of design used for them.

290. INDUSTRIAL PRACTICE I. Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisites: Must be accepted for the program by the cooperative program coordinator. Practice in industry and comprehensive written reports of this practice.

291. INDUSTRIAL PRACTICE II. Sem. 1 and 2. SS. cr. 0. For cooperative program student only. Prerequisites: Must be accepted for the program by the cooperative program coordinator. Practice in industry and comprehensive written reports of this practice.

292. CO-OP SEMINAR I. Sem. 1. Class 1, cr. 1. For students returning from first work period.

Lectures by faculty and students on subjects which relate the academic work and the industrial experience. Written reports on the industrial experience are required and these shall include a documentation of the student's success in finding application of specified academic activities.

293. CO-OP SEMINAR II. SS. Class 1, cr. 1. For students returning from second work period.

Continuation of CHE 292.

UNDERGRADUATE LEVEL
Upper-Division Courses

311. INTRODUCTORY CHEMICAL ENGINEERING THERMODYNAMICS. Sem. 1 and 2. Class 3, cr. 3. (5 CHE). Prerequisites: CHE 205, MA 262, CHM 373, or equivalent.

Basic concepts and use of the thermodynamic functions of entropy, enthalpy, and free energy; relationships among variables; properties of pure fluids and mixtures; change of properties on mixing; application of the conditions of thermodynamic equilibrium as defined by Gibbs to phase and chemical equilibria; thermodynamic processes and efficiencies.

337. TRANSFER OPERATIONS. Sem. 1 and 2. Class 3 or 4, cr. 3 or 4. (5 CHE, 7 IE, and 7 MSE). Prerequisites: CHM 373, CHE 206, MA 262 or equivalent.

Quantitative study of chemical engineering operations involving flow of fluids through conduits and porous media; conductive, convective, and radiative heat exchange; and mass transfer by diffusion.

338. TRANSPORT PHENOMENA. Sem. 1 and 2. Class 3, cr. 3. (6 CHE, el.). Prerequisites: CHE 337 and CHE 311 or equivalent.

Introduction to mass, momentum and energy transport; the equations of change; analytical solution to problems in viscous flow, heat conduction, and diffusion; dimensional analysis; correlation of mass, momentum, and heat transfer coefficients.

344. CHEMICAL ENGINEERING LABORATORY I. Sem. 1 and 2. SS. Lab. 6, cr. 2. (6 CHE). Prerequisites: CHE 311 and 337.

Quantitative experimental study of fluid mechanics and heat transfer and their application to filtration, evaporation, pumps, mixing, etc.; comparison of the operation of actual equipment with theory; digital computers and programming; library work and report writing.

392. INDUSTRIAL PRACTICE III. Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisites: Must be accepted for the program by the cooperative program coordinator.

Practice in industry and comprehensive written reports of this practice.

393. INDUSTRIAL PRACTICE IV. Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisites: Must be accepted for the program by the cooperative program coordinator.

Practice in industry and comprehensive written reports of this practice.

394. INDUSTRIAL PRACTICE V. Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisites: Must be accepted for the program by the cooperative program coordinator.

Practice in industry and comprehensive written reports of this practice.

395. CO-OP SEMINAR III. Sem. 2. Class 1, cr. 1. For students returning from third work period.

Continuation of CHE 293.

411. CHEMICAL ENGINEERING PROBLEMS. Lab. 3 to Class 1, Lab. 9, cr. 1 to 4. (el.). Prerequisites: CHE 311, 344, and 445.

To provide experience in research and development: either directed or independent experimental work. May be repeated for credit.

439. REACTION KINETICS AND CHEMICAL EQUILIBRIUM. Sem. 1 and 2. Class 3, cr. 3. (7 CHE). Prerequisites: CHE 311, CHM 374.

Study of chemical equilibria, rates of chemical reaction, and catalysis. Applications to product specifications and equipment design.

445. CHEMICAL ENGINEERING LABORATORY II. Sem. 1 and 2. SS. Lab. 6, cr. 2. (7 CHE). Prerequisite: CHE 338; prerequisite or corequisite: CHE 344.

Continuation of CHE 344 covering operations involving mass transfer such as distillation, absorption, extraction, drying, humidification, etc.; study of rates and equilibria in simple chemical and reaction system; study of chemical processes; library work and report writing.

449. MATHEMATICAL APPLICATION IN ECONOMICS AND OPTIMIZATION. Sem. 1 and 2. Class 2, cr. 2. (CHE 7). Prerequisites: CHE 337 and CHE 311.

Techniques for study of the economics of new and replacement equipment. Costing of equipment, plant, and plant operation. Optimization methods applied to process components for selection, design, and operation of equipment. Estimation of process profitability.

450. CHEMICAL PROCESS DESIGN. Sem. 1 and 2. SS. Class 2, Problem Lab. 2, cr. 3. (8 CHE). Prerequisites: CHE 337 and CHE 439.

Design and analysis of chemical process systems. Use of chemical kinetics and thermodynamics, transfer operations, and economics in system design and operation. Mathematical modeling and application of optimization techniques.

456. PROCESS DYNAMICS AND CONTROL. Sem. 1 and 2. Class 2, Lab. 3, cr. 3. (7 or 8 CHE). Prerequisites: CHE 338 and EE 201.

The dynamic response and control of chemical processing equipment, such as heat exchangers, chemical reactors, and absorption towers. Use is made of fundamental techniques of servomechanism theory, such as block diagrams, transfer functions, frequency response, and analog computation.

491. PROFESSIONAL GUIDANCE. Sem. 1. cr. 0. (7 CHE).

Lectures to acquaint the senior students with profession ethics, job opportunities, graduate study, graduate schools, continuing study, and services of professional societies.

DUAL LEVEL—UNDERGRADUATE AND GRADUATE

510. INTERMEDIATE CHEMICAL ENGINEERING THERMODYNAMICS. Sem. 2. Class 3, cr. 3. Prerequisite: CHE 311 or equivalent.

Chemical engineering thermodynamics, with emphasis on chemical and phase equilibria.

511. CHEMICAL ENGINEERING PROJECTS. Sem. 1 and 2. Class 1, Lab. 6, cr. 3. Prerequisites: CHE 338 and CHM 374.

Development of an individual research project, either experimental or computational, accompanied by a seminar.

524. DESIGN AND ANALYSIS OF CHEMICAL ENGINEERING EXPERIMENTS. Sem. 2. Class 3. cr. 3. (el.).

Application of statistical methods in planning and analyzing chemical engineering experiments. Factorial experiments, mathematical models, regression, and response surfaces are studied through practical examples.

526. CHEMICAL ENGINEERING KINETICS. Sem. 1. Class 3, cr. 3. Should be preceded by CHE 439 and CHM 374, or equivalent.

Analysis of rate data from complex reaction systems; reaction mechanisms, especially heterogeneous catalysis; simple design application.

527. ADVANCED CHEMICAL ENGINEERING CALCULATIONS. Sem. 1. Class 3, cr. 3. Prerequisites: CHE 338 and MA 262.

Application of mathematical techniques to solution of chemical engineering problems. Problems from the areas of transport phenomena, thermodynamics, chemical reactor design, and staged operations.

Techniques include vector-matrix algebra and calculus, tensor analysis, Laplace transforms, orthogonal functions, and dimensional analysis.

537. **TRANSFER OPERATIONS.** Sem. 1 and 2. Class 4, cr. 3. (el.). Prerequisites: CHM 373, CHE 206, MA 262, or equivalent.

Quantitative study of chemical engineering operations involving flow of fluids through conduits and porous media; conductive, convective, and radiative heat exchange; and mass transfer by diffusion.

538. **TRANSPORT PHENOMENA.** Sem. 1 and 2. Class 3, cr. 3. (el.). Prerequisites: CHE 537 and CHE 311, or equivalent.

Introduction to mass, momentum, and energy transport; the equations of change; analytical solution to problems in viscous flow, heat conduction, and diffusion; dimensional analysis; correlation of mass, momentum, and heat transfer coefficients.

539. **COMPUTER SIMULATION IN CHEMICAL PROCESS DESIGN.** Sem. 1. Class 2. Lab. 3, cr. 3. (el.).

Elements of programming digital computers. Application of various programming techniques to the simulation of chemical process components. A part of the course is devoted to individual projects in process simulation.

542. **CHEMISTRY AND ENGINEERING OF HIGH POLYMERS.** Sem. 1 and 2. Class 3, cr. 3. (el.). Prerequisites: CHM 262 and 374.

Kinetics and mechanism of formation, commercial organic technology of manufacture, industrial fabricating techniques, and principal uses of natural, artificial, and synthetic fibers, plastics, and elastomers.

543. **CHEMICAL PROCESS LABORATORY.** Sem. 1 and 2. Lab. 3 to Lab. 9, cr. 1 to 3. (el. 7, 8 CHE, S). Prerequisites or corequisites: CHE 206 and CHM 262.

Special projects in chemical synthesis.

558. **PETROLEUM REFINERY ENGINEERING.** Sem. 1. Class 3, cr. 3. Prerequisite or corequisite: CHE 338.

Application of chemical engineering fundamentals to petroleum processing methods and equipment.

559. **INDUSTRIAL CHEMICAL PROCESSING.** Sem. 1 or 2. Class 3, cr. 3. (el.). Prerequisite: CHE 311; prerequisite or corequisite: CHE 439, or permission of the instructor.

A survey of the chemical process industries illustrating the use of chemical equilibria, heat and material balances, engineering, and economics in the successful operation of a process.

597. **SPECIAL TOPICS IN CHEMICAL ENGINEERING.** Hours and credits to be arranged.

May be taken again for additional credit by consent of instructor.

GRADUATE LEVEL

610. **ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS.** Sem. 1, Class 3, cr. 3.

611. **ADVANCED TOPICS IN CHEMICAL ENGINEERING THERMODYNAMICS.** Class 3, cr. 3.

620. **TRANSPORT PROCESSES.** Sem. 2. Class 3, cr. 3.

622. **HEAT TRANSFER.** Sem. 1, 1971. Class 3, cr. 3.

623. **EQUILIBRIUM STAGE SEPARATIONS.** Class 3, cr. 3.

624. **MASS TRANSFER.** Sem. 1, 1970. Class 3, cr. 3.

626. **MIXING AND SCALE-UP.** Sem. 1, 1971. Class 3, cr. 3.

627. **DESIGN AND ANALYSIS OF CHEMICAL ENGINEERING EXPERIMENTS.** Sem. 1. Class 3, cr. 3.

629. **ADVANCED CHEMICAL PROCESSES.** Sem. 2, 1971. Class 3, cr. 3.

635. **CHEMICAL ENGINEERING FLUID DYNAMICS.** Class 3, cr. 3.

644. **NUCLEAR CHEMICAL ENGINEERING.** Class 3, cr. 3.

656. **ADVANCED PROCESS CONTROL.** Sem. 2, 1970. Class 3, cr. 3.

660. **CHEMICAL REACTOR DESIGN.** Sem. 2. Class 3, cr. 3.

662. **CATALYSIS.** Sem. 1, 1970. Class 3, cr. 3.

690. **SEMINAR IN CHEMICAL ENGINEERING.** cr. 0.

697. **SPECIAL TOPICS IN CHEMICAL ENGINEERING.** Hours and credits to be arranged.

698. **RESEARCH IN CHEMICAL ENGINEERING.** M.S. Thesis.

699. **RESEARCH IN CHEMICAL ENGINEERING.** Ph.D. Thesis.

CIVIL ENGINEERING

J. F. McLaughlin, Head of the School
W. H. Goetz, Assistant Head of the School

Distinguished Professor: K. B. Woods, Goss Professor of Engineering

Professors: D. E. Bloodgood, C.E.; K. S. Curtis, M.S.C.E.; J. W. Delleur, D.Eng.Sc.; W. L. Dolch, Ph.D.; S. B. Elrod, M.S.E.; J. E. Etzel, Ph.D.; W. H. Goetz, M.S.Ch.E.; J. E. Goldberg, Ph.D.; W. L. Grecco, Ph.D.; M. J. Gutzwiller, M.S.C.E.; M. E. Harr, Ph.D.; J. M. Hayes, C. E.; W. R. Judd, A.B.; E. J. Kirsch, Ph.D.; G. A. Leonards, Ph.D.; W. J. Luzadder, M.S.C.E.; J. F. McLaughlin, Ph.D.; H. L. Michael, M.S.C.E.; R. D. Miles, M.S.C.E.; J. H. Porsch, M.S.C.E.; M. B. Scott, M.S.C.E.; P. E. Soneson, M.S.E.; G. H. Toebes, Ph.D.; H. R. Wilke, M.S.C.E.; E. J. Yoder, M.S.C.E.

Associate Professors: R. L. Airgood, M.S.I.E.; A. G. Altschaeffl, Ph.D.; J. M. Bell, Ph.D.; K. E. Botkin, M.S.I.E.; S. Diamond, Ph.D.; W. I. Freel, M.S.C.E.; J. A. Havers, Ph.D.; J. E. Hittle, M.S.C.E.; W. J. Kay, M.S.E.; L. H. Kemmer, M.S.E.; L. A. Kivioja, Ph.D.; R. H. Lee, Ph.D.; D. W. Levandowski, Ph.D.; A. D. M. Lewis, M.S.C.E.; C. W. Lovell, Jr., Ph.D.; J. G. McEntyre, Ph.D.; W. N. Melhorn, Ph.D.; V. J. Meyers, Ph.D.; E. M. Mikhail, Ph.D.; C. B. Monk, M.S.; W. H. Perloff, Ph.D.; M. W. Pullen, Ph.D.; C. F. Scholer, Ph.D.; D. G. Shurig, M.S.E.; N. M. Smith, Ph. D.; J. D. Wolszon, Ph.D.; L. E. Wood, Ph.D.; P. T. Yeh, Ph.D.; C. H. Zacker, B.S.C.E. (Calumet Campus)

Assistant Professors: W. Baron, Ph.D.; D. H. Bowers, B.F.A.; D. L. Brenchley, Ph.D.; F. W. Duff, B.S.I.Ed.; J. T. Gaunt, Ph.D.; A. Giorgini, Ph.D.; C. P. L. Grady, Ph.D.; K. W. Heathington, Ph.D.; T. V. Jennings, Ph.D.; T. Korman, Ph.D.; J. V. Smith, M.S.I.Ed.; R. P. Thompson, M.S.; T. R. West, Ph.D.

Visiting Assistant Professors: D. Blank, M.S.; T. P. Chang, Ph.D.; A. S. Ramamurthy, Ph.D.; R. A. Rao, Ph.D.; M. H. Ueberschaer, Ph.D.

Visiting Research Associate: D. Ravina, D.Sc.

Instructors: L. A. Brown, M.S.; J. H. Packer, M.S.M.E. (Calumet Campus); G. M. Rand, M.S.; S. E. Rand, M.S.; C. D. Sutton, M.S.C.E.

JOINT HIGHWAY RESEARCH PROJECT

J. E. McLaughlin, director; H. L. Michael, associate director.

HIGHWAY ENGINEERING RESEARCH PROJECT FOR INDIANA COUNTIES

K. B. Woods, director; J. F. McLaughlin, associate director.

URBAN RESEARCH PROJECT

H. L. Michael, in charge.

ENGINEERING GRAPHICS

UNDERGRADUATE LEVEL
Lower-Division Courses

110. DRAFTING FUNDAMENTALS. Sem. 1. Class 1, Lab. 6, cr. 3. (1 IED, el.).
A basic course in drawing; orthographic projection, pictorial drawing, print reading, and reproduction of drawings. Problems designed to require practical reasoning and develop good techniques.

111. ADVANCED DRAFTING. Sem. 1 and 2. Class 1, Lab. 6, cr. 3. (2 IED, el.). Prerequisite: EG 110.
Preparation of assembly and detail drawings, including fasteners, limit dimensioning, and shop notes. Intersections and developments with sheet metal applications. Symbols and construction details used in architectural drafting.

112. LAYOUT, LETTERING, AND TYPOGRAPHY. Sem. 1 and 2. Class 1, Lab. 6, cr. 3.
History and forms of principal alphabets. Practice in hand lettering to include the engineering alphabet and main display alphabets. Practice in use of mechanical lettering devices. Layout of simple pages and posters including illustrations and types. Mrs. Rand.

113. SLIDE RULES AND GRAPHS. Sem. 1 and 2. Lab. 2, cr. 1. (el. S, 1, 2, 3, 4 ENGR). Prerequisite or corequisite: MA 112 or 151.
Principles and use of the slide rule for division, multiplication, trigonometry, powers, and roots. Properties and types of coordinate graphs for scientific and engineering purposes; calculating and plotting graphs; uniform, log, semilog, and others.

114. DRAFTING I. Sem. 1 and 2. Lab. 6, cr. 2. (IED, el.).
A basic course in geometrical constructions, multiview drawing, dimensioning, pictorial drawing, and sketching. Problems designed to require practical reasoning and develop good techniques.

115. DRAFTING II. Sem. 1 and 2. Lab. 6, cr. 2. (IED, el.). Prerequisite: EG 114.
Preparation of simple assembly and detail drawings, including sectioning, conventional practice, bearings, fasteners, limit dimensions, and shop notes. Print reading, inking, and reproduction of drawings. Exercises designed to require practical reasoning and develop good techniques.

116. GRAPHICS I. Sem. 1 and 2. Class 1, Lab. 4, cr. 2. (1 or 2 ENGR, el.).
Basic graphical methods—instrument and freehand—useful in engineering layout and design for analysis and communication. Multiview representation with some sketching and basic dimensioning practices. Auxiliary views with sectioning and some conventional representations. Engineering lectures and counseling for scheduling by Department of Freshman Engineering. Professor Porsch and staff.

117. GRAPHICS II. Sem. 1 and 2. Class 1, Lab. 4, cr. 2. (2 or 3 ENGR, el.). Prerequisite: EG 116 or equivalent.
Basic pictorial methods—instrument and freehand—useful in engineering layout and design for analysis and communication. Graphical techniques: vector, calculus-differentiation, and integration. Multiview resolution of intersections of plane and curved surfaces. Engineering lectures and counseling for scheduling by Department of Freshman Engineering. Professor Porsch and staff.

118. ENGINEERING GRAPHICS. Sem. 1 and 2. S.S. Class 1, Lab. 6, cr. 3. (1 or 2 ENGR, el.). Prerequisite or corequisite: MA 161.
Basic graphical and pictorial methods—instrument and freehand—useful in engineering layout and design for analysis and communication. Multiview drawing with auxiliary views, sectioning, conventional practices and some dimensioning. Graphical techniques: vectors, calculus: differentiation and integration. Multiview resolution of intersections of plane and curved surfaces. Engineering lectures and counseling for scheduling by Department of Freshman Engineering.

210. INDUSTRIAL SKETCHING. Sem. 1 and 2. Lab. 6, cr. 2. (3 IED, el.). Prerequisite: EG 110.
The application of freehand sketching on paper and the blackboard of industrial problems in representation and design using axonometric, oblique, perspective, and multiview drawings. Laboratory problems include drawing from the object, layout from notes, and simple design problems. Introduction to shade and shadow and artist's perspective.

212. DESCRIPTIVE GEOMETRY. Sem. 1 and 2. cr. 2 or cr. 3. (3 IED, el.). Prerequisites: EG 110 and 111, or 118.
Relations of points, lines, and surfaces and their graphical representation. Intersections and developments of plane and curved surfaces. Graphical synthesis as applied to layout, delineation, and solution of spatial problems. Warped and double-curved surfaces.

213. FREEHAND SKETCHING. Sem. 1 and 2. Lab. 6, cr. 2. (op. 5 H, el.).
Line sketching and shading in pencil and charcoal of objects as they appear to the eye. Mrs. Rand.

220. BASIC ARCHITECTURAL DRAWING. Sem. 1. Class 1, Lab. 6, cr. 3.
Drafting equipment, graphical principles, nomenclature, building procedures, plans, elevations, sections, details as related to the field of architecture. The coverage to prepare the student for a complete set of plans and specifications to be developed in course EG 320. Professor Bowers.

