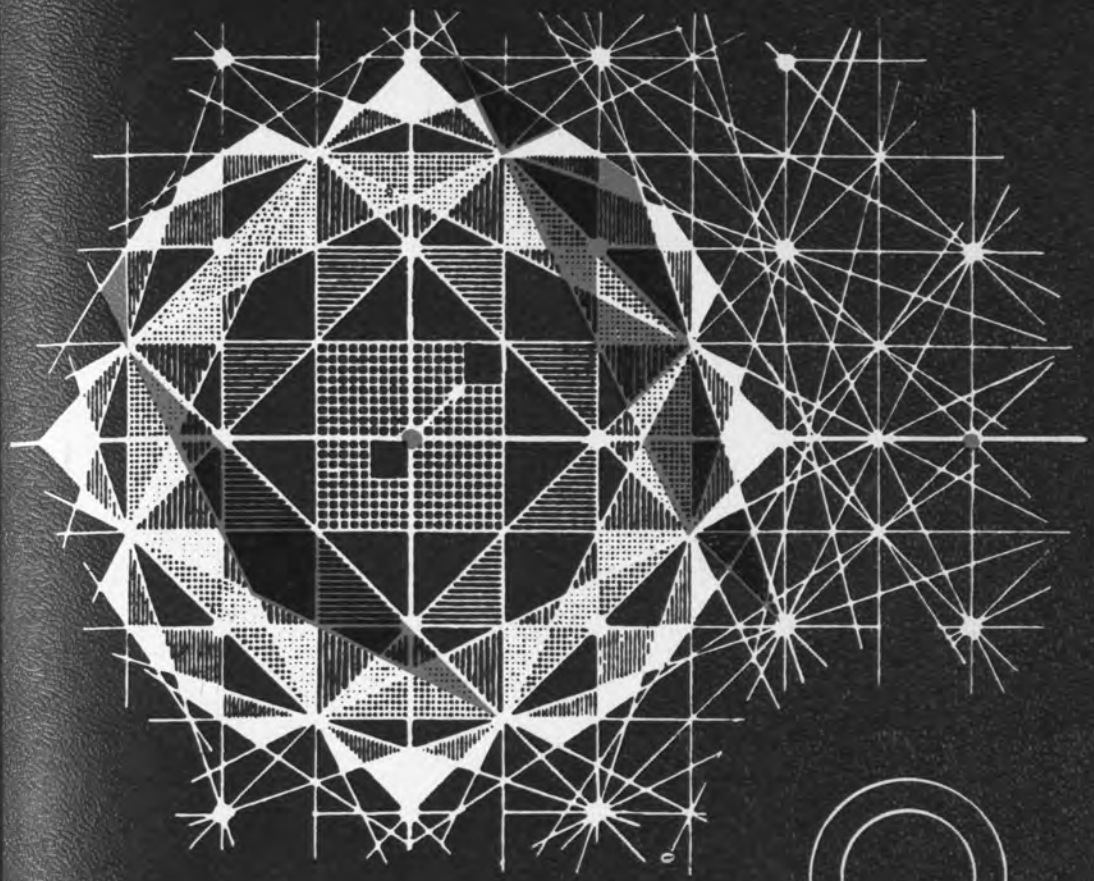
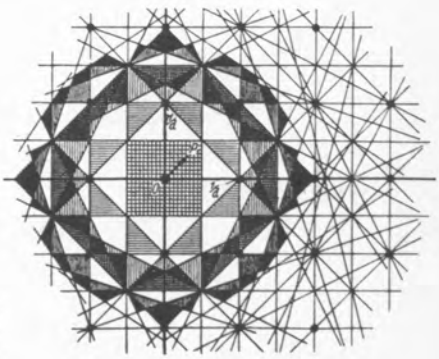


CARNEGIE

GRADUATE STUDY IN ENGINEERING AND SCIENCE

CARNEGIE INSTITUTE OF TECHNOLOGY
Schenley Park, Pittsburgh 13, Pennsylvania



The cover design has been derived from this diagram of electron energy levels in a crystal of a metal.

SECOND CLASS POSTAGE PAID AT PITTSBURGH, PA.
ISSUED MONTHLY EXCEPT APRIL, MAY, JUNE AND JULY
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CARNEGIE

GRADUATE STUDY IN ENGINEERING AND SCIENCE

CARNEGIE INSTITUTE OF TECHNOLOGY

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Evening Classes

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Summer Session

Outlines for a High School Course

Introduction

Carnegie Institute of Technology has three main objectives—undergraduate education, graduate education, and research and creative attainment.

The university consists of five major divisions.

The College of Engineering and Science offers four-year courses leading to the degree of Bachelor of Science in chemistry, mathematics, and physics; chemical, civil, electrical, mechanical, and metallurgical engineering. The College accepts candidates for the degrees of Master of Science and Doctor of Philosophy in these fields and in nuclear engineering and nuclear science. Interdisciplinary doctoral programs are offered by the College in applied materials sciences and systems and communication sciences. A four-year curriculum leading to the B.S. degree is offered in industrial management under the direction of the Graduate School of Industrial Administration in cooperation with the College of Engineering and Science.

The coeducational College of Fine Arts grants the degree of Bachelor of Fine Arts to students who complete the four-year curriculum in drama, music, painting, design, sculpture, or the graphic arts design option. Students who complete the graphic arts management option, offered in cooperation with the Graduate School of Industrial Administration, receive the Bachelor of Science degree. A five-year course in architecture leads to the degree of Bachelor of Architecture. Graduate students in the College of Fine Arts may work toward the Master of Fine Arts degree in architecture, art education, drama, music, music education, painting, design, or sculpture.

Margaret Morrison Carnegie College for women grants the Bachelor of Science degree to students completing the four-year curricula in business studies, biological sciences, home economics, and technical writing and editing. The degree of Bachelor of Arts is granted in economics, English, history, modern languages, natural sciences, psychology and social studies. Graduate work is offered in biological sciences and in home economics education.

The Division of Humanities and Social Sciences offers courses in economics, English, history, modern languages and psychology which complement the technical undergraduate work in each college. The degrees of Master of Science and Doctor of Philosophy are granted candidates in the fields of economics and psychology.