221. BASIC PICTORIAL REPRESENTATION. Sem. 1. Class 1, Lab. 6, cr. 3.
Introduction to both freehand and mechanical techniques of architectural pictorial representation using monochromatic media. Exercises in isometric and perspective systems, shades and shadows, and value relationships. Familiarization in the use of various dry media plus opaque and transparent water color. Prof. J. V. Smith.

UNDERGRADUATE LEVEL
Upper-Division Courses

310. DRAWING TEACHING PRACTICE. Sem. 1 and 2. Class 1, Lab. 4, cr. 3. (op. 5 IED, el.). Prerequisite: EG 115.
Assignment to assist with the laboratory work in the EG 110 classes. Seminar meetings and papers on objectives, content, methods, and testing in engineering drawing.

311. INDUSTRIAL ARTS DESIGN. Sem. 1 and 2. Lab. 6 to 9, cr. 2 or 3; or Class 1, Lab. 6, cr. 3. (4 IED, el.). Prerequisite: EG 111.
A basic course in design applied to shop projects. Laboratory problems include instruction in various mediums and crafts used in designing utilitarian objects for improved appearance and use. Professor Bowers.

312. SHADES, SHADOWS, AND PERSPECTIVE. Sem. 1 and 2. Class 1, Lab. 6, cr. 3. (el.). Prerequisite: EG 110, 118.
Graphic representations of shades and shadows on buildings and geometric forms. Parallel and angular perspective. Use of color in rendering. Prof. J. V. Smith.

315. GRAPHICAL PRESENTATION OF DATA. Sem. 1 and 2. Lab. 6, cr. 2.
Different kinds and types of charts, graphs, and diagrams. Considerations in plotting scientific data. Preparation of finished art for reproduction. Professor Bowers.

316. SPECIAL DRAWING. Sem. 1 and 2. Lab. 3 to Lab. 9, cr. 1-3. (el.). May be rescheduled for three hours additional credit. Must be preceded by EG 111 or 118.
Problems selected to suit the needs of the students. Professor Porsch.

317. PRODUCTION ILLUSTRATION. Sem. 2. Lab. 6, or Class 1, Lab. 6, cr. 2 or 3. (el.). Prerequisite: EG 118 or 111.
To give the student a good knowledge of and some experience in graphical construction and some rendering techniques necessary to produce accurate pictorial drawings suitable for catalogs, production planning, and design analysis. Professors Botkin and Elrod.

318. PROJECTS IN TECHNICAL ILLUSTRATION. Sem. 1 and 2. Class 1, Lab. 6, cr. 3. Prerequisite: EG 113.
Directed work in initial planning, production, and completion of finished art for industrial brochures, catalogs, and other industrial publications. Additional instruction in keylining, color separation, and other techniques used in industrial publication.

319. BASIC PRODUCT DESIGN. Sem. 1 and 2. Class 1, Lab. 6, cr. 3. Prerequisite: EG 311.
Introduction to creative design for consumer products. Practice and techniques of depicting form, material, and finish with colored pictorial and modelled representation. Technique of problem analysis followed by problem synthesis. Professor Bowers.

320. ADVANCED ARCHITECTURAL DRAWING. Sem. 2. Class 1, Lab. 6, cr. 3. Prerequisite: EG 220.
The skills and techniques of preparing working drawings for residential construction, stressing the influence of building trade procedures and construction materials upon design. Professor Bowers.

321. ADVANCED PICTORIAL REPRESENTATION. Sem. 2. Class 1, Lab. 6, cr. 3. Prerequisite: EG 221.

The fundamentals of color and its importance in pictorial representation. Rendering of the entourage and textures. Color renderings of architectural interiors and exteriors. Prof. J. V. Smith.

417. INDUSTRIAL DESIGN FOR ENGINEERS. Sem. 2. Class 1, Lab. 6, cr. 3. (el. ENGR). Prerequisite: EG 118.

Basic principles of art as applied to design and color harmony and their application to industrial design. Laboratory problems in designing utilitarian objects for improved appearance and use. Professor Bowers.

418. GRAPHICAL COMMUNICATION AND SYNTHESIS FOR ENGINEERS. Sem. 1 and 2. Lab. 6, cr. 2. (7 AE, el.). Prerequisite: EG 118 or equivalent.

Graphical synthesis as applied to engineering product evolvement. Design layouts, visualization, and specification drawings of engineering components. Drawing practices for aeronautical, automotive, and precision manufacturing industries. Professor Elrod and staff.

DUAL LEVEL—UNDERGRADUATE AND GRADUATE

510. INTRODUCTION TO DESIGN AND COLOR FOR ENGINEERS AND SCIENTISTS. Sem. 2. Class 1, Lab. 6, cr. 3. Prerequisite: EG 118 or permission of instructor.

A course specially designed for students majoring in scientific fields to acquaint them with modern thinking in the related fields of design and color. Practical exercises in different mediums (pencil, ink, pastel, watercolor and oil) are integrated with lectures and projects dealing with dynamic symmetry, principles of design as applied in industry, and the Munsell system of color notation.

513. NOMOGRAPHIC DRAWING. Sem. 2. Class 2, Lab. 3, cr. 3. Prerequisites: EG 118; and MA 162, or MA 111 and 221.

Graphical presentation of data; theory and construction of alignment charts and special slide rules; determination of equations to represent empirical data.

518. ADVANCED DESCRIPTIVE GEOMETRY. Sem. 2. Class 1, Lab. 3, or Class 1, Lab. 6, cr. 2 or 3. Prerequisite: EG 118.

Graphical and algebraic representation and application of plane and space curves, single and double curved surfaces, and warped surfaces; fundamentals of perspective and other pictorial means of representation. Professors Elrod and Porsch.

519. PROJECTS IN GRAPHICS. Sem. 1 and 2. cr. 1 to 6, hours to be arranged. Prerequisite: EG 118.

Directed work on individual problems and research in graphical computation and representation. Professor Porsch and staff.

CIVIL ENGINEERING

UNDERGRADUATE LEVEL

Lower-Division Courses

191. CIVIL ENGINEERING PRACTICE I. Sem. 1 and 2. SS. cr. 0. For cooperative program students only.

Practice in industry and written reports of this practice.

206. ENGINEERING SURVEYS I. Sem. 1 or 2. Class 1, Lab. 6, cr. 3. (3 CE). Prerequsite or corequisite: MA 162.

Mensuration through the application of surveying techniques; the theory of errors and their analysis; fundamental concepts of horizontal, vertical, and angular measurement; basic surveying operations and computations; control systems and datums for engineering surveys; locating and positioning man-made structures.

207. ENGINEERING SURVEYS II. Sem. 1 or 2. Class 1, Lab. 3, cr. 2. (4 CE) Prerequisite: CE 206.

Advantages, disadvantages, and restrictions of various methods and techniques used in surveying and mapping practice; fundamental principles and theories involved in establishing directional control, mapping an area by tacheometry and photogrammetry, and subdividing and describing an area; geodetic relationships and problems; planning and specifications.

290. CIVIL ENGINEERING SEMINAR. Sem. 1. Class 1, cr. 0. (3 CE).

Lectures drawn from all fields in civil engineering to give background material in what civil engineers do, and what they may be expected to do in the future. An orientation course to better inform students of the various areas in civil engineering, to assist them in the selection of electives suited to their own particular talents and abilites, and to instill in them a sense of professional ethics and responsibilty.

291. CIVIL ENGINEERING PRACTICE II. Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisite: CE 191.

Practice in industry and written reports of this practice.

299. CIVIL ENGINEERING SEMINAR. Sem. 2. Class 1, cr. 0. (4 CE).

Continuation of CE 290.

333. ENGINEERING MATERIALS. Sem. 1 and 2. Class 1, Lab. 6, cr. 3. (5 CE). Prerequisite: ESC 223.

Nature and performance of materials under load. Important engineering materials for evaluation of physical and mechanical properties include: ferrous and nonferrous metals, plastics, bituminous materials, Portland cement, aggregates, concrete, and timber.

334. MATERIALS SCIENCE. Sem. 1 and 2. Class 2, Lab. 1, cr. 2. (6 CE). Prerequisite: CE 333.

Structure of matter. Intermolecular forces. States of aggregation. Response of ideal and real materials to load. Failure and fracture.

342. MECHANICS OF FLUIDS. Sem. 1 and 2. Class 3, Lab. 3, cr. 4. (5 CE). Prerequisites: MA 262 and ESC 223.

Properties of fluids, fundamentals of statics, kinematics, and dynamics of fluid flow. Dimensional analysis, boundary layer, and viscosity effects; flow around submerged bodies. Open channel and closed conduit flows. Principles demonstrated through formal laboratory experiments and special projects.

350. ENVIRONMENTAL ENGINEERING I. Sem. 1 and 2. Class 2, cr. 2. (5 CE). Prerequisite or corequisite: CE 342.

The scientific foundation of environmental engineering. Professor Etzel and staff.

360. TRANSPORTATION ENGINEERING I. Sem. 1 and 2. Class 2, Lab. 3, cr. 3. (6 CE). Prerequisite: CE 207.

A coverage of the development, economics, finance, location, and geometric design of transportation systems.

370. STRUCTURAL MECHANICS. Sem. 1 and 2. Class 2, Lab. 3, cr. 3. (5 CE). Prerequisite: ESC 223.

Analysis of statically determinate structures; reactions, shears, bending moments, and direct stresses due to fixed and moving loads; influence lines and loading criteria for beams and framed structures.

371. STATICALLY INDETERMINATE STRUCTURES. Sem. 1 and 2. Class 3, cr. 3. (6 CE). Prerequisite: ESC 223 and CE 370.

A thorough drill in computing deflection of beams; statically indeterminate analysis by moment areas, consistent deflections, slope deflection, and moment distribution.

380. SOIL MECHANICS. Sem. 1 and 2. SS. Class 2, Lab. 3, cr. 3. (6 CE). Prerequisites: CE 342 and CE 333. Corequisite: CE 334.

Identification and engineering classification of soils. Permeability, strength, and compressibility of soils. Capillary phenomena and concepts of shrinkage, frost action, and drainage. Stresses in earth masses. Theories of lateral earth pressure, pressure distribution, and consolidation.

390. ANALYSIS OF CIVIL ENGINEERING PROBLEMS. Sem. 1 and 2. Class 3, cr. 3. Prerequisite: MA 262.

Basic techniques of formulating and solving civil engineering problems by employing the methods of Laplace transforms, Fourier series, linear algebra, and orthogonal functions. Consideration of partial differential equations and solution by analytical, numerical, and graphical methods.

391. CIVIL ENGINEERING PRACTICE III. Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisite: CE 291.

Practice in industry and written reports of this practice.

420. CONSTRUCTION ENGINEERING AND MANAGEMENT I. Sem. 1 and 2. Class 2, cr. 2. (7 CE). Prerequisite: senior standing.

Basic characteristics of the construction industry. Study of contractors organization; project management and planning; construction economics and operations. Introduction to network scheduling by CPM and PERT. Professor Havers.

453. ENVIRONMENTAL ENGINEERING II. Sem. 1 and 2. Class 2, Lab. 3, cr. 3. (7 CE). Prerequisite: CE 350.

Planning and design of water supplies, water distribution systems, sewers, and wastewater treatment facilities. Professor Etzel and staff.

461. TRANSPORTATION ENGINEERING II. Sem. 1 and 2. Class 3, cr. 3. (7 CE). Prerequisites: CE 360 and CE 380.

Design of highway and airport pavement systems, subgrade, bases, flexible and rigid pavements; selection of pavement types; quality control; pavement evaluation; drainage; and maintenance.

462. **HIGHWAY PLANNING AND DESIGN.** Sem. 1 or 2. Class 3, cr. 3. (el. CE). Prerequisite: CE 360.

Detailed development and application of the concepts of modern highway planning and design for rural and urban areas.

470. **STRUCTURAL DESIGN IN METALS.** Sem. 1 and 2. Class 2, Lab. 3, cr. 3. (8 CE). Prerequisite: CE 371.

The elements of structural design in metals including: tension members and their connections; compression members and their connections; rolled and built-up flexural members; structural connections, including welding, riveting, and high strength bolts.

472. **RIGID FRAMES.** Sem. 1 and 2. Class 3, cr. 3. Prerequisite: CE 371.

Basic procedures in analysis of rigid frames having members of constant or variable moment of inertia; method of angle changes, slope deflection, and column analogy. Design of rigid frame structures.

473. **THEORY OF REINFORCED CONCRETE.** Sem. 1 and 2. SS. Class 3, Lab. 3, cr. 4. (7 CE). Prerequisite: CE 371.

Theory and design of slabs, beams, columns, footing, and retaining walls. Introduction to principles of prestressed concrete.

476. **REINFORCED CONCRETE DESIGN.** Sem. 1 and 2. Class 3, cr. 3. Prerequisite: CE 473.

Design of eccentric and combined footings, two-way reinforced floor slabs, flat slab floor systems, continuous span slab bridge, ultimate strength design, and introduction to fundamentals of prestressed concrete. Professors Gutzwiller and Lee.

477. **TIMBER DESIGN.** Sem. 1. Class 2. Lab. 3, cr. 3.

Design of parts of modern timber structures, exclusive of arches. Professor Soneson.

479. **ARCHITECTURAL ENGINEERING.** Sem. 1 or 2. Class 2, Lab. 3, cr. 3. (op. 7 CE, el.). Prerequsite or corequisite: CE 473.

Design of simple floor and roof systems; use of building materials; drafting for plans and details for ordinary buildings; shop drawings; survey of mechanical drawing. Professor Soneson.

481. **FOUNDATION AND EARTH STRUCTURES.** Sem. 1 and 2. Class 2, Lab. 3, cr. 3. (7 CE). Prerequisite: CE 380.

Methods and programs for subsurface investigations and sampling of soils. Theories of ground water flow and compactibility of soils. Control of ground water. Design of bracing systems, shallow and deep foundations for bridges and buildings. Principles of embankment, cut slope, and earth dam design.

482 **SOIL PROPERTIES AND THEIR MEASUREMENT.** Sem. 2. Class 2, Lab. 3, cr. 3. (el. CE). Prerequisite: CE 380.

A study of the theories of strength, compressibility, and permeability, including a critical review of basic assumptions and of methods for measuring the essential parameters. Planning, execution and interpretation of soil testing programs. Professor Lovell.

490. **ENGINEERING INSPECTION TRIP.** cr. 0. (7 CE). Required of all seniors in civil engineering.

Inspection of engineering establishments, industrial plants, new construction, and municipal and transportation facilities. Covering two to four days during either semester or during one of the regular vacations of the academic year. A special fee is charged to cover the costs of lodging. Professor Kay.

491. **CIVIL ENGINEERING PRACTICE IV.** Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisite: CE 391.

Practice in industry and written reports of this practice.

492. **CIVIL ENGINEERING PRACTICE V.** Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisite: CE 491.

Practice in industry and written reports of this practice.

493. **CIVIL ENGINEERING APPLICATIONS OF DIGITAL COMPUTERS.** Sem. 1 and 2. Class 1, cr. 1. Prerequisite: Senior standing or permission of instructor.

Digital computer programming for the solution of problems selected from various areas of civil engineering. Professor Lewis.

498. **CIVIL ENGINEERING DESIGN PROJECT.** Sem. 1 and 2. Lab. 9, cr. 3. (8 CE or el.). Prerequisites: CE 453, 461, 473 and 481; prerequisite or corequisite: CE 470.

Integration of geologic, structural, transportation, hydraulic, and sanitary aspects in the conception, planning, and design of a civil engineering project.

499. **RESEARCH IN CIVIL ENGINEERING.** (el.). Credit arranged.

DUAL LEVEL—UNDERGRADUATE AND GRADUATE

500. **GEODETIC SURVEYING.** Sem. 1. Class 2, Lab. 3, cr. 3. Prerequisite: CE 207 or equivalent.

Horizontal and vertical geodetic control surveys, including precise traverses, triangulation, trilateration, and leveling; condition equations and least squares adjustment; Legendre's theorem and additament methods; geodetic computation of lengths, azimuths and positions; spherical and plane coordinates; geodetic datums; ultraprecise surveys; engineering use of geodetic data. Professor Curtis.

501. **CARTOGRAPHIC SURVEYING.** Sem. 1 or 2. Class 2, Lab. 3, cr. 3. Prerequisite: CE 207 or equivalent.

Topographic and planimetric surveys for constructing original maps by ground methods including control surveys; development of automatic tacheometric measurements; hydrographic surveying, emphasizing sounding operations and visual and electronic position-location methods; map accuracy, design, compilation, projections, editing, and reproduction; engineering use of cartographic data. Professor Curtis.

502. **LAND SURVEYING.** Sem. 1 or 2. Class 3, cr. 3. Prerequisite: CE 207 or equivalent.

Boundary control; systems used to describe property; rectangular system of public land surveys; writing and interpretation of deed descriptions; plats and computations; subdivision standards; legal aspects; evidence and procedures; right-of-way problems; land surveyors' rights, duties, and liabilities; professional registration requirements.

503. **PHOTOGRAMMETRY.** Sem. 1. Class 2, Lab. 3, cr. 3. Prerequisite: CE 207 or equivalent.

Photogrammetric optics; serial cameras and their calibration; photographic materials; geometry of vertical and tilted aerial photographs; flight planning; stereoscopy and parallax; radialline plots and planimetric mapping; simple parallax instruments; theory of orientation; stereoscopic plotting instruments with optical, optical-mechanical, and mechanical projection; mosaics; terrestrial photogrammetry. Professor Mikhail.

504. **ENGINEERING AND GEODETIC ASTRONOMY.** Sem. 1 or 2. Class 2, Lab. 3, cr. 3. Prerequisite: CE 207 or equivalent.

Celestial sphere and star coordinates; earth and terrestrial coordinates; astronomical and instrumental corrections to observations; determination of astronomical azimuth, latitude, and longitude up to and including second-order accuracy. Professor Kivioja.

505. **ELECTRONIC SURVEYING.** Sem. 1 or 2. Class 2, Lab. 3, cr. 3. Prerequisite: CE 500, and consent of instructor.

Development of electronic surveying systems; analysis of instrumentation, range, and accuracy of various methods including Shoran, Hiran, E.P.I., Loran, Decca, and Raydist but with emphasis on Tellurometer, Geodimeter, and Electro-tape; electromagnetic wave propagation problems; electronic trilateration computation methods.

506. **GEOMETRIC DATA ADJUSTMENT.** Sem. 1. Class 2, Lab. 3, cr. 3. Prerequisites: CE 207 and MA 262, or equivalent.

Errors and propagation of errors in geodesy, photogrammetry, and electronic surveying; adjustment by least squares; derivation and application of methods of variation of parameters and conditions to triangulation, trilaterations, leveling and traverse networks; evaluation of adjusted values and of the mathematical models. Professor Kivioja or Mikhail.

510. **URBAN PLANNING ADMINISTRATION.** Sem. 1. Class 3, cr. 3. Prerequisite: CE 360.

The scope and methods of urban planning administration; planning legislation; planning agencies and planning administration; legal services and regulatory procedures; programming municipal services; finance and administration; external relations; research and planning.

511. **CITY PLANNING PHILOSOPHY AND THEORY.** Sem. 1. Class 3, cr. 3.

A study of the layout and physical development of cities from ancient times to present day with reference to changing concepts of pattern and form; political and social relationships; and functions. The study includes early Greek and Roman cities, early American and European contributions, the Garden City movement, British new towns, planners and their theories and examples of planned twentieth century cities. Professor Grecco.

523. DESIGN OF CONSTRUCTION PLANT. Sem. 1 and 2. Class 3, cr. 3.

A study of economics and functional applications for major categories of construction equipment. Operational characteristics are identified for selected equipment items, and are applied to typical construction situations. Professor Havers.