The Graduate School of Industrial Administration, William Larimer Mellon, Founder, is the first school of its kind in the nation. It offers a two-year graduate program to candidates for the master's degree in industrial administration. The School also grants the degree of Doctor of Philosophy.

Research and creative activity is carried on in each of Carnegie's divisions.

In the College of Engineering and Science, there are several special research laboratories which have received international recognition for the excellence of their work. The Chemistry Department's Coal Research Laboratory conducts investigations on coal and its products, while its Petroleum Research Laboratory investigates the composition and properties of petroleum and its products.

The Metals Research Laboratory of the Department of Metallurgical Engineering pursues basic research on the science of metals, directed toward solving problems of scientific and engineering importance.

The Physics Department's two-million dollar Nuclear Research Center, located on 63 acres in Saxonburg, Pennsylvania, includes a 450-million-electron volt synchrocyclotron which contributes to research in fundamental particle physics and high-temperature nuclear physics.

The Computation Center aids the staff and students of all colleges, as well as industry and government in the community, in the solution of complex problems in research and development. An educational and research program in numerical techniques and digital computer use is also conducted.

Privately controlled, Carnegie Institute of Technology's physical plant and buildings are valued at $37,000,000. The current value of its income-bearing endowment is $58,000,000.

The Carnegie campus in Pittsburgh, Pennsylvania, consists of 82 acres and is located four miles from the business center of the city. It adjoins Schenley Park's wooded acres and one of the city's most attractive residential sections. At Carnegie students enjoy a seclusion seldom found in a metropolitan area. However, Pittsburgh, itself, the center of heavy industry in the United States, provides unusual advantages and opportunities for students studying engineering, science, and management. There are frequent field trips to mills, plants, and research laboratories enabling students to study equipment and processes in operation through first-hand observation. Pittsburgh is, in this sense, a laboratory. Within walking distance of the campus is the city's civic center offering the student great libraries, a museum of natural history, art galleries, a concert and symphony hall, lecture programs, and nearby, a community theater.

The Hunt Library, an air-conditioned four story building centralizes the campus collection of more than 160,000 books, 1,800 regularly-received periodicals and extensive bound files. Special graduate study and research facilities in the handsome new structure are available during the day, in the evening and on weekends.

Carnegie Institute of Technology has made great strides since its founding in 1900 by Andrew Carnegie, the pioneer steel-maker and philanthropist. Ground was broken for the Schenley Park campus in the spring of 1905 and that fall students were accepted for both day and evening courses in engineering and architecture. Graduate work in engineering and science was initiated in 1922 and master's, doctor's and professional degrees were conferred.

The student body which numbered 125 local residents in 1905 has increased until the enrollment at Carnegie today averages 3,500 students from every part of the United States and from many foreign countries. Approximately 50% of these students live on the Carnegie campus. Included in the enrollment are 670 graduate students who are candidates for advanced degrees. In addition there is a combined enrollment of about 2,500 students in the evening classes and summer sessions. More than 400 full-time and part-time faculty members who are outstanding in their fields are responsible for the education of these students.

Thus, Carnegie has progressed steadily from technical and scientific training serving the local community, to professional education with a national and international reputation.

General Information

Degree Programs

The College of Engineering and Science offers programs of advanced study and research leading to the degrees of Master of Science and Doctor of Philosophy in the following fields:

Chemistry	Civil Engineering
Mathematics	Electrical Engineering
Physics	Mechanical Engineering
Chemical Engineering	Metallurgical Engineering

Nuclear Engineering and Science

This catalog also includes programs of graduate study leading to the degree of Master of Science in Bacteriology in the Department of Biological Sciences in Margaret Morrison Carnegie College. Interdisciplinary doctoral programs in applied materials sciences and systems and communication sciences are also included.

MASTER'S DEGREE

A candidate for the master's degree must complete satisfactorily an approved program conforming to the requirements of the department in which he is registered. At least three-fifths of the program must be of graduate level. These requirements include 96 units of satisfactory work at Carnegie and a comprehensive final examination. To be "satisfactory" no grade shall be lower than C, and of the first 120 units taken for graduate credit, the average grade of 96 units shall be at least B.

If a thesis is submitted in partial fulfillment of degree requirements, it must meet the approval of the instructor in charge of the work, the department head, and the Associate Dean—Graduate Studies. Three typewritten copies of the completed thesis must be presented to the department head two weeks before commencement. If the thesis is to be published, the manuscript must be approved before publication by the department. Each published copy must state "Submitted in partial fulfillment of the requirements for the degree of Master of Science at Carnegie Institute of Technology."

DOCTOR'S DEGREE

The degree of Doctor of Philosophy is granted by Carnegie Institute of Technology to candidates who give evidence of proficiency, high attainment, and research ability in the field of their major work, and who have satisfied the specific requirements of the department in which they are enrolled.

Candidates for the doctor's degree should expect to spend at least three years or the equivalent in full-time graduate study, including a minimum of one year's full-time work at Carnegie. The first year of work is usually devoted to concentrated study in fundamental courses. During the second year the course work is continued and research started. The remainder of the work is devoted chiefly to research.

A qualifying examination is given to determine the student's general knowledge of the fields of science or engineering appropriate to his program and his ability to use this knowledge in the solution of problems. Before a candidate can take the qualifying examination, he must demonstrate a reading knowledge in the required foreign languages, usually French and German. In engineering departments, proficiency in only one foreign language, usually German, may be required. A candidate may take the qualifying examination only after an application to do so has been approved by his department. In most departments this examination may be taken in either May or October and must be taken prior to November 1 of the academic year in which the doctor's degree is to be awarded. Upon satisfactorily passing the examination, the student will be accepted as a candidate for the degree of Doctor of Philosophy, and if he has not already received a master's degree, upon application and provided that the other requirements have been met, he may be granted the degree of Master of Science at the next commencement.

The doctoral dissertation must embody the results of extended research, be an original contribution to knowledge, and include material worthy of publication. It should demonstrate the candidate's ability to conduct an independent investigation and to interpret in a logical manner facts and phenomena revealed by the research. Two typewritten copies of the dissertation must be presented to the Office of Graduate Studies through the department in which the research was undertaken; regulations governing the preparation of doctoral theses may be obtained in the Office of Graduate Studies. If the dissertation is accepted, the candidate is eligible for the final public examination upon his thesis subject. Upon satisfactorily passing this examination, he will be recommended for the doctor's degree.

In addition, if the substance of the candidate's dissertation has not already been published or accepted for publication, he must present to the department in which he majored a typewritten manuscript suitable for publication, and this must be done at least one week before the degree is conferred. A sum of $25.00 must be deposited with Carnegie Institute of Technology as a guarantee of delivery of 50 copies of the dissertation printed in full or in part. The deposit will be returned when the 50 copies have been received and need not be made if they are available before the candidate's commencement. Whether publication takes place before or after the granting of the degree, the manuscript must have the approval of the department prior to publication. Each published copy must bear the statement: "Submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Carnegie Institute of Technology."

Admission and Tuition

ADMISSION PROCEDURE

Candidates for advanced degrees must have been graduated from a recognized college, university, or institute of technology.

Applicants for admission to graduate study in the College of Engineering and Science should write to the Office of Graduate Studies requesting an application blank. It is recommended that the initial inquiry be made approximately a year before the applicant plans to begin graduate study. However, before admission can be approved, he must arrange to have a transcript of all but his final year of undergraduate work and three letters of recommendation sent to the Office of Graduate Studies, College of Engineering and Science.

Applicants are required to take the Aptitude and Advanced Tests of the Graduate Record Examination administered by the Educational Testing Service. Instructions for making application will be supplied by the Office of Graduate Studies, College of Engineering and Science. Applicants who find it impossible to take the examination prior to admission may be given a postponement.

One of the admission requirements for all new students is a physical examination, the sole purpose of which is to appraise the student of his physical condition. A Medical Form for Admission will be supplied by the Office of Graduate Studies, College of Engineering and Science.

Graduate students who spend substantially their full time at Carnegie in any combination of study, research, or teaching will be required to sign an agreement indicating their acceptance of the patent policy of the institution. This policy is set forth in a statement adopted by the Trustees. Copies of the patent policy may be obtained in the Office of Graduate Studies, College of Engineering and Science. The rights of Carnegie, if any, in inventions made by any student under the sponsorship of the institution, or employing its facilities, will be subject to determination, unless otherwise expressly agreed, by the applicable law relating to ownership of inventions, implied licenses, and shoprights.

TUITION

The tuition fee, payable at registration, is $725.00 per semester for graduate students carrying a schedule of more than 24 units. Graduate students carrying schedules of 24 units or less in either day or evening classes will pay tuition at the rate of $14.00 per unit.

At the time of graduation, candidates for the master's and doctor's degrees pay a graduation fee of $10.00. Candidates for the doctor's degree make a deposit of $25.00 which is refunded when the college is supplied with 50 printed copies of the dissertation.

Fees are due and payable at the time of semester registration. Carnegie reserves the right to change its fees from year to year without notice.

Regulations governing withdrawal from college, refund of fees, and late registration are the same as those for undergraduate students.

COST OF A YEAR AT CARNEGIE

The principal expenses for graduate students during the calendar year are estimated as follows:

Tuition	$1450.00
Books and Supplies	100.00
Room and Board, approximately*	1000.00
	$2550.00

*This is an estimate for men students living in graduate houses and buying lunches at the college cafeterias.

The figures given above do not include miscellaneous personal expenses, travel, and expenses during college holidays for students who remain at Carnegie. These extra costs may run as high as several hundred dollars.

Students should be prepared to meet all financial obligations during the academic year; if an appointment is held, the student must be prepared to meet all financial obligations until the first salary or stipend payment is made.

Financial Aid

Carnegie Institute of Technology offers assistantships, fellowships, and graduate scholarships to students who are engaged in graduate work. The Office of Graduate Studies, College of Engineering and Science, will send candidates the proper application blank on request.

Teaching Assistantships. A number of third-time and half-time teaching assistantships are available to able graduate students in all departments of the College of Engineering and Science. Nine hours per week of laboratory instruction plus three hours of other duties are assigned to third-time teaching assistants, who may carry a normal load of graduate study. An assignment of twelve hours per week of laboratory instruction plus four hours of other duties is made to half-time teaching assistants, who may carry three-fourths of a normal load of graduate study.

Teaching Fellowships. Teaching fellowships are available in all of the engineering departments. The stipend for these fellowships is the same as a third-time or a half-time teaching assistantship. However, the teaching duties are one-half of those required for the corresponding teaching assistantship. A full graduate load may be taken with either type of teaching fellowship.

Fellowships. Pre-doctoral fellowships are offered by most departments in the College. These are awarded to outstanding graduate students to permit them to devote full time to advanced study and research. A number of these fellowships are supported by special Carnegie Institute of Technology funds, and some are supported by industrial concerns and other outside agencies.

Research Assistantships. Third-time and half-time research assistantships are available in a number of departments. Third-time research assistants may carry a normal load of graduate study and are assigned fifteen hours per week of professional work as assistant to a professor or a member of a laboratory staff. Half-time research assistants may carry three-fourths of a normal load of graduate study and are assigned twenty hours per week of professional work as assistant to a professor or a member of a laboratory staff.

Forgivable Loans. Future engineering teachers who hold a master's degree or its equivalent and are well qualified by intellect and aptitude, but who could not other wise afford to pursue studies toward the engineering doctorate, are eligible to obtain loans, over any period up to three years, up to a maximum of $10,000.00. If, at the termination of graduate study, the student is employed as a full-time faculty member in the U.S. or Canada, the loan is forgiven at the rate of $1000.00 per year or 20 per cent per year whichever is greater. If he is not so employed, the loan is to be repaid to the institution at the minimum rate of $1000.00 per year.

Summer Assistantships. Any graduate student may apply for a part-time or full-time research assistantship during the summer in the research laboratories on work for which no academic credit is allowed.

Tuition Assistantships. These assistantships are available in several departments of the College. The appointee is assigned to three hours per week of laboratory instruction, or its equivalent, plus three hours of other duties, and receives remission of tuition as compensation.

Graduate Scholarships. A limited number of scholarships covering full tuition or part tuition are available to qualified graduate students.