524. LEGAL ASPECTS IN ENGINEERING PRACTICE. Sem. 1 or 2. Class 3, cr. 3.

The legal principles underlying engineering work; the laws of contracts, torts, agency, real property and labor; problems of professional registration and ethics; contract documents including bidding procedure, insurance and surety bonds; specification writing with quality control methods; building codes and statistical approaches to safety concepts. Professor Monk.

525. ELEMENTS OF BUILDING SYSTEMS. Sem. 1. Class 3, cr. 3. Prerequisite: Consent of instructor.

Study of the application of the engineering sciences to air conditioning comfort, acoustical control, plumbing demands, illumination design, power requirements, and vertical transportation in buildings. This course is designed to enhance the student's knowledge of the total building process. Professor Monk.

528. MUNICIPAL ENGINEERING. Sem. 1 or 2. Class 3, cr. 3. Prerequisite: CE 360.

Engineering and legal problems of the city engineer; city government; city surveys; city planning and subdivision design; legal procedures for making public improvements and financing; city maps and records; building codes.

530. PROPERTIES AND PRODUCTION OF CONCRETE. Sem. 1 and 2. Class 3, cr. 3.

Basic properties of hydraulic cements and mineral aggregates and their interactions in concrete. Properties of plastic and hardened concrete. Modifications through admixtures. Production, handling, and placement problems. Specifications, quality control, and acceptance testing, lightweight, heavyweight, and other special concretes. Professor Scholer.

533. PHYSICOCHEMICAL PROPERTIES OF MATERIALS. Sem. 1. Class 3, cr. 3. Prerequisite: CE 334 or consent of instructor.

Atomic and molecular structure, bonding, states of matter, changes of state, phase relationship, solutions, surfaces, application to the properties of engineering materials. Professor Dolch.

535. BITUMINOUS MATERIALS AND MIXTURES. Sem. 2, Class 2, Lab. 3, cr. 3. Prerequisite: CE 333 or consent of instructor.

Consideration of major types of bituminous materials—asphalt cements, cutback asphalts, asphalt emulsions and tars. Influence of chemical composition upon physical properties. Desirable aggregate characteristics for bituminous mixtures. Construction techniques. Current practices for determining optimum asphalt contents. Two one-day field trips are required.

540. OPEN CHANNEL HYDRAULICS. Sem. 1 or 2. Class 3, cr. 3. Prerequisite: CE 342 or equivalent.

Energy and momentum principles; analysis and design of open channels for uniform and nonuniform flow; boundary layer and roughness effects; flow over spillways; energy dissipation; flow in channels of nonlinear alignment and nonprismatic section. Professor Delleur.

541. DESIGN OF HYDRAULIC STRUCTURES. Sem. 1 or 2. Class 3, cr. 3. Prerequisite: CE 342 or equivalent.

Hydraulic design criteria and problems of reservoirs, spillways, outlet works, river training and regulation, transition structures, conduit systems, hydraulic machinery, and harbors. Applications to multiple purpose designs involving flood control, water supply, irrigation, recreation, drainage, and navigation. Professor Toebes.

542. HYDROLOGY. Sem. 1 or 2. Class 3, cr. 3.

Meteorology; precipitational streamflow, evaporation, and transpiration; ground water; runoff relations and hydrographs; elements of stream flow routing, frequency and duration studies, extreme values statistics applied to flood and drought forecasting, application of hydrologic techniques. Problem-oriented computer languages for hydrology and water resources engineering. Professor Delleur.

549. INTERMEDIATE FLUID MECHANICS. (Same as ME 509). Sem. 1 or 2. Class 3, cr. 3.

Fluid properties. Basic laws for a control volume. Kinematics of fluid flow. Dynamics of frictionless incompressible flow. Basic hydrodynamics. Equations of motion for viscous flow, viscous flow applications, boundary layer theory. Unsteady flow. Professor Giorgini.

551. ENVIRONMENTAL ENGINEERING AND ADMINISTRATION. Sem. 1. Class 3, cr. 3. Prerequisite: CE 350.

Engineering and administrative functions in the control of environmental factors affecting man's health and survival. Professor Wilke.

552. DESIGN OF WASTEWATER TREATMENT PLANTS. Sem. 1. Class 2, Lab. 3, cr. 3. Prerequisite: CE 453 or equivalent.

Design of the components of a wastewater treatment plant and the preparation of a plan for a particular city that comprises a suitable combination of the units previously designed. Professor Bloodgood.

553. DESIGN OF WATER TREATMENT PLANTS. Sem. 2. Class 2, Lab. 3, cr. 3. Prerequisite: CE 453.

Concepts, principles, and theory of water plant design using a water source for a particular city and developing a treatment and distribution system for the community. Professor Wilke.

554. CHEMICAL ANALYSIS IN ENVIRONMENTAL ENGINEERING. Sem. 1 and 2. Class 2, Lab. 6, cr. 4. Prerequisite: CE 551 or equivalent.

A survey of basic concepts, applications, and limitations of current chemical and instrumental methods of analysis and separation as applied in environmental engineering research. Professor Wolszon.

555. BIOLOGICAL ASPECTS OF ENVIRONMENTAL POLLUTION CONTROL. Sem. 1 and 2. Class 2, Lab. 3, cr. 3.

Introduction to the microbiological aspects of the techniques used in the testing and treatment of air, water and wastewater. Professor Kirsch.

562. RAILWAY ENGINEERING. Sem. 1. Class 3, cr. 3. Prerequisite: CE 461 or consent of instructor.

Geometric and structural design of railroad facilities; route selection; horizontal and vertical alignment; track structure and layout; operational characteristics of equipment; betterments; maintenance operations and equipment; design, operation, and maintenance of signal systems; materials and stores; operational problems.

563. AIRPORT PLANNING AND DESIGN. Sem. 2. Class 2, Lab. 3, cr. 3. Prerequisite: CE 461 or equivalent.

Historical background of aviation and airport development; financing and estimating demand; aircraft characteristics; air traffic control; site selection; airport configuration; geometric design of landing area; planning and development of terminal areas; lighting, pavement design, and drainage; design of heliports. Professor Grecco.

564. TRAFFIC ENGINEERING—CHARACTERISTICS AND MEASUREMENT. Sem. 1. Class 3, cr. 3. Prerequisite: CE 461 or equivalent.

Analysis of basic characteristics of highway traffic and of the elements influencing these characteristics; drivers, vehicles, the highway volume, density, speed, travel time, delay, stream flow, intersection performance, capacity, accidents, traffic demand, and termination; techniques for measuring characteristics.

565. TRAFFIC ENGINEERING—OPERATIONS AND CONTROLS. Sem. 2. Class 2, Lab. 3, cr. 3. Prerequisite: CE 461 or equivalent.

Techniques for making traffic engineering investigations; traffic laws and ordinances, speed regulation, curb parking regulations, through controls, one-way streets, right-of-way regulation; design and application of signs, markings, lighting; and traffic engineering administration.

567. ENGINEERING USES OF AERIAL PHOTOGRAPHY. Sem. 1. Class 2, Lab. 3, cr. 3.

Airphoto interpretation and application to engineering surveys for city planning, highways, airports, and transportation in general, with emphasis on interpretation of land forms and their influence on location studies. Professor Miles.

568. ENGINEERING SITE SELECTION. Sem. 2, Class 2, Lab. 3, cr. 3. Prerequisites: CE 567 or permission of instructor.

A critical analysis and critique of factors influencing the selection of engineering sites. Case studies will be examined. Effects and significance of natural phenomena are to include climate, geology, soils, hydrology and topography. Also included are discussion of political, social, physical and economical factors. Evaluation and development of site feasibility reports of specific projects. Professor Miles.

569. WATERWAYS, PORTS, AND HARBORS. Sem. 2. Class 3, cr. 3. Prerequisite: CE 342 or ME 310.

Navigable streams, canals, channels locks, and dams; natural and artificial harbors, coastal control, and area development; open roadsteads; jetties, piers, breakwaters, navigational aids, channel depth maintenance; tides, currents, and weather; berthing facilities and equipment; loading facilities and equipment; warehousing and transshipment; port authorities and operation; water navigation project reports; economic considerations.

570. ADVANCED STRUCTURAL MECHANICS. Sem. 1. Class 3, cr. 3. Prerequisites: ESC 223 and MA 262.

Flexure and torsion; energy methods, Castigliano's theorems, complementary energy theorem, Maxwell-Mohr method; indeterminate structural and machine members; introduction to ultimate load analysis of indeterminate members; beam columns and beam-tension members.

573. BASIC VIBRATIONS. Sem. 1 or 2. Class 3, cr. 3. Prerequisites: ESC 223 and MA 262 or equivalent.

Harmonic motion; free and forced vibrations of one degree-of-freedom systems with and without damping; vibration measuring instruments, transmissibility; systems with two or several degrees of freedom; Holzer's method; vibration of rods and beams, critical speed of shafts, Rayleigh and Stodola methods. Professors Goldberg and Meyers.

575. STRUCTURAL LABORATORY. Sem. 1. Lab. 3, cr. 1. Prerequisite: CE 371.

Laboratory studies of structural models and components; mechanical analysis; critical examination of theory. Professor Scott.

576. ADVANCED REINFORCED CONCRETE DESIGN. Sem. 2. Class 3, cr. 3. Prerequisite: CE 473. Credit not given for this course in addition to CE 476.

Design of eccentric and combined footings, two-way reinforced floor slabs, flat slab floor systems, continuous span slab bridge, ultimate strength design, deflection of concrete structures and fundamentals of prestressed concrete. Professors Gutzwiller and Lee.

577. THEORY OF PLATES. Sem. 1. Class 3, cr. 3. Prerequisite: MA 262 or equivalent.

Analysis of circular, rectangular, and continuous plates by classical, numerical and approximate methods. Professors Lee and Meyers.

578. APPLIED ELASTICITY. Sem. 1 and 2. Class 3, cr. 3. Prerequisite: MA 262.

Equations of equilibrium, compatibility and boundary conditions, and their application to plane stress and plane strain problems. Stress functions, strain energy methods, stress distribution in axially symmetrical bodies; special problems in structures involving torsion and bending of prismatical bars. Professors Goldberg and Korman.

579. THEORY OF ELASTIC STABILITY. Sem. 1 or 2. SS. Class 3, cr. 3. Prerequisites: MA 262 or equivalent.

Bending of prismatic bars under simultaneous action of axial and lateral loads; buckling of compressed bars in both the elastic and plastic ranges; design formulas; lateral buckling of beams. Professors Goldberg and Gaunt.

590. SYSTEMS DESIGN AND APPLICATION TO NATURAL RESOURCES. Sem. 1 or 2. Class 3, cr. 3.

Systematic design for large-scale environmental works to control, use, and improve water, air, and land resources; resource system economics and statistics; technical and economic design relations; optimization; systems examples from water supply, water quality, air pollution, power, irrigation, drainage, recreation, and coastal engineering.

592. PLASTIC DESIGN OF STEEL STRUCTURES. Sem. 2. Class 3, cr. 3. Prerequisite: CE 470, or equivalent.

Ultimate load capacity of steel structures; methods of analysis for structures in the plastic range; plastic design of continuous beams, frames, and connections. Professors Gaunt and Hayes.

593. CIVIL ENGINEERING DESIGN BY DIGITAL COMPUTER. Sem. 1 and 2. Class 3, cr. 3. Prerequisite: CE 493, CS 200, or equivalent.

Introduction to design optimization techniques for linear and nonlinear, univariable and multivariable functions with or without constraints. Methods included are search techniques, linear programming, dynamic programming, and backtrack programming. Practice in using the digital computer to apply these methods to civil engineering design problems. Professor Lewis.

597. CIVIL ENGINEERING PROJECTS. Hours and credits to be arranged.

GRADUATE LEVEL

600. GEOMETRIC GEODESY. Class 2, Lab. 3, cr. 3.

601. PHYSICAL GEODESY. Class 2, Lab. 3, cr. 3.

602. CELESTIAL GEODESY. Class 2, Lab. 3, cr. 3.

603. ADVANCED PHOTOGRAMMETRY. Class 2, Lab. 3, cr. 3.

604. ANALYTICAL PHOTOGRAMMETRY. Class 2, Lab. 3, cr. 3.

605. ADVANCED GEOMETRIC DATA ADJUSTMENT. Class 2, Lab. 3, cr. 3.

610. LAND USE CONTROLS. Class 3, cr. 3.

611. TOWN PLANNING DESIGN. Class 1, Lab. 6, cr. 3.

612. URBAN LAND USE PLANNING. Class 3, cr. 3.

613. PLANNING METHODOLOGY AND TECHNIQUES. Class 3, cr. 3.

623. ADVANCED STUDIES OF CONSTRUCTION PLANT. Class 3, cr. 3.

631. AGGREGATES AND AGGREGATE RESEARCH. Class 3, cr. 3.

635. BITUMINOUS MATERIALS AND THEIR USES. Class 2, Lab. 3, cr. 3.

636. DESIGN OF BITUMINOUS MIXES. Class 2, Lab. 3, cr. 3.

638. PHYSIOCHEMICAL INSTRUMENTATION IN MATERIALS RESEARCH. Class 2, Lab. 3, cr. 3.

640. METROLOGY OF TURBULENCE. Class 2, Lab. 3, cr. 3.

642. ADVANCED HYDROLOGY. Class 3, cr. 3.

643. ADVANCED HYDROMECHANICS. Class 3, cr. 3.

644. ADVANCED PROBLEMS IN HYDROMECHANICS AND HYDRAULIC ENGINEERING. cr. 1 to 3.

645. SYSTEM DESIGN IN WATER RESOURCE DEVELOPMENT. Class 3, cr. 3.

646. FLUIDELASTICITY. Class 3, cr. 3.

649. WATER RESOURCES. Class 2, cr. 1.

650. ENVIRONMENTAL RADIATION SURVEILLANCE. SS, Class 2, Lab. 3, cr. 3.

651. ADVANCED ENVIRONMENTAL SCIENCE. Class 3, cr. 3.

652. ADVANCED ENVIRONMENTAL ENGINEERING DESIGN. Class 1, Lab. 6, cr. 3.

653. ADVANCED SANITARY ENGINEERING LABORATORY. Lab. 4, cr. 2, or Lab. 6, cr. 3.

656. INDUSTRIAL WASTE DISPOSAL. Class 3, cr. 3.

657. BIODEGRADATION OF ORGANIC WASTES. Class 2, Lab. 3, cr. 3.

662. HIGHWAY PLANNING AND ECONOMICS. Class 3, cr. 3.

663. THEORY OF TRAFFIC FLOW. Class 3, cr. 3.

664. URBAN TRANSPORTATION PLANNING. Class 3, cr. 3.

665. GEOMETRIC DESIGN OF HIGHWAYS. Class 2, Lab. 3, cr. 3.

666. MATERIALS AND ENGINEERING PROBLEMS OF NORTH AMERICA. Class 3, cr. 3, or Class 3, Lab. 3, cr. 4.

667. AIRPHOTO INTERPRETATION OF SOILS AND ROCKS. Class 1, Lab. 6, cr. 3.

668. HIGHWAY AND AIRPORT PAVEMENT DESIGN. Class 2, Lab. 3, cr. 3.

669. URBAN TRANSPORTATION SYSTEMS. Class 3, cr. 3.

670. NUMERICAL METHODS IN STRUCTURAL ENGINEERING. Class 3, cr. 3.

671. BUILDING ENGINEERING. Class 2, Lab. 3, cr. 3.

672. ADVANCED STUDIES OF STATICALLY INDETERMINATE STRUCTURES. Class 3, cr. 3.

673. STRUCTURAL VIBRATIONS AND IMPACT. Class 3, cr. 3.

674. BRIDGE ENGINEERING. Class 2, Lab. 3, cr. 3.

676. BEHAVIOR OF REINFORCED CONCRETE MEMBERS. Class 3, cr. 3.

677. THEORY AND DESIGN OF SHELLS. Class 3, cr. 3.

678. ADVANCED PROBLEMS IN STRUCTURAL FRAMEWORK. Class 3, cr. 3.

679. BUCKLING STRENGTH OF STRUCTURES. Class 3, cr. 3.

680. THEORETICAL SOILS MECHANICS. Class 3, cr. 3.

681. ENGINEERING PROPERTIES OF SOILS. Class 2, Lab. 3, cr. 3.

682. GROUND WATER AND SEEPAGE. Class 3, cr. 3.

683. ADVANCED FOUNDATION ENGINEERING. Class 3, cr. 3.

84. **APPLIED SOIL MECHANICS.** Class 3, cr. 3.

85. **DESIGN OF EARTH STRUCTURES.** Class 3, cr. 3.

89. **SELECTED TOPICS IN SOIL MECHANICS.** Sem. 1. Class 3, cr. 3.

697. **CIVIL ENGINEERING PROJECTS.** Hours and credits to be arranged.

698. **RESEARCH.** M.S. Thesis.

699. **RESEARCH.** Ph.D. Thesis.

GEOSCIENCES

Civil engineering planning, design, and construction is intimately related o a knowledge of geologic materials, and this relationship is recognized by sharng in joint appointment of faculty, and certain equipment and space assignents, with the Department of Geosciences.

GEOS 381 is a part of the core program in civil engineering and the followng additional courses in geology are appropriate electives for students interested more thorough geological training or graduate work in engineering geology. ourse descriptions may be obtained by reference to the catalog of the School of cience.

UNDERGRADUATE LEVEL

3. **MINERALOGY.** Sem. 1. Class 2, Lab. 3, cr. 3.

4. **PETROLOGY.** Sem. 2. Class 2, Lab. 3, cr. 3.

3. **STRUCTURAL GEOLOGY.** Sem. 1. Class 2, Lab. 3, cr. 3.

1. **GEOLOGY FOR ENGINEERS I.** Sem. 1 and 2. Class 1, Lab. 3, cr. 2 (6 CE). Principles and applications of physical, uctural, and historical geology. Rocks d rock minerals, topograghic and geogic maps, aerial photographs, field ethods, and engineering applications. eld investigations are required. Professor West and staff.

1. **PRINCIPLES OF ECONOMIC GEOLOGY.** Sem. 1. Class 2, Lab. 3, cr. 3.

DUAL LEVEL—UNDERGRADUATE AND GRADUATE

). **SEDIMENTATION.** Sem. 2. Class 3, cr. 3.

. **GLACIAL GEOLOGY.** Sem. 2. Class 3, cr. 3.

523. **GEOMORPHOLOGY.** Sem. 1. Class 2, Lab. 3, cr. 3.

543. **OPTICAL MINERALOGY.** Sem. 1. Class 2, Lab. 3, cr. 3.

555. **GEOPHYSICAL EXPLORATION.** Sem. 1. Class 2, Lab. 3, cr. 3.

584. **GROUND WATER GEOLOGY.** Sem. 2. Class 3, cr. 3.

586. **ENGINEERING GEOLOGY.** Sem. 2. Class 2, Lab. 0, cr. 3.

591. **ADVANCED TOPICS.** Sem. 1 and 2. cr. 1-3. Arrange credit.

593. **GEOLOGY FOR ENGINEERS.** Sem. 1. Class 2, Lab. 3, cr. 3.

GRADUATE LEVEL

640. **PETROGRAPHY OF AGGREGATES.** Sem. 2. Class 2, Lab. 3, cr. 3.

654. **GEOPHYSICAL EXPLORATION FOR ENGINEERS.** Sem. 2. Class 2, Lab. 3, cr. 3.

693. **CLAY MINERALOGY FOR CIVIL ENGINEERS.** Sem. 2. Class 2, Lab. 3, cr. 3.

ELECTRICAL ENGINEERING

J. C. Hancock, Head of the School
A. L. Shelley, Executive Assistant

Professors: L. E. Beck, M.S.E.E.; J. H. Bowman, M.S.E.; G. R. Cooper, Ph.D.; J. E. Eaton, Ph.D.; A. H. El-Abiad, Ph.D.; Stephen Freeman, Jr., S.M.; F. J. Friedlaender, Ph.D.; King-sun Fu, Ph.D.; J. C. Hancock, Ph.D.; G. E. Happell, M.A., M.S.E.; W. H. Hayt, Jr., Ph.D.; W. M. Hesselberth, M.S.; G. W. Hughes, Sc.D.; B. J. Leon, Sc.D.; J. A. McFadden, Ph.D.; C. D. McGillem, Ph.D.; V. L. Newhouse, Ph.D.; E. M. Sabbagh, Ph.D.; F. V. Schultz, Ph.D.; C. W. Steeg, Jr., Ph.D. (Fort Wayne Campus); R. W. Vest, Ph.D.; W. L. Weeks, Ph.D.; T. J. Williams, Ph.D.

Associate Professors: Chin-Lin Chen, Ph.D.; L. O. Chua, Ph.D.; F. J. Clark, Ph.D.; P. B. Cox, M.S.E. (Fort Wayne Campus); C. M. Evans, Ph.D.; Keinosuke Fukunaga, Ph.D.; R. L. Gonzales, Ph.D. (Calumet Campus); R. L. Gunshor, Ph.D.; V. B. Haas, Ph.D.; R. A. Holmes, Ph.D.; R. L. Kashyap, Ph.D.; A. J. Koivo, Ph.D.; L. A. Kramer, M.S.E.E.; D. J. LaMothe, M.S.E.E.; D. A. Landgrebe, Ph.D.; Pen-Min Lin, Ph.D.; J. C. Lindenlaub, Ph.D.; J. Y-S. Luh, Ph.D.; D. B. Miller, Ph.D.; L. L. Ogborn, Ph.D.; E. A. Patrick, Ph.D.; E. M. Schmidt, Ph.D.; R. J. Schwartz, Sc.D.; A. L. Shelley, Ph.D.; L. F. Silva, Ph.D.; K. N. Stanton, Ph.D.; H. W. Thompson, Ph.D.; P. A. Wintz, Ph.D.

Assistant Professors: R. M. Anderson, Ph.D.; Y. E. Chen, Ph.D.; J. W. Hammann, Ph.D. (Calumet Campus); J. F. Hayes, Ph.D.; Yen-Long Kuo, Ph.D.; M. M. Miller, Ph.D.; F. J. Mowle, Ph.D.; G. W. Neudeck, Ph.D.; S. B. Sample, Ph.D.; George Saridis, Ph.D.; V. Y. Shen, Ph.D.; G. S. Tahim, Ph.D. (Indianapolis Campus); R. H. Turpin, Ph.D. (Indianapolis Campus); S. L. Uppal, Ph.D. (Calumet Campus); M. J. Wozny, Ph.D.

Visiting Assistant Profoessors: R. A. Jarvis, Ph.D.; V. E. Mablekos, Ph.D.; R. L. McNally, Ph.D.; Venkitachalam Radhakrishnan, Ph.D.

UNDERGRADUATE LEVEL
Lower-Division Courses

201. **INTRODUCTION TO ELECTRICAL ENGINEERING.** Sem. 1 and 2. SS. Class 3, credit 3. (3 EE). Prerequisites or corequisites: MA 261 and PHYS 261.

Physical basis of circuit analysis. Volt-ampere descriptions of circuit elements. Circuit equations, Kirchhoff's laws, graphical analysis. Vacuum tube and transistor circuits. Exponential transients, sinusoidal steady-state, impedance. Magnetic circuits. Introduction to dc machines. Professor D. Miller and staff.

202. **LINEAR ELECTRONIC CIRCUITS.** Sem. 1 and 2. SS. Class 3, cr. 3. (4 EE). Prerequisite: EE 201.

General analysis methods for linear electronic circuits. Systematic application of Kirchhoff's laws. Steady state frequency domain analysis. Terminal and port description of networks. Filters. Coupled amplifiers. General transient analysis via state variables. Professor El-Abiad and staff.

207. **ELECTRICAL ENGINEERING LABORATORY I.** Sem. 1 and 2. SS. Lab. 3, cr. 1. (3 EE). Prerequisite or corequisite: EE 201.

Laboratory exercises in instrumentation, device characteristics, vacuum tube circuits, waveforms, transistor circuits, magnetic devices, and energy converters. Professor Silva and staff.

208. **ELECTRICAL ENGINEERING LABORATORY II.** Sem. 1 and 2. SS. Lab. 6, cr. 2. (4 EE). Prerequisites or corequisites: EE 207, EE 202, and EE 251.

Laboratory exercises in computer programming, modern devices, nonlinear and piece-wise linear synthesis, unipolar and bipolar transistors, resistive and first order nonlinear circuits, biasing and sensitivity, and linear amplifiers. Professor Lin and staff.

231. ELECTRICAL ENGINEERING. Sem. 1 and 2. SS. Class 2, Lab. 3, cr. 3. (4 ME). Prerequisites or corequisites: MA 202 and PHYS 241.

Introduction to electrical parameters and circuit theory. Linear and nonlinear circuit analysis. Properties of the semiconductor diode. Exponential and sinusoidal circuit excitation. Phasors and resonance. Professor LaMothe and staff.

251. INTRODUCTION TO NONLINEAR CIRCUITS. Sem. 1 and 2. SS. Class 3, cr. 3. (4 EE). Prerequisite or corequisite: EE 202.

Foundations of nonlinear network theory. Operating point problem. Graphical analysis and synthesis of driving point and transfer characteristics of resistive networks. Resistive nonlinear functional networks—clippers, voltage, and current regulators. Iterative piece-wise linear analysis and synthesis of dynamic networks. Dynamic nonlinear functional networks—multivibrators, time base generators. Professors Chua and staff.

291. INDUSTRIAL PRACTICE I. Sem. 1 and 2. SS. cr. 0. For cooperative program students only.

292. INDUSTRIAL PRACTICE II. Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisite: EE 291.

UNDERGRADUATE LEVEL
Upper-Division Courses

301. SIGNALS AND SYSTEMS. Sem. 1 and 2. Class 4, cr. 4. (5 EE). Prerequisite: EE 202 and EE 208.

Description of deterministic signals through the use of Fourier Series, Fourier and Z-Transforms. System description treated by differential and difference equations including transform methods. Computation of system response to both continuous and discrete inputs. Professor Saridis and staff.

302. PROBABILISTIC METHODS IN ELECTRICAL ENGINEERING. Sem. 1 and 2. Class 3, cr. 3. (5 EE). Prerequisite: MA 262; prerequisite or corequisite: EE 301.

An introductory treatment of probability theory including distribution and density functions, moments and random variables. Applications of normal and exponential distributions. Estimation of means, variances, correlation and spectral density functions. Random processes and response of linear systems to random inputs. Professor Cooper and staff.

303. ELECTRONIC SYSTEMS. Sem. 2. Class 3, Problem 2, Lab. 3, cr. 5. (6 EE R&D). Prerequisites: MA 262, EE 202, EE 208, and EE 251.

Analysis, design, and synthesis of electronic systems with emphasis on the application of modern solid state devices in signal processing. Specific topics include vector-matrix formulaton and solution of linear system problems, signal flow graph and feedback concepts, representation of deterministic and random signals with applications to modulation and detection problems. Professor Leon and staff.

307. ELECTRICAL ENGINEERING LABORATORY III. Sem. 1 and 2. SS. Lab. 3, cr. 1. (5 EE). Prerequisite: EE 208; prerequisites or corequisites: EE 301 and EE 311.

Continuation of EE 208. Experimental exercises illustrating concepts in transmission lines, electromagnetic fields, signals and simple systems. Professors C. Chen and Luh.

308. ELECTRICAL ENGINEERING LABORATORY IV. Sem. 1 and 2. SS. Lab. 3, cr. 1. (6, 7 EE). Prerequisite: EE 307; prerequisite or corequisite: EE 352.

Laboratory practice in the design and simulation of electronic, electromechanical and electromagnetic systems employing feedback, modulation and digital logic. Introduction to the use of analog/hybrid computers. Professors Wozny and Ogborn.

311. ELECTRIC AND MAGNETIC FIELDS. Sem. 1 and 2. SS. Class 3, cr. 3. (5EE). Prerequisites: MA 262 and PHYS 261.

Continued study of vector calculus, electrostatics, and magnetostatics. Maxwell's equations. Introduction to electromagnetic waves, transmission lines, and radiation from antennas. Professor Schultz and staff.

314. ELECTRICAL ENGINEERING. Sem. 1 and 2. Class 2, Lab. 3, cr. 3. (8 CE). Prerequisites: MA 262 and PHYS 251.

Basic circuits, electronic and introductory feedback control systems. Professor Beck and staff.

317. ELECTRICAL ENGINEERING. Sem. 1 or 2. Class 2, Lab. 2, cr. 3. (5, 6 ENGR). Prerequisites: MA 262, and PHYS 251 or 211.

Electrical networks, electrical instrumentation, and transfer functions. Professor Freeman and staff.

318. ELECTRICAL ENGINEERING. Sem. 1 or 2. Class 2, Lab. 2, cr. 3. (6, 7 ENGR). Prerequisite: EE 317.

Electromechanical systems, vacuum tubes, transistors, electronic circuits, and elements of feedback theory. Professor Freeman and staff.

319. ELECTRICAL NETWORKS I. Sem. 1 and 2. Class 3, cr. 3. (5 AA&ES). Prerequisites: PHYS 261 and MA 262, or equivalent.

The fundamentals of linear electric networks built on a background of basic physics and elementary differential equations. The basic laws and theorems of electric networks containing resistance, inductance, capacitance, and sources both independent and dependent. Both time and frequency domain considerations are included. Professor Evans and staff.

320. ELECTRICAL NETWORKS II. Sem. 1 and 2. Class 3, cr. 3. (6 AA&ES). Prerequisite: EE 319.

A continuation of EE 319 to include electronic devices such as tubes and transistors. Nonlinear elements are introduced by piece-wise linear and by graphical methods. Professor Evans and staff.

321. ELECTROMAGNETIC ENERGY CONVERSION PRINCIPLES. Sem. 1 and 2. SS. Class 3, cr. 3. (6, 7 EE). Prerequisite: EE 311; prerequisites or corequisites: EE 301 and ESC 306.

Treatment of electromechanical energy convertors with emphasis on their dynamic performance. Equivalent-circuit models and block diagrams for translation and rotational energy transducers. Idealized machines and practical machine considerations. Transformers. Professor Kramer and staff.

342. ELECTRICAL ENGINEERING. Sem. 1 and 2. SS. Class 2, cr. 2. (5 ME). Prerequisite: EE 231.

Continuation of EE 231. Characteristics of electronic devices. Incremental circuit model. Amplifier circuits. Magnetic devices. Generation of voltages and torques. Rotating machinery. Professor LaMothe and staff.

352. INTRODUCTION TO SYSTEM DESIGN. Sem. 1 and 2. SS. Class 3, cr. 3. (6 EE). Prerequisite: EE 301; prerequisite or corequisite: EE 302.

Feedback, modulation, and digital systems. System specification, design, and limitations. Applications in automatic control, electronics, and communications. Emphasis on analog and digital computer simulation and analysis. Professors Ogborn and Wozny.

353. ELECTRONICS. Sem. 1 and 2. SS. Class 3, Lab. 3, cr. 4. (6 ME). Prerequisite: EE 342.

Modeling concepts, analysis of diode, transistor and vacuum tube circuits, introduction to digital systems. Professor Happell and staff.

393. INDUSTRIAL PRACTICE III. Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisite: EE 292.

394. INDUSTRIAL PRACTICE IV. Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisite: EE 393.

395. INDUSTRIAL PRACTICE V. Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisite: EE 394.

400. MODERN DEVICES SEMINAR. Sem. 1 and 2. Class 2, cr. 1. (7, 8 EE). Prerequisite: senior classification.

An introduction by lecture-demonstrations of specialized topics and devices of current interest and future practical value. Professor Hayt.

402. MATERIALS AND CIRCUIT MODELS. Sem. 1 and 2. SS. Class 4, cr. 4. (6, 7, 8 EE). Prerequisites: EE 311, and PHYS 342; prerequisite or corequisite: ME 308.

Conduction processes in metals and semiconductors. PN junctions, transistors, and equivalent circuits. Linear and nonlinear polarization and magnetization processes. Magnetic and dielectric devices and circuit models. Professor Schwartz and staff.

407. ELECTRICAL ENGINEERING LABORATORY V. Sem. 1 and 2. SS. Lab. 3, cr. 1. (6, 7, 8 EE). Prerequisite or corequisite: EE 402.

Continuation of EE 308. Laboratory practice and experimental exercises related to EE 402 with emphasis on the interaction of fields and materials in practical electromechanical and electro-

magnetic circuits and systems. Professor Thompson.

409. **ENGINEERING ADMINISTRATION.** Sem. 1 and 2. SS. Class 3, cr. 3. (7, 8 EE). Prerequisite: senior classification.

Value and use of money; depreciation, economic selection, cost determination; business law, engineering procedures, and professional ethics.

432. **ELECTRIC POWER SYSTEMS.** Sem. 1 and 2. Class 3, cr. 3. (el.). Prerequisite: EE 202.

Three-phase circuits. Equivalent single phase circuits. Electrical characteristics of lines, transformers, generators, and loads with particular reference to their behavior when interconnected as systems. Professor Eaton and staff.

440. **TRANSMISSION OF INFORMATION.** Sem. 1 and 2. SS. Class 3, Lab. 3, cr. 4. (el.). Prerequisites: EE 301 and EE 352.

Applications of statistical communication theory to amplitude, phase, and frequency modulation. Also treated are matched filtering, correlation, and signal detection with applications to various digital data systems. Heavy emphasis on engineering applications of the theory with numerous design problems. Professor Lindenlaub and Staff.

441. **DISTRIBUTED-PARAMETER SYSTEMS.** Sem. 1 and 2. SS. Class 3, cr. 3. (el.). Prerequisite: EE 311.

Transient and steady state behavior of transmission lines; wave guides, antennas, propagation, noise, microwave sources, system design. Professor Weeks and staff.

445. **ELEMENTARY NETWORK SYNTHESIS.** Sem. 1 and 2. Class 3, Lab. 3, cr. 4. (el.). Prerequisites: EE 301, EE 307, and EE 352.

Synthesis of linear one-ports and two-ports to meet varied specifications by appropriate techniques. Laboratory work partly use of digital computer in design, partly assembly and test of student's designs. Professor Leon.

452. **TRANSIENTS IN ELECTRONIC CIRCUITS.** Class 3, Lab. 3, cr. 4. (el.). Prerequisite: EE 352 or EE 353.

Linear and nonlinear wave-shaping circuits, timing circuits, tube and semiconductor devices operating in the switching mode; pulse transformers and delay lines. Professor Happell.

455. **SOLID STATE CIRCUIT ANALYSIS AND DESIGN I.** Sem. 1 and 2. Class 3, cr. 3. (el.). Prerequisite: EE 202 and EE 251; recommended prerequisite or corequisite: EE 402.

Analysis and design of circuitry containing both discrete and integrated solid state elements. Applications involving bipolar and field effect transistors, diodes, electro-optic devices, and thermal components. Emphasis is on the design engineer's approach to electronic circuit problems. Professor Silva and staff.

456. **SOLID STATE CIRCUIT ANALYSIS AND DESIGN II.** Sem. 2. Class 3, cr. 3. (el.). Prerequisite: EE 455.

Design and application of integrated circuits as a continuation of the material on integrated circuits introduced in EE 455. In addition, the material on circuits containing thyristors, uni-junction transistors and silicon controlled switches will be expanded. Design skills emphasized. Professor Silva and staff.

463. **INTRODUCTION TO INFORMATION PROCESSING.** Sem. 1 and 2. Class 3, cr. 3. (el.). Prerequisites: EE 301 and EE 352.

An introductory survey of concepts and methods for modern information processing with emphasis on the digital approach. Topics include discrete coding, analog-to-digital conversion, computer processing techniques, and illustrative applications. Professor Landgrebe and staff.

465. **DESIGN OF HYBRID COMPUTING SYSTEMS.** Sem. 2. Class 3, Lab. 3, cr. 4. (el.). Prerequisite: EE 352.

Introduction to the design of analog/hybrid computing elements and hybrid linkage systems, I/O structure of digital processor for hybrid implementation. Advanced hybrid concepts. Hybrid considerations for real time simulation. Professor Wozny and staff.

466. **INTRODUCTION TO THE DESIGN OF DIGITAL COMPUTERS.** Sem. 1 and 2. Class 3, cr. 3. (el.). Prerequisite: junior classification.

Introduction to the functional design of digital computers. Topics include basic machine organization, algorithms for high speed digital computation and their hardware realization. Design of both fixed point and floating point arithmetic units and the design of special purpose digital hardware. Professor Mowle and staff.

467. **INTRODUCTORY DIGITAL COMPUTER LABORATORY.** Sem. 1 and 2. Lab. 3, cr. 1. (el.). Prerequisite or corequisite: EE 466.

Laboratory experiments follow closely the material of EE 466. Emphasis is on the hardware implementation of the computational algorithms of high speed digital computers. Professor Mowle and staff.

469. **INTRODUCTION TO THE THEORY OF COMPUTING MACHINES.** Sem. 2. Class 3, cr. 3. (el.). Prerequisite: junior classification.

Some of the topics treated in the course are: the concept of finite state machine and its analysis, machine minimization, computable functions, recursive functions and propositional calculus. Professor Kashyap and staff.

480. **NUMERICAL ANALYSIS FOR ELECTRICAL ENGINEERS.** Sem. 2. Class 3, cr. 3. (el.). Prerequisite: EE 352 or senior classification.

Application of the digital computer to the solution of electrical engineering problems using the methods of numerical analysis. Professor Freeman and staff.

483. **AUTOMATIC CONTROL SYSTEMS.** Sem 1 and 2. SS. Class 3, cr. 3. (el.). Prerequisite: EE 352.

Component and system transfer functions. Transient response to deterministic inputs and definition of time domain specifications. Open and closed loop frequency response. Bode diagrams, Nyquist diagrams, root locus, and frequency specifications. Stability and relative stability criteria. Introduction to synthesis. Professor Wozny and staff.

490. **SEMINAR IN ELECTRICAL ENGINEERING.** Sem. 2. Class 1, cr. 1. (6 EE Honors).

Introduction to current areas for research in electrical engineering. Staff.

495. **SELECTED TOPICS IN ELECTRICAL ENGINEERING.** cr. 1 to 4. (el.).

496. **ELECTRICAL ENGINEERING PROJECTS.** (el.). Hours and credits to be arranged.

DUAL LEVEL—UNDERGRADUATE AND GRADUATE

500. **RANDOM VARIABLES AND SIGNALS.** Sem. 1 and 2. SS. Class 3, cr. 3. Prerequisites: EE 440 or EE 483 or graduate standing.

Engineering applications of probability theory. Problems on events, independence, random variables, distribution and density functions, expectations, and characteristic functions. Dependence, correlation, and regression; multivariate Gaussian distribution. Stochastic processes, stationarity, ergodicity, correlation functions, spectral densities, random inputs to linear systems; Gaussian processes. The Graduate Committee.

502. **LUMPED SYSTEM THEORY.** Sem. 1 and 2. Class 3, cr. 3. Prerequisite: EE 440 or EE 483 or graduate standing.

Basic methods of modern system theory. Time domain techniques for both linear and nonlinear systems. Characterization of both continuous and discrete-time linear systems in the time and frequency domains. Energy relationships and the restriction that positive energy storage places on physical systems. The Graduate Committee.

504. **ELECTROMAGNETIC FIELD THEORY.** Sem. 1 and 2. SS. Class 3, cr. 3. Prerequisite: EE 311 or graduate standing.

Review of general concepts (Maxwell's equations, materials interaction, boundary conditions, energy flow), statics (Laplace's equation, Poisson's equation, mapping), distributed parameter systems (classification of solutions, transmission lines and waveguides), radiation and antennas (arrays, reciprocity, Huygen's principle), a selected special topic (e.g., quantum electronics, plasmas, coupled modes, relativity). The Graduate Committee.