Guest Fellowships. Subject to the limitations of space and facilities, Carnegie Institute of Technology will grant holders of doctor's degrees the privilege of carrying on fundamental research in the physical sciences and engineering in the Carnegie laboratories. Such persons may attend lecture courses at the graduate level in their field of specialization, and they have the privilege of attending seminars. There will be no charge except for laboratory expenses. Applications for privileges as a guest fellow should be addressed to the Office of Graduate Studies, College of Engineering and Science.

Loans. Carnegie maintains long-term loan funds from which students may borrow. Loans are available to any deserving students. There is no interest charged for the loan until after the student has graduated, and the money can be borrowed on the security of the student's personal note with the signature of his parent or guardian. Attention is given to the applicant's scholastic record, evidence of his need for financial assistance, his good character, and his professional promise. Applications should be made to the Chairman, Committee on Financial Aid.

Health

Two physicians and two registered nurses, aided by consulting physicians, staff the Department of Health. The physicians are available during their office hours to all full-time students, and upon call to dormitory residents in case of confining illness.

Emergency and minor treatment by the Department staff is given without charge. Should hospitalization become necessary, arrangements have been made with a neighboring hospital to admit the student on recommendation of the Department to semi-private room service, the cost of which, up to a maximum of $15.00 per day, will be borne by Carnegie for a maximum of seven days. Other hospital costs, such as laboratory fees, special medicine, nursing, or medical attention beyond the service of the Carnegie staff are borne by the student.

A voluntary health insurance program is available for a nominal premium to cover medical expenses beyond those assumed by the university.

Living Accommodations

The Mudge Graduate House, which was a privately owned mansion recently bequeathed to Carnegie Tech, has been adapted to accommodate 50 graduate men. A new wing accommodates an additional 90. It is a splendid residence for graduate men, providing attractive rooms, spacious lounges, and dining facilities.

Robert E. Doherty Graduate House is a modern 52 unit apartment dwelling on campus for married graduate students and their families. It provides 16 efficiency and 36 one-bedroom apartments.

Inquiries concerning accommodations in the Mudge Graduate House and Robert E. Doherty Graduate House should be addressed to the Head of Men's Housing. His office will also help students who wish to find rooms or apartments off campus.

Graduate School of Industrial Administration

WILLIAM LARIMER MELLON, *Founder*

The Graduate School of Industrial Administration offers a two-year program in Industrial Administration, primarily for men holding bachelor's degrees in engineering

or science who wish to point toward future management responsibilities rather than toward technical engineering careers. The graduate program is planned to combine an undergraduate engineering, science, or mathematics background with graduate work concentrated primarily on administration and economics. Special emphasis is placed on preparing men for eventual management positions in industries where knowledge of technology and engineering plays a vital role. This program leads to the degree of Master of Science.

GSIA also offers doctoral programs leading to the degree of Doctor of Philosophy in Industrial Administration and in Industrial and Mathematical Economics. These programs, designed especially for men looking toward teaching and research, combine advanced work in mathematics, economics, the behavioral sciences, and quantitative methods with training on business problems, including modern developments in the use of computers in industry, operations research, and similar approaches.

Complete information on the School's objectives and program is included in a separate bulletin, which may be obtained by writing to the Graduate School of Industrial Administration, Carnegie Institute of Technology.

Graduate Study in Psychology

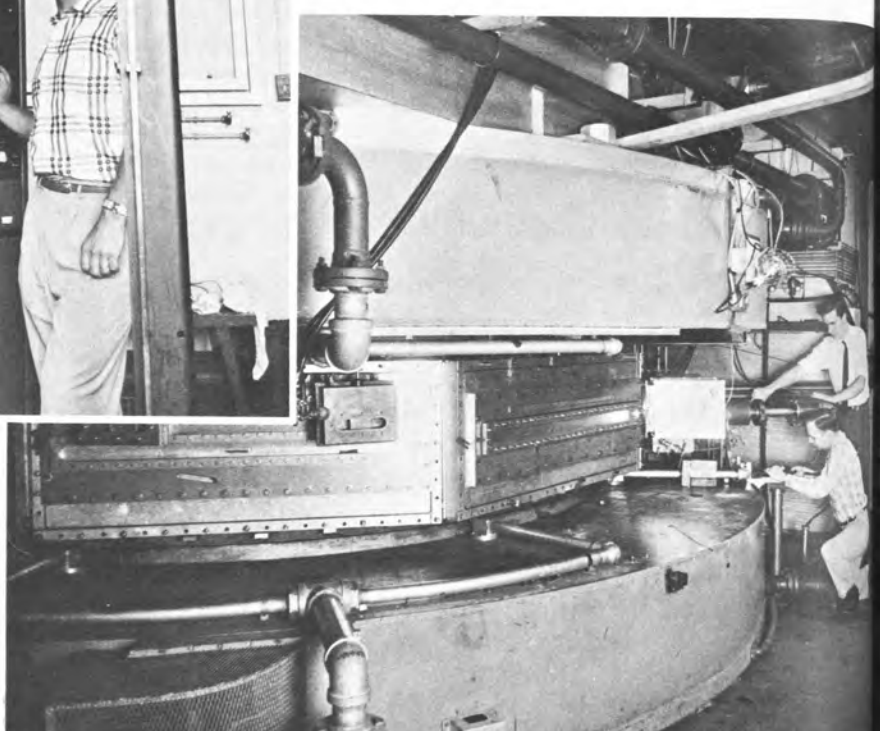
The Department of Psychology offers doctoral programs leading to the degree of Doctor of Philosophy in Psychology. The graduate work in psychology at Carnegie emphasizes quantitative approaches, particularly, but not exclusively, in the areas of (1) social and organizational psychology, (2) cognitive processes, and (3) systems and communication sciences. Applications are invited from students with undergraduate science, engineering, and mathematics degrees as well as students having undergraduate majors in psychology or other social sciences.

The graduate programs in psychology are administered by the Department of Psychology under supervision of the Committee on Graduate Degrees in the Social Sciences and Industrial Administration. Complete information on the programs is included in the bulletin of the Graduate School of Industrial Administration, Carnegie Institute of Technology, and may be obtained from the Department of Psychology or from the Graduate School of Industrial Administration.