506. **ELECTRICAL PROPERTIES OF MATERIALS.** Sem. 1 and 2. SS. Class 3, cr. 3. Prerequisite: EE 402 or graduate standing.

Review of quantum mechanics. Crystal structure. Bravais lattices, energy bands. Conduction processes in metals and nonmetals, effective mass, scattering mechanisms, continuity equation and junction theory. Fields-material interaction including dielectric losses and magnetic permeability. Energy converting properties of solids. The Graduate Committee.

513. **ELECTROMAGNETIC BOUNDARY-VALUE PROBLEMS.** Class 3, cr. 3. Prerequisite: EE 504 or consent of instructor.

Boundary-value problems of electromagnetic theory with application to electrostatics and passive microwave systems.

Properties and applications of Bessell and Legendre functions. Emphasis is placed on obtaining solutions in forms suitable for engineering applications. Computer solutions will be utilized where practicable. Professor Evans.

515. ELECTRICAL INSTRUMENTATION. Class 2, Lab. 3, cr. 3. (nonEE, el.). Prerequisite: EE 314, EE 318, or equivalent.

Basic electrical measurements. Measurement of nonelectrical quantities by electrical means. Transducers. Professor LaMothe.

516. INDUSTRIAL ELECTRONIC CONTROL. Class 2, Lab. 3, cr. 3. (nonEE, el.). Prerequisite: EE 314, EE 318, or equivalent.

Electronic methods as applied to the control of industrial products and machinery. Professor LaMothe.

517. BIOLOGICAL ELECTRONICS. Sem. 1. Class 3, cr. 3. (el.). Prerequisites: graduate standing and facility in algebra and trigonometry.

This course is intended for graduate students in biological science, psychology, pharmacology, veterinary science, and speech and hearing science. Not open to students in engineering or physics.

Introduction to the circuit concept and methods of circuit analysis. Properties of electronic devices which are pertinent to biological instrumentation. Actual electronic instruments and systems in use in biological research discussed. Professor Hughes.

518. INFORMATION TRANSMISSION, MODULATION, AND NOISE. SS. Class 3, cr. 3. Prerequisite: Graduate standing and equivalents of EE 352 and MA 302. (This course is intended for graduate students majoring in areas other than electrical engineering. Not open to students majoring in electrical engineering.)

The concepts of the information content of signals and the information capacity of communication channels are introduced. The effect of ionized media upon electromagnetic waves is discussed with emphasis being upon the attenuation, reflection and refraction, and scattering of the incident wave. Signal and system theory is reviewed as a background to the treatment of analog and digital modulation-demodulation techniques. Noise limitations of circuit devices and their effect on communication systems are analyzed. Professor Lindenlaub.

520. MAGNETICS. Class 3, cr. 3. Prerequisite: EE 402 and EE 407.

Diamagnetism, paramagnetism, ferro-, ferri-, and antiferromagnetism. Fine particles and applications to permanent magnets and tape recording. Domains and domain walls. Models of thin film and bulk material magnetic flux reversal processes. Computer magnetics. Circuits containing nonlinear magnetic elements. Professors Friedlaender and Silva.

523. (MSE 523). PHYSICAL CERAMICS. Sem. 1. Class 3, cr. 3. Prerequisite: Senior or graduate classification in science or engineering.

Fundamental concepts of the physical properties of ceramic materials and the relation of these properties to atomic interactions and microstructure. Areas covered include structure and phase relationships in crystalline ceramics; glasses; surfaces and interfaces; sintering and diffusion; mechanical, thermal, electrical, and optical properties; and ceramic processing as it influences properties. Professor Vest.

525. MODERN METHODS OF ELECTRICAL MACHINE ANALYSIS. Sem. 1 and 2. Class 3, cr. 3. Prerequisite: EE 321 or by consent of instructor.

The use of matrix algebra is advocated in this course for the development of performance equations of d.c. and a.c. machines. The d, q, o, the symetrical components, the α, β and o transformations are introduced for the study of machines in general. Professor Sabbagh.

527. DIRECT ENERGY CONVERSION. Sem. 2. Class 3, cr. 3. Prerequisite: EE 402 or by consent of instructor.

Fundamental concepts and requirements of direct energy conversion. Primary emphasis is on the microscopic details and models of direct energy conversion processes. Professor Schwartz.

532. COMPUTATIONAL METHODS FOR POWER SYSTEM ANALYSIS I. Sem. 1. Class 3, cr. 3. Prerequisite or corequisite: EE 321.

Electrical characteristics of power system components, system modeling, and matrix analysis of large networks. Professor El-Abiad and staff.

533. COMPUTATIONAL METHODS FOR POWER SYSTEM ANALYSIS II. Sem. 2. Class 2, Lab. 3, cr. 3. Prerequisite: EE 532 or by consent of instructor.

Application of numerical techniques and computer methods to the solution of a variety of problems related to the planning, design, and operation of electric power systems. Professor El-Abiad.

536. BIOLOGICAL ENGINEERING. Sem. 1. Class 2, Lab. 3, cr. 3. Prerequisites: Graduate standing and MA 223-224 or equivalent. Not open to students in engineering.

Introduction to the fundamental laws and concepts of the physical sciences with an emphasis on electrical and electromechanical systems. Professors Clark and Schmidt.

537. PRINCIPLES OF ENGINEERING ANALYSIS. Sem. 2. Class 2, Lab. 3, cr. 3. Prerequisite: EE 536. Not open to students in engineering.

A further development of the techniques and methods used in the physical sciences. Material will include the mathematics and methods needed to analyze biological systems and to build analog models of such systems. The treatment will be fundamental and thus applicable to most phases of biological research. Professors Clark and Schmidt.

538. ENGINEERING TECHNIQUES IN BIOLOGICAL RESEARCH. Sem. 1. Class 2, Lab. 3, cr. 3. Prerequisite: EE 537. Not open to students in engineering.

Will cover the development and use of analog and mathematical methods of analysis with an emphasis on systems. Current techniques and instrumentation used in biological research will be stressed. Professors Clark and Schmidt.

540. ANTENNAS: DESIGN AND APPLICATIONS. Class 3, cr. 3. Prerequisites: EE 441; prerequisite or corequisite: EE 504.

Electrically small antennas; arrays; wire antennas and feeding arrangements; aperture antennas such as slots, horns, and parabolic reflectors; antennas for multiple frequencies including log-periodic and other frequency independent types; receiving antennas and the concept of antenna temperature; antenna measurements and evaluation. Professor Weeks.

542. UHF AND MICROWAVE LABORATORY. Sem. 1 and 2. SS. Class 0, Lab. 3, cr. 1. (el.). Prerequisite or corequisite: EE 441 or EE 541, or graduate standing.

A self-contained laboratory of 15 experiments in ultra-high-frequency and microwave measurements and devices. Professor Weeks and staff.

544. COMMUNICATION NETWORKS. Sem. 1. Class 3, cr. 3. Prerequisite: EE 445, or consent of instructor.

Methods of linear network synthesis with emphasis on techniques applicable to L-C and R-C wave filters and equalizers

546. LINEAR GRAPHS AND ELECTRICAL NETWORKS. Sem. 1. Class 3, cr. 3. Prerequisite: EE 301.

Introduction to linear graph theory with emphasis on applications to electrical network theory. Classical network equilibrium equations. Formulation of the state equations. Topological formulas for network functions. Signal flow graph method of circuit and system analysis. The network flow problem. Professor Lin.

547. AN INTRODUCTION TO STATISTICAL COMMUNICATION THEORY. Sem. 1 and 2. SS. Class 3, cr. 3. Prerequisite: EE 500.

Communication as a statistical decision problem. Random signals in linear systems. Multidimensional Gaussian random processes. Vector representation of channels and signals, orthogonal expansions of signals, and geometric interpretation of signals in N-dimensional space. Information theory. Optimum receivers. Probability of error. Important channel models and analysis of various modulation methods. Optimum mean square filtering and estimation theory. Professor McGillem and staff.

548. LINEAR ACTIVE NETWORK THEORY. Sem. 2. Class 3, cr. 3. Prerequisite: EE 502; corequisite: MA 525.

Foundations of linear networks; concepts of passivity, activity, reciprocity, causality and stability. Scattering matrix and its application to broadband matching problems. Negative resistance amplifiers. Synthesis of active RC networks. Sensitivity. Professor Kuo.

549. PULSE-CODE MODULATION SYSTEMS. Sem. 2. Class 3, cr. 3. Prerequisite: EE 500.

The problem of transmitting analog signals over digital channels is studied. A mathematical model of a complete PCM system is presented and its performance analyzed. The theoretical foundations of information sources and a number of source encoding, quantization, and channel coding strategies are developed. Synchronization and data formating are discussed along with space and commercial applications. Professors Hayes and Wintz.

552. QUANTUM ELECTRONICS. Sem. 2. Class 3, cr. 3. Prerequisites: EE 504 and PHYS 550 or EE 506, or by consent of instructor.

An introduction to masers and lasers. The topics include brief review of quantum mechanics and theory of atomic spectra, interaction of radiation with matter, microwave masers, solid state lasers, gas lasers, injection lasers and application of lasers to communication systems, nonlinear optics, welding and machining.

554. ELECTRONIC INSTRUMENTATION AND CONTROL CIRCUITS. Class 3, cr. 3. (el.). Prerequisites: EE 301 and EE 352.

Analysis and design of special amplifiers, pulse circuits, operational circuits, DC amplifiers, and transducers used in instrumentation, control, and computation. Professor Ogborn.

555. SEMICONDUCTOR-CIRCUIT ANALYSIS. Sem. 1 and 2. Class 3, cr. 3. Prerequisites: EE 352 and EE 402.

Transistors as circuit elements, DC bias and stability, low-frequency small-signal amplifiers, power amplifiers, regulated power supplies, high-frequency models, broad-band low-pass amplifiers, band-pass amplifier, transistors as switches, oscillators, tunnel diodes, tunnel diode circuits. Professor Hesselberth.

556. SEMICONDUCTOR DEVICES. Class 3, cr. 3. Prerequisite: EE 352 or equivalent.

The electrical properties and applications of semiconductor devices. Professor Thompson.

557. SEMICONDUCTOR ELECTRONICS LABORATORY. Sem. 1 and 2. Class 1, Lab. 4, cr. 3. Must be preceded by either EE 402 or consent of instructor. (Limited registration.)

Experiments on basic concepts in solid state materials, device technology, and design. Resistivity thermoelectric power, temperature dependence of specific heat, Hall effect, mobility, lifetime abrupt and diffused junctions, destructive and nondestructive analysis. Professor Thompson.

560. FUNDAMENTALS AND APPLICATIONS OF ACOUSTICS. Sem. 2. Class 3, cr. 3. (Offered in 1970-71 and alternate years.) Prerequisite: MA 262 or equivalent.

Electromechanical circuit analysis with particular attention to mechanical impedance, distributed parameter and traveling-wave systems. Sound radiating systems and transducers. Sound sensation and the hearing mechanism. Professor Hughes.

563. INFORMATION PROCESSING. Sem. 1. Class 3, cr. 3. Prerequisites: EE 500, MA 511, and knowledge of material in EE 463 desirable.

Discussion of basic theoretical methods for information processing; trade offs between digital and analog approaches for implementing the methods are emphasized. Topics include methods for signal representation, data compression, decision making, digital filtering, digital error problems, and man-machine interaction. Professor Patrick and staff.

564. INTRODUCTION TO FORMAL LANGUAGES AND SYNTACTIC ANALYSIS. Sem. 1. Class 3, cr. 3. Prerequisite: EE 469 or CS 484.

Introduction to phase-structure grammar, context-sensitive, context-free, and finite-state languages. Discussion of recognition devices such as pushdown automata, linear bounded automata, stack automata, and balloon automata. Decision problems and measures of complexity of languages. Special topics include modified grammars, stochastic languages, and some current topics of interest. Professor Fu and staff.

566. COMPUTER SYSTEM WORKSHOP. Sem. 1. Class 2, Lab. 3. (arrange hours), cr. 3. (el.). Prerequisite: EE 466 or graduate standing.

Discussion of the important concepts in computer systems. Topics selected may include computer memory, special purpose computer systems, redundant computation, parallel processing, large scale integration, residue number systems, and hybrid computation systems. Students are expected to carry out a design project in the general area of computer systems. Computer Area Staff.

568. INTRODUCTION TO ARTIFICIAL INTELLIGENCE AND PATTERN RECOGNITION. Sem. 1. Class 3, cr. 3. Prerequisite: EE 302.

Introduction to the basic concepts and various approaches of making systems behave intelligently. The topics considered in this course include theory of neural nets, basic pattern recognition techniques and training methods, visual and speech recognition machines, game playing machines, heuristic programming, and problem solving machines. Professor Fukunaga.

569. THEORY OF SEQUENTIAL NETWORKS. Class 3, cr. 3. Prerequisite: EE 466 or equivalent or consent of instructor.

Sequential machine models, regular expressions, the state assignment problem, machine minimization techniques, asychronous switching theory, and analysis and synthesis of linear sequential networks. Professor Mowle.

571. ELECTRICAL TRANSIENTS. Class 3, cr. 3. (el.). Prerequisite: EE 301.

Application of the classical operator, and Laplace transform methods in determining equations and wave forms of transient quantities in electrical circuits and electromechanical systems. Professor Shelley.

576. FUNDAMENTALS OF SIGNAL DESCRIPTION. Sem. 1. Class 3, cr. 3. Prerequisites: EE 440 and MA 510, or graduate standing.

The study of techniques for representing and analyzing signals. Emphasis on the practical application of theoretical approaches. Topics include Fourier analysis, generalized functions, sampling, time-bandwidth product, signal dimensionality, instantaneous spectra, analytic signals and Hilbert Transforms, orthogonality and more general signal representations. Professor Landgrebe.

583. INTRODUCTION TO AUTOMATIC CONTROL SYSTEMS. Class 3, cr. 3. Prerequisite: Graduate standing (For Off-Campus non-electrical engineering majors).

Mathematical modeling of a system. Linear systems analysis in the time and frequency domains. State variables and transfer functions. Stability, controllability, and observability. Feedback control design techniques. Equalizer synthesis on Bode-Nyquist and root-locus diagrams. Analytic design and parameter optimization techniques.

585. DIGITAL PROCESS CONTROL AND MATHEMATICAL MODELING OF INDUSTRIAL SYSTEMS. Sem. 2. Class 3, cr. 3. Prerequisite: EE 483 or equivalent.

This course describes the present status of automatic control in industry with emphasis on the application of digital control. Problems involved in the use of both supervisory and direct digital control systems will be presented and the development of process mathematical models will also be covered. Professor Williams and staff.

586. INTRODUCTION TO MODERN CONTROL THEORY. Sem. 1 and 2. Class 3, cr. 3. Prerequisite: EE 502 or EE 583 for off-campus students.

Discussion of basic theoretical methods in modern control theory. Topics include parameter optimization techniques, maximum principle and dynamic programming approaches to optimal control problems, second variation technique and sufficient conditions, singular control and introduction to adaptive control.

587. DESIGN AND COMPUTATIONAL TECHNIQUES FOR CONTROL SYSTEMS. Sem. 1 and 2. Class 2, Lab. 3 (arrange hours), cr. 3. Prerequisite or corequisite: EE 586.

Discussion of practical design and computational techniques for control systems. Analog, digital and hybrid simulations are employed for laboratory experiments. Topics include frequency domain design techniques, analog simulation of linear methods in optimal control problems.

588. INTRODUCTION TO ANALYSIS OF NONLINEAR SYSTEMS. Sem. 1 and 2. Class 3, cr. 3. Prerequisite or corequisite: EE 502.

Applications of phase plane methods and classification of singular points. Iteration and perturbation techniques. Jump resonance. Limit cycles. Relaxation oscillations. Introduction to Liapunov and asymptotic stability. Professor Haas and staff.

595. SELECTED TOPICS IN ELECTRICAL ENGINEERING. (el.). Hours and credits to be arranged.

597. ELECTRICAL ENGINEERING SEMINAR. Sem. 1 and 2. Class 1, cr. 0.

All graduate students in electrical engineering are required to attend the Electrical Engineering Staff Seminar during their first two semesters in residence. The Graduate Committee.

GRADUATE LEVEL

611. ELECTROMAGNETICS III. Class 3, cr. 3.

614. MICROWAVE ELECTRONICS. Class 3, cr. 3.

623. ELECTROCERAMICS. Class 3, cr. 3.

625. MODERN THEORIES OF ALTERNATING-CURRENT MACHINES. Class 3, cr. 3.

635. OPTIMIZATION AND ECONOMIC OPERATION OF INTEGRATED POWER SYSTEMS. Class 3, cr. 3.

636. DYNAMICS AND CONTROL OF INTEGRATED POWER SYSTEMS. Class 3, cr. 3.

639. SELECTED STUDIES IN ENERGY SOURCES AND SYSTEMS. Class 3, cr. 3.

641. SIGNAL ESTIMATION AND FILTERING THEORY. Class 3, cr. 3.

642. INFORMATION THEORY. Class 3, cr. 3.

643. PULSE TECHNIQUES. Class 3, cr. 3.

646. SIGNAL DETECTION THEORY. Class 3, cr. 3.

647. MODULATION AND DETECTION OF ANALOG SIGNALS. Class 3, cr. 3.

648. OPTIMAL NONLINEAR NETWORK SYNTHESIS. Class 3, cr. 3.

649. STOCHASTIC PROCESSES IN ELECTRICAL ENGINEERING. Class 3, cr. 3.

650. STATISTICAL LEARNING THEORY. Class 3, cr. 3.

655. PARTICLE-FIELD INTERACTIONS. Class 3, cr. 3.

656. ANALYSIS OF SEMICONDUCTOR DEVICES. Class 3, cr. 3.

668. ARTIFICIAL INTELLIGENCE. Class 3, cr. 3.

669. SELECTED TOPICS IN AUTOMATA THEORY AND FORMAL LANGUAGES. Class 3, cr. 3.

678. ANALYSIS OF FORCED NONLINEAR SYSTEMS. Class 3, cr. 3.

687. SELF-ORGANIZING CONTROL SYSTEMS. Class 3, cr. 3.

688. STABILITY AND SYNTHESIS OF NONLINEAR CONTROL SYSTEMS. Class 3, cr. 3.

689. ADVANCED TOPICS IN AUTOMATIC CONTROL. Class 3, cr. 3.

690. SAMPLED-DATA CONTROL SYSTEMS. Class 3, cr. 3.

692. STOCHASTIC CONTROL SYSTEMS. Class 3, cr. 3.

693. OPTIMUM CONTROL SYSTEMS. Class 3, cr. 3.

695. SEMINAR IN ELECTRICAL ENGINEERING. Class 3, cr. 3.
A. Statistical communication theory.
B. Electromagnetics.
C. Nonlinear circuit theory.

696. ADVANCED ELECTRICAL ENGINEERING PROJECT. Hours and credits to be arranged.

697. SELECTED TOPICS IN ELECTRICAL ENGINEERING. Hours and credits to be arranged.

698. RESEARCH. M.S. Thesis.

699. RESEARCH. Ph.D. Thesis.

INDUSTRIAL ENGINEERING

Professor Leimkuhler, Head of the School

Professors: H. T. Amrine, M.S.M.E.; J. W. Barany, Ph.D.; J. H. Greene, Ph.D.; O. D. Lascoe, M.S.Ed.; F. F. Leimkuhler, D.Eng.; R. Reed, Ph.D.

Associate Professors: M. M. Barash, Ph.D.; J. R. Buck, Ph.D.; E. G. Kirkpatrick, M.S.; R. W. McDowell, M.S.I.E.; C. L. Moodie, Ph.D.; P. A. Reed, Ph.D.; C. P. Smith, M.S.I.E.

Assistant Professors: R. F. Adams, M.S.; Y. I. El Gomayel, Ph.D.; T. W. Hill, Ph.D.; S. H. Mann, Ph.D.; A. Ravindran, Ph.D.

UNDERGRADUATE LEVEL
Lower-Division Courses

30. STATISTICAL CONTROL I. Sem. 1 and 2. Class 3, cr. 3. (4 IE). Prerequisite: MA 261.

Descriptive statistics, basic probability and distribution theory, experimental statistics, introduction to design of engineering experiments. Applications oriented to production engineering problems. Professors Barany, Kirkpatrick, and Mann.

231. COMPUTERS AND COMPUTER METHODS. Sem. 1 and 2. Class 1, Lab. 2, cr. 2. (3 IE). Prerequisite: MA 161 or equivalent.

An introduction to digital computers and computer programming with application to scientific and information processing problems. Professor Moodie and staff.

283. INDUSTRIAL ENGINEERING SEMINAR. Sem. 1 and 2. Class 1, cr. 1. (3 IE).

Survey of industrial engineering and related activities in the industrial enterprise; interrelationship of the various functions, such as industrial organization, research and engineering, production processes and controls, methods engineering, plant layout, and quality control. Professor Amrine and staff.

290. INDUSTRIAL PRACTICE I. Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisite: Must be accepted for the program by the cooperative program coordinator.

Practice in industry and comprehensive written reports of this practice.

291. INDUSTRIAL PRACTICE II. Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisite: IE 290.

Practice in industry and comprehensive written reports of this practice.

UNDERGRADUATE LEVEL
Upper-Division Courses

330. STATISTICAL CONTROL II. Sem. 1 and 2. Class 3, cr. 3. (5 IE). Prerequisite: IE 230 or STAT 511.

Continuation of IE 230. Design of experiments with multifactors based on equal-interval data. Analysis of nominal and ordinal data. Applications to industrial control systems. Professors Barany, Kirkpatrick, and Mann.

331. MEASUREMENTS AND AUTOMATIC CONTROL SYSTEMS. Sem. 1 and 2. Class 2, Lab. 2, cr. 3. (6 IE). Prerequisites: EE 317; prerequisite or corequisite: ME 307.

Methods for measuring and adapting physical variables; basic concepts in automatic feedback control of machines and processes. Transfer function and control loop development, stability, and frequency response. Professor Hill.

335. INTRODUCTION TO MATHEMATICAL PROGRAMMING. Sem. 1 and 2. Class 3, cr. 3. (6 IE). Prerequisites: IE 231 and MA 262.

Applications of linear algebra to industrial problems; linear programming. Professors Hill and Ravindran.

343. ENGINEERING COST ANALYSIS. Sem. 1 and 2. Class 3, cr. 3. (5 IE). Prerequisite: MA 261.

Cost measurement and control in engineering studies. Basic accounting concepts, income measurement and valuation problems. Manufacturing cost control and standard cost systems. Capital investment, engineering alternatives, and equipment replacement studies. Professors Buck and Kirkpatrick.

365. ORGANIZATION FOR PRODUCTION. Sem. 1 and 2. Class 3, cr. 3. (el. ENGR). Prerequisite: MA 262.

Basic course in the management of the production operation introducing functional information such as planning and control of production, inventory, and quality. An analysis of the economic problems of production management together with an introduction to quantitative methods and decision making.

366. ELEMENTS OF PRODUCTION MANAGEMENT. Sem. 1 and 2. SS. Class 3, cr. 3. (IS 6, el.). Prerequisite: junior standing; engineering students should take IE 365.

Introductory course in production management, with emphasis on plant layout, work methods and measurement, production planning and control, materials handling, and cost and quality control.

385. MANUFACTURING PROCESS DESIGN. Sem. 1 and 2. Class 2, Lab. 2, cr. 3. (5 IE).

Analytical study of manufacturing processes and process design; design for production, including tool and materials planning; economic considerations in process selection. Professor El Gomayel.

386. WORK ANALYSIS. Sem. 1 and 2. Class 2, Lab. 2, cr. 3. (6 IE). Prerequisites: IE 330 and IE 343.

Methods engineering and work measurement; the nature of human work; and job evaluation. Professor Buck.

392. INDUSTRIAL PRACTICE III. Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisite: IE 291.

Practice in industry and comprehensive written reports of this practice.

393. INDUSTRIAL PRACTICE IV. Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisite: IE 392.

Practice in industry and comprehensive written reports of this practice.

394. **INDUSTRIAL PRACTICE V.** Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisite: IE 393.

Practice in industry and comprehensive written reports of this practice.

431. **SYSTEMS ANALYSIS AND DESIGN.** Sem. 1 and 2. Class 3, cr. 3. (7 IE). Prerequisites: IE 331 and IE 335.

Analysis and synthesis of operational control systems; application of decision, communication, queueing, reliability, and sequencing theories; systems simulation and introduction to network analysis. Professors Moodie, P. A. Reed, and R. Reed.

444. **ENGINEERING ADMINISTRATION.** Sem. 1 and 2. Class 3, cr. 3. (8 IE). For industrial engineering students only; intended for the final semester of the student's undergraduate program.

Engineering procedures, managing engineering functions; human relations. Professors Amrine and P. Reed.

470. **MATERIALS PROCESSING.** Sem. 1 and 2. SS. Class 2, Lab. 3, cr. 3. (7 ME, 7 IE and el.) Prerequisite or corequisite: ESC 223.

The interrelations of materials, processes, and design with various aspects of manufacturing. Professor Lascoe and staff.

471. **TOOLING AND PRODUCTION PROCESSES.** Sem. 2. Class 2, Lab. 2, cr. 3. (el. ENGR). Prerequisite: IE 470.

Production methods in manufacturing. Tooling analysis, production capabilities, material and design considerations. Production turning, casting, stamping and forming, machining centers, electrical machining concepts and plastics for tooling. Professor Lascoe.

477. **WORK METHODS AND MEASUREMENT.** Sem. 1 and 2. Class 3, cr. 3. (IS 6, 7, el.). Prerequisite: IE 365 or IE 366, or equivalent.

Work analysis; principles and techniques of motion study; nature of human work; design of work methods; work measurement; work sampling; predetermined time systems.

478. **PRODUCTION PLANNING AND CONTROL.** Sem. 1 and 2. Class 3, cr. 3. (el. ENGR). Prerequisite: IE 365.

The basic concepts, principles, objectives, and functions involved in the design of manufacturing processes and control of production in industry. Economic aspects of manufacturing procedures. Professor Greene and staff.

483. **PRODUCTION CONTROL.** Sem. 1 and 2. Class 3, cr. 3. (7 IE). Prerequisites: IE 385 and 386.

Analysis and design of production and inventory control systems; data handling; quality and cost control aspects. Professors Greene and Moodie.

484. **FACILITIES DESIGN.** Sem. 1 and 2. Class 2, Lab. 2, cr. 3. (8 IE). Prerequisite. IE 483; prerequisite or corequisite: IE 431.

Facilities planning and industrial plant design; materials handling; plant engineering; physical plant economics. Prof. R. Reed and staff.

499. **RESEARCH IN INDUSTRIAL ENGINEERING.** Sem. 1 and 2. (el.).

Hours and credit to be arranged with approval of the head of the department.

DUAL LEVEL—UNDERGRADUATE AND GRADUATE

530. **QUALITY CONTROL.** Sem. 1 and 2. SS. Class 3, cr. 3. Prerequisite: IE 330 or STAT 511 or equivalent.

Principles and practices of quality control in industry; administrative and engineering aspects of quality control programs; introduction to statistical quality control. Professor Kirkpatrick.

531. **AUTOMATIC CONTROL OF MACHINES AND PROCESSES.** Sem. 2. (Offered in 1969-70 and alternate years). Class 3, cr. 3. Prerequisite: IE 331 or equivalent.

Analysis and synthesis of automatic control systems, with application to machines and processes. Compensation networks for proportional, integral, and derivative action using electrical, pneumatic, or hydraulic control elements. Digital and analog machine control and process control computers. Professor Barash.

532. **RELIABILITY.** Sem. 2. Class 3, cr. 3. Prerequisite: IE 330 or equivalent.

Application of quantitative methods to the design and evaluation of industrial processes and systems for assuring reliability of performance. Economic and manufacturing control activities related to product engineering aspects of reliability. Professor Barash.

535. **MATHEMATICAL PROGRAMMING OF INDUSTRIAL PROBLEMS.** Sem. 1 and 2. SS. Class 3, cr. 3. Prerequisite: IE 335 or consent of instructor.

Development of analytical techniques for the solution of engineering and economic problems. Construction of mathematical models, with emphasis on linear models and linear programming. Professors Hill and Ravindran.

536. **OPERATIONS RESEARCH.** SS. Sem. 1 and 2. Class 3, cr. 3. Prerequisite: IE 330 and IE 335 or consent of instructor.

An introduction to the literature and methodology of operations research (exclusive of linear programming). Applications to process design, inventory and production control, scheduling, waiting-lines and replacement problems. Professors Baker, Buck, and Leimkuhler.

537. **ADVANCED MATHEMATICAL PROGRAMMING OF INDUSTRIAL PROBLEMS.** Sem. 2. Class 3, cr. 3. Prerequisite: IE 535 or consent of instructor.

Review of the theory of linear programming and its application to the transportation and network problems. Theory and special applications of quadratic, convex, and dynamic programming. Professors Hill and Ravindran.

543. **MANUFACTURING ANALYSIS.** Sem. 1 and 2. SS. Class 3, cr. 3. (Available for credit only to honors students in industrial engineering and graduate students from other departments.)

Organization for production, manufacturing processes, process design, production control, forecasting, inventory control, estimating, data processing and system designing. Professors El Gomayel and Greene.

544. **MANUFACTURING MANAGEMENT.** Sem. 1 and 2. SS. Class 3, cr. 3. (Available for credit only to honors students in Industrial Engineering and graduate students from other departments.)

Work methods and measurement, job evaluation, and fundamentals of engineering economy and accounting as applied to manufacturing. Professors Adams and Buck.

545. **ENGINEERING ECONOMIC ANALYSIS.** Sem. 2. Class 3, cr. 3. Prerequisite: IE 335 and either IE 343 or IE 544 or equivalent.

Engineering economic analysis for the industrial enterprise, including cost control, valuation, depreciation, investment studies, replacement theory, and taxation. Professors Buck and Leimkuhler.

546. **ECONOMIC DECISIONS IN ENGINEERING.** Sem. 1. Class 3, cr. 3. Prerequisites: IE 431, IE 536, or equivalent or consent of instructor.

Analytical models and techniques as applied to industrial problems of replacement, production, resource allocation and related problems involving probabilistic behavior. Emphasis is given to model assumptions, implications, input data, and other information at the operating level. Professor Buck.

566. **PRODUCTION MANAGEMENT CONTROL.** Sem. 1. SS. Class 3, cr. 3. Prerequisite or corequisite: IE 483, or IE 543 and IE 544, or equivalent.

Background and development of production management plus current concepts and controls applicable to production management functions. Professors Amrine and Greene.

571. **MACHINING SYSTEMS.** Sem. 1. Class 2, Lab. 2, cr. 3. Prerequisite: IE 470 or permission of instructor.

Basic machine-tool-workpiece systems. Theory of metal cutting applied to tool design. Geometry of form generation. Structural and functional characteristics of machine tools. Accuracy aspects—analysis of geometric, kinematic and dynamic errors. Dynamic stability of machining systems—causes and prevention of vibrations and chatter. Professor Barash.

572. **ADVANCED MATERIALS PROCESSING.** Sem. 2. Class 3, cr. 3. Prerequisite: IE 470 or IE 571, or equivalent.

Theory of forming, cutting, and removing of metallic and nonmetallic materials. Application of plasticity in forming and cutting; abrasive machining; electric machining; other modern manufacturing processes. Professor Barash.

576. **JOB DESIGN AND STANDARDIZATION.** Sem. 2. Class 3, cr. 3. Prerequisite: IE 386, IE 477, or IE 544.

Advanced study on work center design and methods for improving human work. Details of work sampling, predetermined time systems, standard data development, machine interference and fatigue allowances, and statistical aspects of work measurement. Consideration in jig and fixture design and mechanized handling of materials. Current research in work methods and measurement. Professors Barany and Buck.

Michael Golden Engineering Laboratories

579. ADVANCED PRODUCTION CONTROL. Sem. 1 and 2. Class 3, cr. 3. Prerequisite: IE 478, IE 483, IE 543, or consent of instructor.

Analysis of modern, quantitative techniques of production planning and control. Design of production control systems using methods of mathematical programming, probabilistic and deterministic models. Professors Greene and Moodie.

583. MATERIAL HANDLING AND INDUSTRIAL MECHANIZATION. Sem. 1. Class 2, Lab. 2, cr. 3. Prerequisite: IE 484.

Analysis for design and operation of handling systems with emphasis on industrial mechanization and automation. Analytical methods and simulation of material handling systems. Professor R. Reed.

590. TOPICS IN INDUSTRIAL ENGINEERING. Sem. 1 and 2. SS. Credit and hours to be arranged.

Selected topics in industrial engineering for seniors and graduate students. May be repeated with permission of adviser.

595. PROJECTS IN MACHINABILITY. Sem. 1 and 2. cr. 1-6 (el.). Prerequisite: IE 470 and IE 571.

Projects in metal cutting, drilling, milling, and grinding. Hours and credit to be arranged with approval of the head of the school. Professors Barash, Lascoe, and staff.

GRADUATE LEVEL

601. METHODS OF EXPERIMENTAL RESEARCH. Class 3, cr. 3.

602. ORGANIZATIONAL ANALYSIS FOR RESEARCH AND ENGINEERING. Sem. . (Offered in 1970-71 and alternate years). Class 3, cr. 3.

631. ADVANCED SYSTEMS ANALYSIS AND DESIGN. Sem. 1. Class 3, cr. 3.

632. SCHEDULING MODELS. Sem. 2. Class 3, cr. 3.

635. APPLICATIONS OF MATHEMATICAL PROGRAMMING. Sem. 1. (Offered in 1969-70 and alternate years). Class 3, cr. 3.

636. QUEUEING THEORY. Class 3, cr. 3.

637. ANALYSIS OF INVENTORY SYSTEMS. Sem. 1. Class 3, cr. 3.

666. PRODUCTION MANAGEMENT ANALYSIS. Class 3, cr. 3.

672. AUTOMATIC MANUFACTURING SYSTEMS. Sem. 1. (Offered in 1970-71 and alternate years). Class 3, cr. 3.

679. MANUFACTURING APPLICATIONS OF DATA PROCESSING. Sem. 2. (Offered in 1969-70 and alternate years). Class 3, cr. 3.

686. SEMINAR IN INDUSTRIAL ENGINEERING. Sem. 2. (Offered in 1970-71 and alternate years). Class 3, cr. 3.

690. ADVANCED TOPICS IN INDUSTRIAL ENGINEERING. Sem. 1 and 2. SS. Credit and hours to be arranged.

697. SEMINAR. Sem. 1 and 2. Class 1, cr. 0.

698. RESEARCH IN INDUSTRIAL ENGINEERING. M.S. Thesis.

699. RESEARCH IN INDUSTRIAL ENGINEERING. Ph.D. Thesis.

MATERIALS SCIENCE AND METALLURGICAL ENGINEERING

R. E. Grace, Head of the School
G. L. Liedl, Assistant Head of the School

Distinguished Professor: Reinhardt Schuhmann, Jr., Sc.D., Ross Professor of Engineering.

Professors: R. E. Grace, Ph.D.; C. T. Marek, M.S.; R. W. Vest, Ph.D.; P. G. Winchell, Ph.D.

Associate Professors: P. W. Case, M.S.; J. R. Cost, Ph.D.; P. B. Eaton, M. S.; S. J. Hruska, Ph.D.; G. L. Liedl, Ph.D.; W. C. Phelps, Jr., Ph.D.; R. H. Spitzer, Ph.D.

Assistant Professor: M. A. Dayananda, Ph.D.

Postdoctoral Research Associate: O. P. Katyal, Ph.D.

Instructor in Research: Janet M. Cody, B.S.Met.E.

UNDERGRADUATE LEVEL
Lower-Division Courses

201. ENGINEERING PROBLEMS IN MATERIALS PROCESSING AND METALLURGICAL ENGINEERING. Sem. 1. Class 2, Lab. 2, cr. 3. (3 MSE, el.). Prerequisites or corequisites: CHM 116, MA 261, and PHYS 251.

Definition of systems and unit processes emphasizing mass and energy balances and measures of efficiency. Application to the solution of comprehensive problems in materials processing and metallurgical engineering. Professor Hruska.

202. MICROSTRUCTURE OF SOLIDS. Sem. 2. Class 2, Lab. 3, cr. 3. (4 MSE, el.).

Introduction to the crystalline state; atomic arrangements, imperfections in crystals, diffusion. Equilibrium diagrams, multicomponent systems. Equilibrium and nonequilibrium microstructures in metallic and nonmetallic solids. Laboratory experiments relating properties to structure. Professors Cost and Dayananda.

291. INDUSTRIAL PRACTICE I. Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisite: Must be accepted for the program by the cooperative program coordinator.

Practice in industry and comprehensive written reports of this practice. Professors Phelps and Hruska.

292. INDUSTRIAL PRACTICE II. Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisite: MSE 291.

Practice in industry and comprehensive written reports of this practice.

UNDERGRADUATE LEVEL
Upper-Division Courses

353. INTRODUCTION TO STRUCTURE AND DIFFRACTION. Sem. 1. Class 3, Lab. 3, cr. 4. (5 MSE, el.). Prerequisite: MA 262.

Introduction to geometrical crystallography, symmetry, and crystal structure. Production of X-radiation. Diffraction of X-rays and electrons by crystals. Applications of diffraction to the characterization of crystalline materials. Professor Liedl.

360. METALLURGICAL THERMODYNAMICS. Sem. 2. Class 3, cr. 3. (6 MSE, el.). Prerequisite or corequisite: CHM 374 or equivalent.

Review of thermodynamics, especially principles of reversible processes, chemical equilibrium, and phase equilibria. Applications to high temperature metallurgical reactions, phase transformations in metals and alloys, and physical behavior of metals. Professor Schuhmann.

365. KINETICS IN CONDENSED SYSTEMS. Sem. 2. Class 3, cr. 3. (6 MSE, el.). Prerequisite or corequisite: CHM 374 or equivalent.

Diffusion and phase transformations; applications to reactions in metals, ceramics, and semiconductors. Professor Hruska.

393. INDUSTRIAL PRACTICE III. Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisite: MSE 292.

Practice in industry and comprehensive written reports of this practice.

394. INDUSTRIAL PRACTICE IV. Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisite: MSE 393.

Practice in industry and comprehensive written reports of this practice.

395. **INDUSTRIAL PRACTICE V.** Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisite: MSE 394.

Practice in industry and comprehensive written reports of this practice.

411. **ENGINEERING MATERIALS.** Sem. 1 and 2. Class 3, cr. 3. (7 ME, 8 ChE, el.). Prerequisites: A course in thermodynamics and a course in strength of materials.

Structure of metals, ceramics, polymers, and other solid engineering materials. Crystallographic principles. Chemical bonding. Crystal imperfections. Phase equilibria. Irreversible processes in solids. Relations of structure to mechanical, physical, and chemical properties. Applications to materials selection and design. Staff.

430. **MATERIALS AND PROCESSING DESIGN I.** Sem. 1. Class 1, cr. 1. (7 MSE, el.).

Definition of engineering research and design problems involving metals, alloys, ceramics, semiconductors, etc. Professional guidance and inspection trips. Professor Eaton and staff.

431. **MATERIALS AND PROCESSING DESIGN II.** Sem. 2. Class 2, Lab. 6, cr. 4. (8 MSE, el.).

Teams of students seek creative solutions to problems defined in MSE 430. Staff.

448. **PHYSICAL METALLURGY.** Sem. 1. Class 3, Lab. 3, cr. 4. (7 MSE, el.). Prerequisites: MSE 353 and 360, or equivalent.