Graduate Study in Evening and Part-Time Classes

Graduate subjects and programs leading to the degree of Master of Science are also offered in several fields of engineering and science in evening classes and on a part-time basis. Holders of the bachelor's degree who show promise of profiting by graduate work may apply for admission to a program of study leading to the master's degree, or may take an elective program of courses for which they possess degree prerequisites. All inquiries and requests for the proper blanks for making application should be addressed to the Office of Graduate Studies, College of Engineering and Science, Carnegie Institute of Technology.

A Jr. Research Metals Engineer uses the Instron testing machine to strain zone-melted, high purity iron prior to growing a single crystal.



The Physics department's two-million dollar Nuclear Research Center includes a 450-million-electron volt syncrocyclotron.

Another facility of [illegible] College of Engineering and Science—the new [illegible] M. Scaife Hall of [illegible]

The Robert E. Doherty Graduate House is a modern dwelling for married graduate students and their families.

The Mudge Graduate House is a splendid residence for graduate men.

Biological Sciences

DUANE THAYER MAUNDER, HEAD

The Department of Biological Sciences offers the student an opportunity to earn the degree of Master of Science in Bacteriology.

To be permitted to enroll with a full-time graduate schedule, a student must have completed a regular four-year course in a college or university of recognized standing, usually with a major in bacteriology or other biological science, or chemistry. The student's undergraduate scholastic record must have been well above average.

Students whose undergraduate records show definite ability to undertake graduate work but who are deficient in certain necessary undergraduate courses, such as general bacteriology, may be admitted to graduate study in the Department. However, such students will be required to pass suitable courses which will not contribute toward the requirements for the master's degree.

In planning the program of study for a graduate student, the Department will consider his previous training, his major interests, and the research facilities of the Department.

MASTER'S DEGREE

In addition to the general requirements for the master's degree (page 8), candidates for the degree of Master of Science in Bacteriology are required to complete at least 96 units of work, distributed as follows:

1. Graduate courses in the Department of Biological Sciences—at least 48 units.
2. Graduate or advanced undergraduate courses in related fields which are pertinent to the objectives of the student's program—at least 18 units.
3. Research leading to preparation of a thesis—not less than 21 units nor more than 31 units.
4. Advanced undergraduate courses in the Department of Biological Sciences—not more than 24 units.

GRADUATE AND ADVANCED UNDERGRADUATE COURSES

Please see pages 30-31 for a description of the graduate and advanced undergraduate courses offered by the Department of Biological Sciences.

Chemical Engineering

CARL CORYDON MONRAD, HEAD

The primary purpose of graduate work in the Department of Chemical Engineering is to train superior students to do original work in chemical engineering development and process analysis.

To be permitted to enroll with a full-time graduate schedule, a student must have completed a regular four-year course in chemical engineering in a college or university of recognized standing. Furthermore, the undergraduate scholastic record of the student must have been superior.

Entering students whose undergraduate preparation has been satisfactory may be able to complete the requirements for the degree of Master of Science in one academic year. Able students from other fields, or chemical engineering students whose records show definite ability to undertake graduate work but who are deficient in certain undergraduate requirements, may be admitted to graduate study in the department. However, such students will be required to pass suitable undergraduate courses which will not contribute toward the requirements for an advanced degree. Such students will be unable to complete the requirements for the master's degree in one academic year.

In planning the program of study for a graduate student, the Department will consider his previous training, his major interests, and the research facilities of the Department.

MASTER'S DEGREE

In addition to the general requirements for the master's degree (page 8), candidates for the degree of Master of Science in Chemical Engineering are required to complete at least 96 units of work, distributed as follows:

1. Graduate courses in the Department of Chemical Engineering—at least 48 units, including GE751, GE752, GE753, GE754, and GE755.
2. Research and thesis—not more than 40 units.
3. Graduate or advanced undergraduate courses in related minor fields—at least 18 units.
4. Advanced undergraduate courses in the Department of Chemical Engineering—not more than 18 units.

DOCTOR'S DEGREE

In addition to the general requirements for the doctor's degree (page 9), candidates for the degree of Doctor of Philosophy in Chemical Engineering must complete a total of at least 150 units of work exclusive of thesis, distributed as follows:

1. Graduate courses in the Department of Chemical Engineering—at least 75 units.

2. Graduate or advanced undergraduate courses in at least two related fields—at least 50 units.
3. Advanced undergraduate courses in the Department of Chemical Engineering—not more than 18 units.

GRADUATE AND ADVANCED UNDERGRADUATE COURSES

Please see pages 31-32 for a description of the graduate and advanced undergraduate courses offered by the Department of Chemical Engineering.

Chemistry

ROBERT BURNELL CARLIN, HEAD

The purpose of graduate study in the Department of Chemistry is to educate and train students to carry out independent research in the field of chemistry.

To be permitted to enroll with a full-time graduate schedule, a student must have completed a regular four-year course in a college or university of recognized standing. Furthermore, the undergraduate scholastic record of the student must have been well above average.

Undergraduate work should include the following:

A. Differential and integral calculus—6 semester hours
(Differential equations also desirable)
B. College physics—9 semester hours
C. General and analytical chemistry—15 semester hours
D. Physical chemistry—8 semester hours
E. Organic chemistry—8 semester hours

Students whose records show definite ability to undertake graduate work but who are deficient in certain undergraduate requirements may be admitted to graduate work, but such students will be required to pass without credit suitable undergraduate courses which will not contribute toward the requirements for an advanced degree.

In planning the program of study for a graduate student, the Department will consider his previous training, his major interests, and the research facilities of the Department.

MASTER'S DEGREE

In addition to the general requirements for the master's degree (page 8), candidates for the degree of Master of Science in Chemistry are required to complete at least 96 units of work, distributed as follows:

1. Graduate courses in the Department of Chemistry—at least 40 units.
2. Graduate or advanced undergraduate courses in related minor fields—at least 18 units.
3. Thesis or advanced laboratory work—not more than 40 units.
4. Undergraduate work in the Department of Chemistry—not more than 18 units.