Constitution and properties of metals and alloys under equilibrium and nonequilibrium conditions. Professors Cost and Winchell.

470. **CHEMICAL METALLURGY.** Sem. 1. Class 3, Lab. 3, cr. 4. (7 MSE, el.). Prerequisite: MSE 360 or equivalent.

Applications of physical chemistry to metallurgical systems. The unit processes of extracting metals from ores, including reduction of oxides, refining of liquid metals, gas-solid reactions, and smelting. Laboratory studies in unit processes of metallurgical engineering with emphasis on underlying principles. Professor Phelps.

497. **SELECTED TOPICS IN MATERIALS SCIENCE AND METALLURGICAL ENGINEERING.** Sem. 1 and 2. SS. (el.). Hours and credits to be arranged. Staff.

DUAL LEVEL—UNDERGRADUATE AND GRADUATE

507. **CRYSTAL PLASTICITY.** Sem. 2. Class 3, cr. 3. (el.). Prerequisites: A course in mechanics and MSE 353, or equivalent.

Plastic deformation of crystals. Introduction to dislocation theory. Professor Winchell.

522. **ADVANCED FERROUS METALLURGY.** Sem. 2. Class 3, cr. 3. (el.). Prerequisite: MSE 470 or equivalent.

Selected topics in the production of iron, steel, and ferrous alloys. Physical chemistry of iron and steel. Professor Phelps.

523. **PHYSICAL CERAMICS.** Sem. 1, Class 3, cr. 3. (See EE 523). Prerequisite: Senior or graduate classification in science or engineering.

Fundamental concepts of the physical properties of ceramic materials and the relation of these properties to atomic interactions and microstructure. Areas covered include structure and phase relationships in crystalline ceramics; glasses; surfaces and interfaces; sintering and diffusion; mechanical, thermal, electrical and optical properties; and ceramic processing as it influences properties. Professor Vest.

536. **SOLIDIFICATION OF CASTINGS.** Sem. 1. Class 3, cr. 3. (el.). Prerequisite: MSE 411 or equivalent.

A study of solidification of metal in molds involving the characteristics of liquid-solid phase transformations, sand and metal thermal behavior, macroscopic structures, mechanical properties, and casting defects. Professor Marek.

537. **FOUNDRY ENGINEERING PROBLEMS.** Sem. 2. Class 1, Lab. 6, cr. 3. (el.). Prerequisite: MSE 536.

Investigation of foundry engineering problems. Laboratory work to accompany investigation. Discussion of problems in seminar. Professor Marek.

550. **PROPERTIES OF SOLIDS.** Sem. 1 and 2. Class 3, cr. 3. (8 ME, el.). Prerequisite: PHYS 342 or equivalent.

Applications of physics to the understanding of the properties of solids. Crystal structure, band theory, and imperfections in solids. Electrical, magnetic, thermal, and mechanical properties. Professors Liedl and Cost.

575. **TRANSPORT PHENOMENA IN SOLIDS.** Sem. 1. Class 3, cr. 3. (el.). Prerequisite: Senior standing in Engineering or Science.

Energetics and kinetics of phase changes in metals and alloys. Nucleation and growth models with special emphasis on role of crystal defects. Selected topics in multicomponent diffusion. Professors Dayananda and Grace.

576. **CORROSION.** Sem. 2. Class 3, cr. 3. (el.). Prerequisites or corequisites: CHM 373 or MSE 411.

Rate-controlling steps in electrode processes; activation, ohmic, and concentration polarization; passivation; potentiostatic studies and alloy design; applications to engineering systems. Staff.

597. **SELECTED TOPICS IN MATERIALS SCIENCE AND METALLURGICAL ENGINEERING.** Sem. 1 and 2. SS. (el.). Hours and credits to be arranged. Staff.

GRADUATE LEVEL

619. **ADVANCED PHYSICAL METALLURGY.** Sem. 1. Class 3, cr. 3. (Offered in 1971-72 and alternate years.)

620. **ADVANCED PHYSICAL METALLURGY.** Sem. 2. Class 3, cr. 3. (Offered in 1970-71 and alternate years.)

623. **ELECTROCERAMICS.** Sem. 2. Class 3, cr. 3. (See EE 623).

630. **DIFFRACTION.** Sem. 2. Class 3, cr. 3. (Offered in 1971-72 and alternate years.)

659. **THERMODYNAMICS OF SOLUTIONS.** Sem. 1. Class 3, cr. 3. (Offered in 1970-71 and alternate years.)

690. **SEMINAR IN MATERIALS SCIENCE AND METALLURGICAL ENGINEERING.** Sem. 1 and 2. Class 1, cr. 0.

697. **SPECIAL TOPICS IN MATERIALS SCIENCE AND METALLURGICAL ENGINEERING.** Sem. 1 and 2. SS. Hours and credits to be arranged.

698. **RESEARCH IN MATERIALS SCIENCE AND METALLURGICAL ENGINEERING.** M.S. Thesis.

699. **RESEARCH IN MATERIALS SCIENCE AND METALLURGICAL ENGINEERING.** Ph.D. Thesis.

MECHANICAL ENGINEERING

P. W. McFadden, Head of the School

Distinguished Professors: William E. Fontaine, M.S.M.E., Herrick Professor of Engineering; Yeram S. Touloukian, Ph.D., Alcoa Professor of Engineering.

Professors: D. E. Abbott, Ph.D.; V. E. Bergdolt, Ph.D.; C. L. Brown, Ph.D.; Raymond Cohen, Ph.D.; W. B. Cottingham, Ph.D.; R. W. Fox, Ph.D.; R. J. Grosh, Ph.D.; A. S. Hall, Ph.D.; G. A. Hawkins, Ph.D.; A. R. Holowenko, M.S.E.; Wolfgang Leidenfrost, Dr. Ing.; P. W. McFadden, Ph.D.; C. W. Messersmith, M.S.E.; Joseph Modrey, Ph.D.; F. B. Morse, M.S.M.E.; J. R. Osborn, Ph.D.; B. E. Quinn, Ph.D.; B. A. Reese, Ph.D.; Find Sandgren, M.S.; R. J. Schoenhals, Ph.D.; A. R. Spalding, Ph.D.; R. Viskanta, Ph.D.; C. F. Warner, Ph.D.; E. R. F. Winter, Ph.D.

Associate Professors: M. J. Crocker, Ph.D.; D. P. DeWitt, Ph.D.; C. M. Ehresman, M.S.M.E.; R. E. Garrett, Ph.D.; V. E. Goldschmidt, Ph.D.; R. E. Goodson, Ph.D.; J. F. Hamilton, Ph.D.; J. D. Hoffman, Ph.D.; F. P. Incropera, Ph.D.; M. R. L'Ecuyer, Ph.D.; P. E. Liley, Ph.D.; A. T. McDonald, Ph.D.; R. A. Olsen, M.S.M.E.; C. W. Rezek, Ph.D.; J. G. Skifstad, Ph.D.; J. K. Stene, Ph.D.; W. H. Stevenson, Ph.D.; H. D. Thompson, Ph.D.; Kenneth Wark, Ph.D.; E. J. Wellman, Ph.D.

Assistant Professors: K. H. Hawks, Ph.D.; B. M. Hillberry, Ph.D.; R. G. Leonard, Ph.D.; A. M. Mellor, Ph.D.; C. L. Nachtigal, Ph.D.; J. T. Pearson, Ph.D.; B. E. Qvale, Ph.D.; Werner Soedel, Ph.D.; D. R. Tree, Ph.D.; S. Wittig, Dr. Ing.

UNDERGRADUATE LEVEL
Lower-Division Courses

200. **THERMODYNAMICS I.** Sem. 1 and 2. SS. Class 3, Problems 1, cr. 3. (4 ME). Prerequisite: MA 261.

First and second laws, entropy, reversible and irreversible processes, properties of pure substances. Application to engineering problems. Professor Wark.

261. **INTRODUCTION TO ENGINEERING DESIGN.** Sem. 1 and 2. SS. Class 2, Lab. 3, cr. 3. (3 ME). Prerequisite or corequisite: ESC 221.

Principles of kinematics and mathematical modeling of machine elements. Application of these principles to specific engineering problems and also to problems of wider scope requiring the decision making and creative thought process characteristics of engineering design. Professor Rezek and staff.

285. **INDUSTRIAL PRACTICE I.** Sem. 1 and 2. SS. cr. 0. For cooperative program students only.

Practice in industry and comprehensive written reports of this experience.

286. **INDUSTRIAL PRACTICE II.** Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisite: ME 285.

Practice in industry and comprehensive written reports of this experience.

287. **INDUSTRIAL PRACTICE III.** Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisite: ME 286.

Practice in industry and comprehensive written reports of this experience.

288. **INDUSTRIAL PRACTICE IV.** Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisite: ME 287.

Practice in industry and comprehensive written reports of this experience.

289. **INDUSTRIAL PRACTICE V.** Sem. 1 and 2. SS. cr. 0. For cooperative program students only. Prerequisite: ME 288.

Practice in industry and comprehensive written reports of this experience.

UNDERGRADUATE LEVEL
Upper-Division Courses

302. **THERMODYNAMICS II.** Sem. 1 and 2. SS. Class 3, cr. 3. (5 ME). Prerequisite: ME 200.

Reversibility, availability, power cycles and the conversion of heat into work; combustion, heat pumps, refrigeration and air conditioning. Professor Brown and staff.

303. **THERMODYNAMICS.** (Indianapolis Campus only.) Class 4, cr. 4. Prerequisites: MA 262 and PHYS 251.

Introduction to the laws of thermodynamics. First law in closed and open systems. Second law from both microscopic and macrosopic viewpoints. Properties from statistical mechanics. Applications to engine cycles and chemical reactions. Staff.

305. **GENERAL THERMODYNAMICS I.** Sem. 1 and 2. Class 3, cr. 3. (5 AE). Prerequisites: MA 262 and PHYS 251 or 261.

First and second laws, properties. Application to several types of systems. Professor Brown and staff.

306. **GENERAL THERMODYNAMICS II.** Sem. 1 and 2. Class 3, cr. 3. (6 AE).

Continuation of ME 305. Thermodynamic properties, mixtures, thermochemistry and chemical equilibrium, cycles, introduction to statistical thermodynamics. Professor Brown and staff.

307. **ELEMENTS OF THERMODYNAMICS.** Sem. 1 and 2. SS. Class 3, cr. 3. (5 AGEN, 5 CE, 6 IE). Prerequisites: MA 262 and PHYS 251 or 261.

Fundamentals of thermodynamics, Maxwell relations, properties, processes, applications to power generation, refrigeration, air conditioning, and fluid transfer. Professor Brown and staff.

308. **THERMOPHYSICS.** Sem. 1 and 2. SS. Class 4, cr. 4. (6 EE). Prerequisite: MA 318.

Energy balances and equations of state for fixed mass systems, properties, second law of thermodynamics, entropy. Introduction to kinetic theory and transport properties and to the statistical mechanics of independent particles. Fundamentals of heat transfer by conduction, convection, and radiation. Professor Brown and staff.

310. **FLUID MECHANICS.** Sem. 1 and 2. SS. Class 3, Problem 1, Lab. 2, cr. 4. (5 ME, 6 AGEN). Prerequisites: MA 262, ESC 206, and ME 200.

Continuum, velocity field, fluid statics, basic conservation laws for systems and control volumes, dimensional analysis.

Euler and Bernoulli equations, viscous flows, boundary layer, flow in channels and around submerged bodies, one dimensional gas dynamics. Professors Fox, McDonald and staff.

315. **HEAT AND MASS TRANSFER.** Sem. 1 and 2. SS. Class 3, Lab. 2, cr. 4. (6 AGEN, 6 ME). Prerequisite or corequisite: ME 302 and 310.

Fundamental principles of heat transfer by conduction, convection and radiation; mass transfer by diffusion and convection. Emphasis on process heat transfer and application to design. Professors Tree, Pearson, and staff.

340. **MEASUREMENTS AND COMPUTERS.** Sem. 1 and 2. SS. Class 2, Lab. 3, cr. 3. (5 ME). Prerequisite: MA 262, and EE 231.

Characterization and behavior of typical measuring systems with emphasis on transfer function and frequency response techniques. Transducers, amplifiers, computing devices, readout devices, and their response to steady and transient phenomena. Calibrations and data analysis techniques are introduced. Introduction to analog and digital computers. Professor Ehresman and staff.

370. **MACHINE ANALYSIS AND DESIGN.** Sem. 1 and 2. SS. Class 3, Lab. 3, cr. 4, (6 ME). Prerequisite: ME 261 and ME 340.

Applications of Mechanics I and II (statics and dynamics) to machines. Analytical, graphical, and computer techniques for kinematic and dynamic analysis. Kinematic and dynamic synthesis. Professors Holowenko and Quinn.

416. **HEATING AND AIR CONDITIONING.** Sem. 1 and 2. SS. Class 3, cr. 3. (Tech. el. ME). Prerequisite: ME 302 or 307.

Calculation of heating and cooling loads for air conditioning; design of heating systems. Psychometrics. Study of systems for air conditioning; design of ductwork; the heat pump; high temperature water distribution. Particular emphasis on practical applications. Professor Morse.

417. **COMMERCIAL AND INDUSTRIAL AIR CONDITIONING.** Sem. 2. Class 3, cr. 3. (Tech. el. ME). Prerequisite: ME 302 or 307.

Economics of commercial and industrial air conditioning systems. Selection of equipment. Sound generation, measurement, transmission and attenuation. Mass transfer. Air conditioning design project. Emphasis on practical problems. Professor Morse.

421. **REFRIGERATION AND CRYOGENICS.** Sem. 1. Class 3, cr. 3. (Tech. el. ME). Prerequisite or corequisite: ME 302 or 307.

Thermodynamics of refrigeration cycles. Centrifugal and reciprocating compressor performance analysis. Economics of large chilled water plants. Refrigeration applications in chemical industry, dam construction, medicine and aircraft. Liquefied gases and industrial uses of cryogenics. Semester design project. Professor Morse.

430. **POWER ENGINEERING.** Sem. 2. Class 3, cr. 3. (Tech. el. ME). Prerequisite: ME 302.

Raw energy, combustion, energy cycles, steam power plants, fuel bed and suspension firing, steam generators, heat exchangers, draft, fuel and ash handling, dust collection, prime movers, condensers, feedwater heating, pumps and piping, heat balance, water supply and conditioning, controls, supercritical—and nuclear steam plants, internal combusion engines, gas turbines, water power, economics of power systems, the variable load problem, plant selection criteria, station performance characteristics, and energy rates. Professor Olsen.

433. **PRINCIPLES OF TURBOMACHINERY.** Sem. 1. Class 3, cr. 3. (Tech. el. ME). Prerequisites: ME 302 and ME 310.

Unified treatment of principles underlying fluid mechanic design of gas, vapor, and hydraulic turbines, pumps, fans and compressors. Fluid mechanic design of stator and rotor blades, nozzles, and diffusers. Inspection trip to industrial plant required. Professor Qvale and staff.

440. **INTERNAL COMBUSTION ENGINES.** Sem. 1 and 2. SS. Class 3, cr. 3. (Tech. el. ME). Prerequisite: ME 302, 307, or 308.

Basic principles; theoretical and actual cycles; performance characteristics; combustion; carburetion; air capacity; fuels and lubricants; accessories and controls. Professor Stene.

451. **JET PROPULSION POWER PLANTS.** Sem. 1 and 2. Class 3, cr. 3. (Tech. el. ME). Prerequisites: ME 302 and ME 310.

Basic principles and analysis of performance characteristics of air breathing jet propulsion systems (turbojet, turbofan, turboprop, ramjet, scramjet). Gas dynamic analysis of flow through engine components (inlets, combustors, nozzles, etc.). Characteristics of compressors and turbines. Professor L'Ecuyer.

452. **PROPULSION SYSTEMS FOR SPACE FLIGHT.** Sem. 1 and 2. Class 3, cr. 3. (Tech. el. ME). Prerequisites: ME 302 and ME 310.

Flight mechanics and the propulsion system requirements for terrestrial and interplanetary flight. Basic principles and performance of solid and liquid chemical rocket propulsion systems. Elements of nuclear rockets, nuclear-electrical power systems, and electrical propulsion systems. Professor Warner.

463. **ENGINEERING DESIGN I.** Sem. 1 and 2. SS. Class 3, cr. 3. (7ME). Prerequisites: ME 370 and ESC 223; Corequisite: ME 315. Must be taken concurrently with ME 465.

Application of the design process to the design of various engineering components and systems. Mathematical modeling in design. Material behavior and selection in design. Strength, fluid, mechanical and thermal problems are considered. Professor Hillberry and staff.

464. **ENGINEERING DESIGN II.** Sem. 1 and 2. SS. Class 2, cr. 2. (8 ME). Prerequisite: ME 463. Must be taken concurrently with ME 466.

Lectures in engineering design with emphasis on interdisciplinary problems. Advanced engineering modeling. Design use of tools and techniques such as computers, optimization theory, decision theory, and statistics. Professor Garrett and staff.

465. **DESIGN PROJECT I.** Sem. 1 and 2. SS. Lab. 6, cr. 2. Must be taken concurrently with ME 463.

This course and ME 466 constitute a two semester sequence involving a comprehensive independent design project. The projects are chosen such that the students will demonstrate their ability to bring to bear their total engineering experience to date. The student is encouraged to select his own project. Professor Cottingham.

466. **DESIGN PROJECT II.** Sem. 1 and 2. SS. Lab. 9, cr. 3. Must be taken concurrently with ME 464.

Continuation of ME 465. Professors Cottingham and Hillberry.

467. **STUDENT-INDUSTRY PROJECT.** Sem. 1 and 2. Hours to be arranged, cr. 3 (Tech. el. ME). Prerequisite: senior standing.

Students are assigned in groups to work for the entire semester on a current engineering problem in industry. The project could involve all phases of the design process or could emphasize special portions. Discussion meetings with engineers from industries are held as often as necessary. Emphasis is placed on the academic approach to problems. Professor Holowenko.

475. **SYSTEM ANALYSIS AND CONTROL.** Sem. 1 and 2. SS. Class 2, Lab. 3, cr. 3. (7 ME). Prerequisites: MA 302 and ME 340.

Principles of automatic control as applied to engineering systems. Solution techniques for linear systems. Control system components and transfer functions. Frequency response techniques for improving system performance. Performance criteria and overall system design requirements. Professor Rezek and staff.

490. **DIRECTED READING IN MECHANICAL ENGINEERING.** Sem. 1 and 2. SS. cr. 1-4. Available upon arrangement with the head of the school. Limited to students having a cumulative index of 4.8 or higher. May be repeated for credit.

497. **SELECTED TOPICS IN MECHANICAL ENGINEERING.** Sem. 1 and 2. SS. cr. 1-6.

Available upon arrangement with the head of the school. May be repeated for credit.

499. **RESEARCH IN MECHANICAL ENGINEERING.** Sem. 1 and 2. SS. cr. 3. (Tech. el. ME). Available upon arrangement with the head of the school. Limited to students having a cumulative index of 4.8 or higher.

500. **THERMODYNAMICS.** Sem. 1 and 2. SS. Class 3, cr. 3. (Tech. el. ME). Prerequisite: ME 302.

The empirical, physical basis of the laws of thermodynamics. Formulation of the definitions and laws from the postulational approach. Properties and relations between properties in homogeneous and heterogeneous systems. The criteria of equilibrium. Application to a variety of systems and problems including phase and reaction equilibrium. Professors Brown, Qvale, and Wark.

501. **STATISTICAL THERMODYNAMICS.** Sem. 1. Class 3, cr. 3. (Tech. el. ME). Prerequisites: ME 302.

Experimental evidence for the quantization of energy and the existence of wave particle duality. Development of the Schröedinger theory and solution of simple cases. Details of atomic and molecular structure. The Maxwell-Boltzmann formulation of statistical mechanics and application to radiation and perfect gas behavior. The Gibbs formulation of statistical mechanics and application to metals, crystals, and real gases. Professor Incropera.

505. **HEAT AND MASS TRANSFER.** Sem. 1 and 2. SS. Class 3, cr. 3. Prerequisite: ME 315.

Heat conduction and mass diffusion in one, two, and three dimensions with application of analytical, numerical, and analogical techniques; treatment of convective heat and mass transfer for internal and external flows by dimensional analysis, integral method, and use of analogies between heat, mass, and momentum transport; radiation heat transfer for surfaces and gases; selected topics including combined heat and mass transfer, two phase heat transfer, and high speed flow phenomena. Professors Leidenfrost and Pearson.

506. **TWO-PHASE FLOW AND HEAT TRANSFER.** Sem. 2. Class 3, cr. 3. (Tech. el. ME, ChE). Prerequisite: ME 315.

Two-phase flow, homogeneous model, drift velocity model, drift flux model, separated model, dimensional analysis, interfacial conditions, empirical treatment, LMN model, annular and stratified flow, pool boiling, bubble dynamics, forced convection boiling, critical heat fluxes, condensation, fluidized beds, experimental techniques. Professor Winter.

509. **INTERMEDIATE FLUID MECHANICS.** Sem. 1 and 2 (SS. in odd-numbered years). Class 3, cr. 3. (Tech. el. ME). Prerequisites: ME 310 or equivalent.

Fluid properties, basic laws for a control volume, kinematics of fluid flow, dynamics of frictionless incompressible flow, basic hydrodynamics, equations of motion for viscous flow, viscous flow applications, boundary layer theory, unsteady flow. Professors McDonald and Abbott.

510. **GAS DYNAMICS.** Sem. 1 and 2. (SS. in even-numbered years.) Class 3, cr. 3. (Tech. el. ME.) Prerequisite: ME 310.

Flow of compressible fluids including one-dimensional gas dynamics, isentropic flow, normal and oblique shocks, Rayleigh line and Fanno line flows. Multidimensional compressible flow including irrotational flow and method of characteristics. Shock reflection and interaction. Professors Wellman and Hoffman.

511. **MAGNETO-FLUID-DYNAMICS.** Sem. 2. Class 3, cr. 3. (Tech. el. ME). Prerequisite: ME 310.

Review of electrodynamics. Analysis of the flow of electrically conducting fluids in electromagnetic fields. Development of the equations of motion and energy relations. Magnetic field diffusion and magnetohydrodynamic wave propagation. Applications to ionized gases. Channel flow problems and analysis of pump, flowmeter, and generator performance. Review of experiments with liquid metals and plasma. Professor Wellman.

513. **ENGINEERING ACOUSTICS.** Sem. 1. Class 3, cr. 3. Prerequisite: ME 563.

Mechanical impedance concepts. Wave motion. Fourier series and integrals. Electromagnetic, solid mechanical, and fluid mechanical wave equations for general motion. Plane acoustic equations. Plane wave sound generation and transmission by walls and in horns. Response of lumped parameter systems to plane waves. Muffler theory. Professor Crocker.

518. **CRYOGENIC ENGINEERING.** Sem. 1. Class 3, cr. 3. (Tech. el. ME). Prerequisites: ME 315, and PHYS 342 or 542.

The production of low temperatures, properties of cryogenic fluids, properties of materials at low temperature, thermometry, low temperature techniques, low temperature phenomena. Professors Cottingham and Hawks.

525. COMBUSTION. Sem. 2. Class 3, cr. 3. Prerequisite: ME 501.

Physical and chemical aspects of basic combustion phenomena. Rate processes and chemical kinetics. Chain reaction theory. Chain and thermal ignition. Detonation, deflagration, diffusion flames, heterogeneous combustion. Professor Mellor.

528. AIR POLLUTION. Sem. 2. Class 3, cr. 3. Prerequisites: ME 302 or 306 or 307 and ME 310 or permission of instructor.

Definition of the air pollution problem. Kinds and sources of pollutants. Meteorology and the transport and movement of pollutants. Methods of controlling the quantities of dust, fumes, and mists generated in industrial processes. Aircraft, truck, and automobile exhausts and the pollution of the atmosphere. Biological and economic aspects of air pollution. Professor Warner.

530. ENERGY CONVERSION. Sem. 2. Class 3, cr. 3. (Tech. el. ME). Prerequisites: ME 302, and prerequisite or corequisite: PHYS 342 or 542.

Energy sources; basic science of energy conversion; thermoelectric, thermionic, and magnetohydrodynamic systems; photovoltiac effects; solar cells and fuel cells. Professor Olsen.

541. DIESEL ENGINES. Sem. 2. Class 3, cr. 3. (Tech. el. ME). Prerequisite: ME 440.

The fundamentals of the modern diesel engine with special emphasis on the high-speed type; structural features; fuel-injection systems; combustion, combustion chamber design; performance. Professor Stene.

550. INTRODUCTION TO MISSILE AND SPACE SYSTEMS DESIGN. Sem. 1 and 2. Class 3, cr. 3. (Tech. el. ME). Prerequisite: senior standing.

Trajectory analysis, fundamental characteristics and design principles pertinent to guided missiles, space vehicles and their propulsion systems. Elements of inertial and noninertial guidance systems as applied to missile and space systems. Professor Osborn.

560. KINEMATICS. Sem. 1. Class 3, cr. 3. (Tech. el. ME). Prerequisite: ME 370.

Geometry of constrained plane motion with applications to linkage design. Type and number synthesis, size synthesis. Graphical, analytical, and computer techniques. Professor Hall.

563. MECHANICAL VIBRATIONS. Sem. 1 and 2. SS. Class 3, cr. 3. (Tech. el. ME.) Prerequisites: ESC 223 and ME 340.

Review of systems with one degree of freedom including the Laplace transformation. LaGrange's equations of motion for multiple degree of freedom systems. Transfer functions for harmonic response, impulse response, and step response. Convolution integrals for response to arbitrary inputs. Principle frequencies and modes. Introduction to phase-plane for nonlinear problems. Applications to critical speeds, measuring instruments, isolation, torsional systems. Professor Hamilton.

566. MECHANICS OF MACHINERY. Sem. 1. Class 3, cr. 3. (Tech. el. ME). Prerequisite: senior standing.

Selected topics in machine analysis, such as cam radius of curvature, planetary gearing, circulating power, efficiency, minimum equivalent polar moment of inertia, stresses due to inertia forces, balancing of engines. Professor Holowenko.

567. DYNAMIC PROBLEMS IN DESIGN. Sem. 1. Class 3, cr. 3. (Tech. el. ME). Prerequisite: senior standing.

Design and analysis of linear and nonlinear devices required to have specified dynamic characteristics. Deterministic and random inputs are considered. Professor Quinn.

569. MECHANICAL BEHAVIOR OF MATERIALS. Sem. 2. Class 3, cr. 3. Prerequisites: ME 463 or MSE 411.

A study of how loading conditions and environmental conditions can influence the behavior of materials in service. Elastic and plastic behavior, fracture, fatigue, low and high temperature behavior, viscoelastic behavior, damping, and corrosion are covered. Emphasis is on methods of treating these conditions in design. Professor Hillberry.

570. MACHINE DESIGN. Sem. 2. Class 2, Lab. 3, cr. 3. (Tech. el. ME). Prerequisite: ME 463.

Analysis of stresses and deflections due to complicated loadings; investigation of specific problems to illustrate methods of analysis and development of solutions; individual design on an original project. Professor Holowenko.

571. LUBRICATION THEORY AND BEARING DESIGN. Sem. 1. Class 3, cr. 3. (Tech. el. ME.)

Dry friction, boundary and thick film lubrication, theory and application of hydrodynamic and hydrostatic lubrication to journal and thrust bearings. Elastohydrodynamic theory, rolling bearing mechanics, and reliability theory. Bearing materials and lubricating systems. Bearing-rotor stability mechanics. Professor Modrey.

573. COMPUTER METHODS IN MECHANICAL DESIGN. Sem. 1. Class 3, cr. 3. Prerequisite: consent of instructor.

Modeling, design, and analysis of mechanical devices or systems by the use of digital computers. Emphasis is placed on numerical techniques, optimum seeking methods and computer graphics. Interdisciplinary design problems may be selected for the required project. Professor Garrett.

575. THEORY AND DESIGN OF CONTROL SYSTEMS. Sem. 1 and 2. Class 3, cr. 3. (Tech. el. ME.) Prerequisite: ME 475.

Techniques for modeling and control of systems using state and frequency domain descriptions, linear system theory, performance evaluation, compensation techniques, comparison of classical and modern design techniques. Professor Nachtigal and staff.

585. INSTRUMENTATION FOR DYNAMIC SYSTEMS. Sem. 2. Class 2, Lab. 3, cr. 3. Prerequisite: consent of instructor.

Measurement as viewed from physics and energy transduction. Instruments for basic measurement in the various engineering fields, instrumentation systems, error analysis, dynamic analysis of instrumentation systems, data acquisition and reduction using computers, A-D and D-A conversion, projects. Professors Nachtigal and Leonard.

587. ENGINEERING OPTICS. Sem. 1. Class 3, cr. 3. (Laboratory work can be undertaken for additional credit by special arrangement.) Must be preceded by B.S. in engineering or consent of instructor.

Fundamentals of geometrical and physical optics as related to problems in engineering research and design. Characteristics of imaging systems; properties of coherent and incoherent light sources; optical properties of materials. Diffraction, interference, polarization, and scattering theories as related to optical measurement techniques. Professor Stevenson.

597. SELECTED TOPICS IN MECHANICAL ENGINEERING. Sem. 1 and 2. SS. cr. 1-6. Available on arrangement with the head of the school. May be repeated for credit.

GRADUATE LEVEL

600. ADVANCED THERMODYNAMICS. Class 3, cr. 3.

601. ATOMIC AND MOLECULAR INTERACTIONS. Class 3, cr. 3.

604. DIFFUSION OF HEAT AND MASS. Class 3, cr. 3.

605. CONVECTION OF HEAT AND MASS. Class 3, cr. 3.

606. RADIATION HEAT TRANSFER. Class 3, cr. 3.

610. BOUNDARY LAYER THEORY. Class 3, cr. 3.

611. PRINCIPLES OF TURBULENCE. Class 3, cr. 3.

612. ENGINEERING ASPECTS OF TURBULENCE. Class 3, cr. 3.

613. ADVANCED ENGINEERING ACOUSTICS. Class 3, cr. 3.

625. COMBUSTION. Class 3, cr. 3.

650. JET PROPULSION SYSTEMS. Class 3, cr. 3.

651. GAS TURBINES AND JET PROPULSION. Class 3, cr. 3.

652. ROCKET JET PROPULSION. Class 3, cr. 3.

653. PROPULSION GAS DYNAMICS. Class 3, cr. 3.

654. SPACE PROPULSION SYSTEMS. Class 3, cr. 3.

655. DYNAMICS OF REAL GASES. Class 3, cr. 3.

660. ADVANCED KINEMATICS. Class 3, cr. 3.

663. ADVANCED MECHANICAL VIBRATIONS A. Class 3, cr. 3.

664. ADVANCED MECHANICAL VIBRATIONS B. Class 3, cr. 3.

667. ADVANCED DYNAMICAL PROBLEMS IN MACHINE DESIGN. Class 3, cr. 3.

671. ADVANCED BEARINGS AND LUBRICATION. Class 3, cr. 3.

676. **NONLINEAR CONTROL SYSTEMS.** Class 3, cr. 3.

677. **LINEAR CONTROL AND ESTIMATION THEORY.** Class 3, cr. 3.

678. **DISTRIBUTED SYSTEMS MODELING AND CONTROL.** Class 3, cr. 3.

679. **SPECIAL TOPICS IN SYSTEMS.** Class 3, cr. 3.

691. **JET PROPULSION SEMINAR.** cr. 2-10.

697. **MECHANICAL ENGINEERING PROJECTS.** Credits and hours to be arranged.

698. **RESEARCH.** M.S. Thesis.

699. **RESEARCH.** Ph.D. Thesis.

NUCLEAR ENGINEERING

P. N. Powers, Head of the Department
A. Sesonske, Assistant Head of the Department

Professors: H. E. Hungerford, Ph.D.; S. McLain, Ph.D.; K. O. Ott, Ph.D.; P. N. Powers, Ph.D.; A. Sesonske, Ph.D.

Associate Professors: R. E. Bailey, Ph.D.; O. H. Gailar, Ph.D.

Assistant Professors: P. J. Fulford, Ph.D.; J. O. Schiffgens, Ph.D.; E. R. Stansberry, B.S.

UNDERGRADUATE LEVEL
Lower-Division Courses

200. **INTRODUCTION TO NUCLEAR ENGINEERNG I.** Sem. 1. Class 3, Lab. 2, cr. 4. Prerequisites: PHYS 152 and MA 162 or equivalent.

Lectures and laboratory demonstrations designed to acquaint students with the field of nuclear engineering. Concepts of potential, nuclear models, fission, fusion, cross sections, and radioactivity. Experiments in radiation measurements and data handling techniques.

201. **INTRODUCTION TO NUCLEAR ENGINEERING II.** Sem. 2. Class 3, Lab. 2, cr. 4. Prerequisite: NUCL 200 or equivalent.

Continuation of NUCL 200. Transport processes and material problems. Reactor design principles, fuel cycles, and economics. Interaction of nuclear power and society. Laboratory in activation, neutron detection, and reactor coolants.

UNDERGRADUATE LEVEL
Upper-Division Courses

300. **ATOMIC AND NUCLEAR INTERACTIONS.** Sem. 1. Class 3, cr. 3. Prerequisites: MA 262 and PHYS 342.

Classification of atomic and nuclear interactions and the kinetics and dynamics of two-body interactions. Review of atomic structure and an introduction to pertinent nuclear models. Introduction to quantum mechanics and two-body interaction potentials. Discussion of cross-sections. Application of cross-section information to nuclear engineering problems.

310. **INTRODUCTION TO TRANSPORT PROPERTIES.** Sem. 2. Class 3, cr. 3. Prerequisites: MA 262 and NUCL 201.

Characteristics of the general problem of analyzing the macroscopic properties of matter in terms of microscopic phenomena. Development of the transport equation based on the postulates of statistical mechanics and intuitive concepts, with applications to mass, momentum, and energy transport. A detailed discussion of the diffusion approximation with special emphasis on neutron diffusion.

311. **INTRODUCTORY NUCLEAR SYSTEM DESIGN.** Sem. 2, Class 3, cr. 3. Prerequisite: Freshman Engineering 111.

An elective course for students desiring nuclear engineering training at the sophomore or junior level. An introduction is provided to the interrelated disciplines which affect nuclear reactor system design.

The design process, engineering economics, physics, and engineering principles. Application to a conceptual design.

405. **NUCLEAR ENGINEERING LABORATORY TECHNOLOGY.** Sem. 1 and 2. Class 2, Lab. 3, cr. 3. Prerequisite or corequisite: ENG 111.

An introduction to nuclear engineering laboratory procedures and techniques for students in the School of Technology. Topics include radiation detection, safety procedures, neutronics, nuclear reactor operation, and related experiments.

DUAL LEVEL—UNDERGRADUATE AND GRADUATE

500. **NUCLEAR ENGINEERING.** Sem. 1 and 2. Class 3, cr. 3. Prerequisite: Senior or graduate standing in engineering or consent of instructor.

An introduction to nuclear reactor principles and engineering applications. Reactor theory; control; energy removal; materials; power reactor systems; propulsion; and other applications.

501. **NUCLEAR ENGINEERING PRINCIPLES.** Sem. 1. Class 3, cr. 3. Prerequisite: graduate standing in engineering, or consent of instructor.

A first course for graduate students desiring a nuclear engineering sequence. Nuclear structure; nuclear radiations; neutron behavior while slowing down and diffusing; fast and thermal reactor theory; and control.

502. **NUCLEAR ENGINEERING SYSTEMS.** Sem. 2. Class 3, cr. 3. Prerequisite: NUCL 501 or equivalent.

Engineering aspects of nuclear power. Materials of construction; fuel and fuel cycles; heat removal; radiation shielding; economics; and nuclear power systems.

504. **NUCLEAR ENGINEERING EXPERIMENTS.** Sem. 2. Class 2, Lab. 3, cr. 3. Prerequisite or corequisite: NUCL 500 or equivalent.

A laboratory course which when coupled with NUCL 500 produces sequence that contains both the theoretical and engineering aspects of nuclear engineering. Topics include radiation detection and analysis; neutronics; radiochemical separations; and nuclear reactor experiments.

505. **NUCLEAR ENGINEERING LABORATORY I.** Sem. 1. Class 2, Lab. 3, cr. 3. Prerequisite or corequisite: NUCL 501 or equivalent.

Experimental study of radioactivity, nuclear instrumentation, and nuclear reactor principles, including neutron moderation and diffusion, shielding, heat transfer, and processing of fuel.

510. **NUCLEAR REACTOR THEORY I.** Sem. 2. Class 3, cr. 3. Prerequisite: NUCL 501 or equivalent.

Introduction to neutron transport theory; multigroup theory; heterogeneous reactors; and reactor kinetics.

520. **RADIATION EFFECTS AND REACTOR MATERIALS.** Sem. 2, Class 3, cr. 3. Prerequisite: NUCL 501, corequisite: NUCL 502.

Introduction to radiation effects in solids and a survey of nuclear reactor materials. Radiation interaction mechanisms and effects on properties. Reactor material characteristics, selection criteria, testing, and economic considerations.

580. **NUCLEAR ENGINEERING LITERATURE.** Sem. 1, Class 1, cr. 1.

A guide to the specialized literature and informational services of nuclear engineering. Practice in literature research methods.

597. **NUCLEAR ENGINEERING PROJECTS I.** Sem. 1 and 2. cr. 1-6.

Development of individual research and study projects.

GRADUATE LEVEL

600. **NUCLEAR POWER SYSTEMS.** Class 3, cr. 3.

601. **NUCLEAR REACTOR SAFETY AND LICENSING.** Sem. 1. Class 3, cr. 3.

602. **NUCLEAR POWER PLANT DESIGN ANALYSIS.** Class 3, cr. 3.

605. **NUCLEAR ENGINEERING LABORATORY II.** Class 1, Lab. 6, cr. 3.

607. **REACTOR KINETICS I.** Class 3, cr. 3.

608. **REACTOR KINETICS II.** Class 3, cr. 3.

610. **NUCLEAR REACTOR THEORY II.** Class 3, cr. 3.

612. **APPLIED REACTOR ANALYSIS.** Class 3, cr. 3.

630. **NUCLEAR RADIATION SHIELDING.** Class 3, cr. 3.

631. **NUCLEAR RADIATION SHIELDING TOPICS.** Class 3, cr. 3.

640. **FAST REACTOR THEORY.** Sem. 1. Class 3, cr. 3.

641. **FAST REACTOR ENGINEERING.** Sem. 2. Class 3, cr. 3.

696. **NUCLEAR ENGINEERING SEMINAR.** Class 1, cr. 0.

697. **NUCLEAR ENGINEERING PROJECTS II.** cr. 1-6.

698. **RESEARCH IN NUCLEAR ENGINEERING.** M.S. Thesis.

699. **RESEARCH IN NUCLEAR ENGINEERING.** Ph.D. Thesis.

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Industrial Education. Industrial Supervision. Nursing. Technology: Architectural, Aviation Electronics, Aviation Maintenance, Chemical, Civil Engineering, Computer, Electrical Engineering, Food Service, Foundry, General Aviation Flight, Industrial Engineering, Industrial Illustration, Mechanical Design-Drafting, Mechanical Engineering, Mental Health, Metallurgical Engineering, Professional Pilot.

VETERINARY SCIENCE AND MEDICINE

D.V.M. degree. Graduate programs in Anatomy, Immunology, Microbiology, Parasitology, Pathology, Pharmacology, Physiology, Clinical Sciences.