DOCTOR'S DEGREE

In addition to the general requirements for the doctor's degree (page 9), candidates for the degree of Doctor of Philosophy in Chemistry must qualify with the following program:

1. Specialization in one of the major fields: physical chemistry, organic chemistry, inorganic chemistry, or nuclear chemistry.
2. A coordinated group of courses in chemistry, including the three basic one-year graduate courses (GS161,162; GS165,166; GS167,168) and advanced courses in the student's major field. In special cases, permission may be granted to substitute for one of the three basic courses a group of courses outside the Department of Chemistry.
3. At least 18 units in one or more minor subjects outside the Department of Chemistry. With the approval of the Department, these courses may be chosen from the following fields: physics, mathematics, chemical engineering or metallurgical engineering. Students majoring in physical chemistry are required to satisfy this requirement with the following courses: S437 Electricity and Magnetism, 9 units; and S436 Physical Mechanics, 10 units; or acceptable substitutes.
4. After satisfactorily passing the basic course in his major field and one foreign language examination, the student begins taking a series of one-hour cumulative examinations, again in his major field. The cumulative examinations are given one each month from October to May, inclusive. Once having started these examinations, the student must continue until he has passed six. The cumulative examinations are taken in place of the qualifying examination described on page 9.

GRADUATE AND ADVANCED UNDERGRADUATE COURSES

Please see pages 32-35 for a description of the graduate and advanced undergraduate courses offered by the Department of Chemistry.

Coal Research Laboratory

JAMES PAUL FUGASSI, Director

The Coal Research Laboratory does fundamental research on coal and products derived from it. The staff conducts investigations seeking to contribute to a better understanding of the mechanisms involved in carbonization, combustion, and hydrogenation of coal as well as to knowledge of the fundamental chemistry and constitution of coal. The Coal Research Laboratory provides assistantships and fellowships for graduate work in chemistry.

Petroleum Research Laboratory

BEVERIDGE JAMES MAIR, Director

The Petroleum Research Laboratory carries on fundamental research through research projects supported by the American Petroleum Institute (API). The research investigations carried on include the following: the fractionation and analysis of petroleum and petroleum products in terms of individual components; the development of fractionating processes; the purification and purity of API Standard and API Research hydrocarbons. The Petroleum Research Laboratory provides a number of assistantships and fellowships for graduate work in chemistry.

Civil Engineering

THOMAS EUGENE STELSON, HEAD

Graduate study in the Department of Civil Engineering provides opportunities for the development of professional engineering competence and scholarly achievement. The program is designed to present the best in fundamental scientific knowledge and engineering methodology for application in the broad field of civil engineering. Students are encouraged to develop creative abilities through course work and research so that they may solve new and old engineering problems with skill and imagination.

The study program is planned with consideration of the student's preparation and his special interests and abilities. Special emphasis in one or more of the following areas may be selected with faculty approval:

A. Fluid Mechanics and Hydraulic Engineering
B. Mechanics and Materials
C. Soil Mechanics and Foundation Engineering
D. Solid Mechanics and Structural Engineering

Admission to full-time graduate study is normally granted to students of superior ability who have completed an undergraduate engineering curriculum substantially equivalent to that prescribed in civil engineering by Carnegie Institute of Technology. Students with inadequate preparation or with undergraduate training in other fields may be admitted to graduate study but will be required to pass suitable undergraduate courses which will not contribute toward requirements for an advanced degree.

MASTER'S DEGREE

In addition to the general requirements for the master's degree (page 8), candidates for the degree of Master of Science in Civil Engineering are required to complete at least 96 units of work, distributed as follows:

1. Graduate courses in the Department of Civil Engineering—at least 45 units.
2. Thesis or graduate projects—not more than 40 units to be credited to the master's program.
3. Auxiliary courses in another department—at least 18 units.
4. Advanced undergraduate courses in the Department of Civil Engineering—not more than 18 units.

DOCTOR'S DEGREE

In addition to the general requirements for the doctor's degree (page 9), candidates for the degree of Doctor of Philosophy in Civil Engineering must complete the following:

1. Qualification in two of the subject-matter areas as listed above.
2. Graduate courses in the Department of Civil Engineering—not less than 75 units.
3. Auxiliary courses in a minor field—not less than 45 units.

GRADUATE AND ADVANCED UNDERGRADUATE COURSES

Please see pages 35-37 for a description of the graduate and advanced undergraduate courses offered by the Department of Civil Engineering.

Electrical Engineering

EVERARD MOTT WILLIAMS, HEAD

The purpose of graduate work in the Department of Electrical Engineering is to prepare students for careers leading to positions of leadership in research, design and development in the electric power, electronics, radio industries or in other industries in which electrical sciences play a significant part.

Objectives are, in general, characterized by breadth rather than specialization; in particular the Department recognizes the value and need of programs which lay the foundations for such careers as those in nuclear engineering, materials engineering, systems engineering, computer applications and data processing, new developments in automatic control, and similar fields which embrace disciplines in science and engineering both within and without the strict confines of ordinary electrical engineering curricula.

To be permitted to enroll with a full-time graduate schedule, a student must have completed a regular four-year course in electrical engineering in a college or university of recognized standing. Furthermore, the undergraduate scholastic record of the student must have been well above average.

PROGRAMS OF STUDY

In planning the program of study for a graduate student, the graduate faculty primarily considers his long-term professional goals. In selecting courses, emphasis is given to appropriate studies in mathematics and physical sciences and such "background" courses as electromagnetic field theory and network theory, with specialization in electrical technology at a minimum.

Two general classes of programs of study are available. The first class is concerned with training for activities which are generally classed as "electrical engineering;" these include work in such areas as electromagnetic fields, active and passive circuits, magnetic amplifiers and related devices, nonlinear circuits and circuit elements, corona and breakdown phenomena, rotating electrical energy converters, servomechanisms, microwaves, etc. The second class of programs comprises activities more commonly described as "interdisciplinary" and includes materials sciences, semiconductor materials and devices, plasma dynamics and magnetohydrodynamics, systems engineering and communication sciences, data processing and computers, etc.

The course requirements in typical first and later graduate year programs are listed below for a few of the options offered by the Department.

GENERALLY REQUIRED COURSES (All options)

		Units
GE475-6	Electromagnetic Field Theory I and II	24
GE471	Advanced Engineering Analysis	12
S255-6	Advanced Calculus	24
S271	Functions of a Complex Variable	9
GE451-4	Seminar	0-12

Additional courses for particular options:

MATERIALS SCIENCES OPTION (Interdisciplinary)

GS453-4	Quantum Theory of Matter I and II	24
GE461-2	Advanced Topics in the Science of Materials	24
S441	Thermodynamics	9
S442	Chemical Physics and Solids	9

PLASMA DYNAMICS AND MAGNETOHYDRODYNAMIC OPTION (Interdisciplinary)

GS453-4	Quantum Theory of Matter I and II	24
GS463-4	Plasma Dynamics and Magnetohydrodynamics	24

CONTROL THEORY (Department)

GE491	Information Theory and Noise	12
GE473	Linear Network Theory	12
GE494	Feedback Control Systems	12
GE496	Advanced Topics in Control Theory	12

SYSTEMS AND COMMUNICATION SCIENCES (Interdisciplinary)

GE491	Information Theory and Noise	12
GE494	Feedback Control Systems	12
GS317-8	Advanced Programming I and II	24
GI506	Complex Information Processes	9
GI343	Optimization Techniques	9
S265-6	Probability and Statistics I and II	18

ELECTROMAGNETIC FIELD THEORY AND MICROWAVES (Departmental)

GE478	Advanced Electromagnetic Field Theory	12
GE492	High Frequency Engineering	12
GE473	Linear Network Theory	12

CIRCUITS AND NETWORKS (Departmental)

GE491	Information Theory and Noise	12
GE492	High Frequency Engineering	12
GE482	Analysis of Nonlinear Magnetic and Dielectric Systems	12
GE473	Linear Network Theory	12

Elective additional courses are chosen from other offerings of the Department of Electrical Engineering and those of other departments.

GRADUATE AND ADVANCED UNDERGRADUATE COURSES

Please see pages 37-39 for a description of the graduate and advanced undergraduate courses offered by the Department of Electrical Engineering.

Mathematics

ALAN JAY PERLIS, HEAD

The Department of Mathematics offers the student an unusual opportunity for graduate work. Courses in pure mathematics enrich his study of applied mathematics and the latter, in turn, provides substance and motivation for the former. The student may eventually specialize in either area or in a combination of both.

To be permitted to enroll with a full-time graduate schedule, a student must have received a bachelor's degree from a college or university of recognized standing. Furthermore, the undergraduate scholastic standing of the student must have been well above average.

Entering students whose undergraduate preparation has been satisfactory may be able to complete the requirements for the degree of Master of Science in one academic year. Students whose records show the capacity to undertake graduate work but who are deficient in certain undergraduate requirements may be admitted to graduate work at Carnegie. Such students may be required to register for appropriate undergraduate courses which do not contribute toward the requirements for an advanced degree.

MASTER'S DEGREE

In addition to the general requirements for the master's degree (page 8), candidates for the degree of Master of Science in Mathematics are required to complete at least 96 units of work, distributed as follows:

1. Graduate courses in the Department of Mathematics—at least 60 units.
2. Advanced undergraduate courses in the Department of Mathematics—not more than 18 units.
3. Graduate or advanced undergraduate courses in allied fields—not more than 36 units.
4. A departmental examination covering Modern Algebra, Advanced Calculus, and Function Theory.

DOCTOR'S DEGREE

In addition to the general requirements for the doctor's degree (page 9), candidates for the degree of Doctor of Philosophy in Mathematics must complete the requirements for the degree of Master of Science in Mathematics, or present evidence of satisfactory completion of equivalent work at a recognized institution. A student must also complete such additional courses as may be required by the Department in preparation for the qualifying examination.

GRADUATE AND ADVANCED UNDERGRADUATE COURSES

Please see pages (39-43) for a description of the graduate and advanced undergraduate courses offered by the Department of Mathematics.

Mechanical Engineering

MILTON CLAYTON SHAW, HEAD

The primary purpose of graduate work in the Department of Mechanical Engineering is advanced training for careers in design, development, research, or teaching in mechanical engineering and closely related fields. The emphasis is on depth of understanding of fundamental principles rather than on knowledge of special methods and technology.

To be permitted to enroll with a full-time graduate schedule, a student must have completed a regular four-year course in mechanical engineering in a college or university of recognized standing. Furthermore, the undergraduate scholastic record of the student must have been well above average.

In planning the program of study for a graduate student, the Department will consider his previous training, his major interests, and the research facilities of the Department.

MASTER'S DEGREE

In addition to the general requirements for the master's degree (page 8), candidates for the degree of Master of Science in Mechanical Engineering are required to complete at least 96 units of work, distributed as follows:

1. Graduate courses in the Department of Mechanical Engineering—at least 45 units, including GE582.
2. Graduate or advanced undergraduate courses in related minor fields—at least 18 units, including advanced courses in mathematics or physics.
3. Project work—at least 6 units, but not more than 36 units. (Not required of Evening students.)

Advanced undergraduate courses in the Department of Mechanical Engineering, to a maximum of 18 units, may be included in the master's program in special cases where equivalent courses have not been part of the candidate's undergraduate program.

DOCTOR'S DEGREE

In addition to the general requirements for the doctor's degree (page 9), candidates for the degree of Doctor of Philosophy in Mechanical Engineering must complete a program approved by the Department, and which in general must include courses in mathematics, physics, and possibly other related fields. Usually the program will be as follows:

1. Graduate courses in the Department of Mechanical Engineering—72 to 120 units.
2. Graduate courses in related minor fields—72 to 120 units.
3. Projects and research—120 units.

GRADUATE AND ADVANCED UNDERGRADUATE COURSES

Please see pages (43-45) for a description of the graduate and advanced undergraduate courses offered by the Department of Mechanical Engineering.

Metallurgical Engineering

CHARLES LAW McCABE, HEAD

The objective of the graduate program in the Department of Metallurgical Engineering is to prepare students for positions of leadership in both the scientific and engineering aspects of metallurgy. Emphasis thus is placed on breadth rather than on specialization. The Department's graduate program covers chemical and physical metallurgy as well as the extension of the principles used herein to the general understanding of materials. The graduate curriculum is designed to develop and correlate the fundamental disciplines of thermodynamics, statistical mechanics, and classical mechanics in the study of metals, alloys, ceramics, and solid, as well as liquid, materials in general.

In planning the student's particular course of study, the faculty considers both the academic background and the long-term professional goals of the student. Students of high scholastic standing who have a bachelor's degree in related fields of science and engineering, as well as metallurgy or metallurgical engineering, are admitted for graduate study in the Department.

MASTER'S DEGREE

In addition to the general requirements for the master's degree (page 8), candidates for the degree of Master of Science in Metallurgical Engineering are required to complete at least 96 units of work, distributed as follows:

1. Graduate courses in the Department of Metallurgical Engineering—at least 40 units. Total graduate courses—at least 58 units.
2. Thesis or equivalent—not more than 38 units. (Not required of Evening students.)
3. Graduate or advanced undergraduate courses in related minor fields—at least 18 units.
4. Advanced undergraduate courses in the Department of Metallurgical Engineering—not more than 18 units.

DOCTOR'S DEGREE

In addition to the general requirements for the doctor's degree (page 9), candidates for the degree of Doctor of Philosophy in Metallurgical Engineering are required to take designated graduate courses in mathematics, chemistry, and physics.

The qualifying examination for each student is normally determined by his particular areas of interest in the fields of physical, chemical, and mechanical metallurgy. However, persons having a bachelor's degree in chemistry, chemical engineering, mechanics, mechanical engineering, or physics may qualify for the degree of Doctor of Philosophy by completion of a program designed for their specific requirements and approved jointly by the Department of Metallurgical Engineering and the department of their bachelor's degree.

GRADUATE AND ADVANCED UNDERGRADUATE COURSES

Please see pages 45-47 for a description of the graduate and advanced undergraduate courses offered by the Department of Metallurgical Engineering.

Metals Research Laboratory

CHARLES LAW McCABE, Director
RICHARD HOLLAND LAMBERT, Associate Director

The Metals Research Laboratory pursues basic research on the science of metals, directed toward a solution of problems which are of scientific and engineering importance. Support for this research work is obtained from government agencies and industry.

The work of the Laboratory is closely correlated with the work of the Department of Metallurgical Engineering. Candidates for the degree of Master of Science or for the degree of Doctor of Philosophy in the Department of Metallurgical Engineering may pursue their research in the Laboratory under the guidance of the faculty of the Department.

Physics

JULIUS ASHKIN, HEAD

Through its research facilities and graduate courses the Department of Physics provides unusual opportunity for training of students in broad areas of nuclear and elementary particle physics and physics of the solid state. The thesis research for the degree of Doctor of Philosophy is directed toward enlarging our understanding of basic physical phenomena.

To be permitted to enroll with a full-time graduate schedule, a student must have completed a regular four-year course in physics in a college or university of recognized standing. Furthermore, the undergraduate scholastic record of the student must have been well above average.

MASTER'S DEGREE

In addition to the general requirements for the master's degree (page 8), candidates for the degree of Master of Science in Physics are required to complete at least 96 units of work, distributed as follows:

1. Graduate courses in the Department of Physics—at least 48 units.
2. Graduate or advanced undergraduate courses in closely allied fields or in physics—at least 24 units (in addition to item 1).
3. Thesis or advanced physics laboratory—not more than 24 units.

DOCTOR'S DEGREE

In addition to the general requirements for the doctor's degree (page 9), candidates for the degree of Doctor of Philosophy in Physics must complete the following:

1. Research experience equivalent to at least 6 units of GS497 or GS476 before taking the qualifying examination.
2. Certain course examinations, e.g., in nuclear physics, physics of solids, higher mathematics, etc., to be determined by the Departmental Committee on Graduate Studies at the time of the qualifying examination on the basis of the student's chosen field of work.

The qualifying examination will cover all of undergraduate physics and the physics taken by a student in the first two years of graduate work: Quantum Mechanics (three semesters), Classical Mechanics, Electricity and Magnetism, and Statistical Mechanics. The mathematics required will include Advanced Calculus and the contents of the Theoretical Physics course. The preparation for the qualifying examination will usually require two years of graduate work and will normally be taken at the end of the fourth or the beginning of the fifth semester. However, if a student is prepared, he may take the examination at an earlier time.

A student is required to submit a first draft of his thesis before terminating residence at Carnegie and not later than one month before the date of his final oral examination.

GRADUATE AND ADVANCED UNDERGRADUATE COURSES

Please see pages 47-51 for a description of the graduate and advanced undergraduate courses offered by the Department of Physics.

Nuclear Research Center

ROGER BEATTY SUTTON, Director
MARTYN FOSS, Associate Director
ROBERT EDWARD WELSH, Assistant Director

The Nuclear Research Center located near Saxonburg, Pa., has as its major functions research in fundamental particle physics and high energy nuclear physics. Major equipment includes a synchrocyclotron which accelerates protons to 450 MEV, beam deflecting magnets, bubble chamber, and other auxiliary detecting devices. There is also a hot laboratory for work in radio-chemical research.

Applied Materials Sciences

Course and research programs are available which emphasize the application of materials sciences—atomic, molecular, and solid state physics, physical chemistry and physical thermodynamics—in advanced areas of civil, electrical, mechanical, and metallurgical engineering. These programs relate to current efforts to apply materials sciences in studies directed toward the understanding of the behavior of gross materials and the applications of the results of these studies for product and component improvement and in new developments in which material properties impose significant limitations. The programs have been established because of the present appreciable gap between the physical scientists' findings at the molecular level and the use of these findings in the solution of the problem of advancing technology.

Typical areas of research are:

Civil Engineering—crack propagation and rapid-fracture phenomena; dynamic behavior of materials and structures; dislocation movement, delayed yield, plastic flow, and creep in metal, soil, and concrete.

Electrical Engineering—magnetic materials and magnetic devices, semiconductor devices including transistors, cryogenic electronics, masers, lasers, and parametric amplifiers, dielectrics and insulators.

Mechanical Engineering—theory of metal forming, e.g., hot and cold rolling, dry friction and the effects of surface treatment on friction.

Metallurgical Engineering—energetics and kinetics of atomic transport processes on solid metal surfaces; the kinetics of phase transformations; dislocation dynamics and interactions; lower yield points and fatigue.

The courses included in typical programs comprise studies in the physical sciences undertaken by students from all departments, such as quantum theory of matter, theory of solids, physical thermodynamics or physical chemistry, etc., and courses with departmental concentration (from among those described under listings for the respective departments).

Degree requirements for students in Applied Materials Sciences conform to those for the department in which the student is enrolled. The degree received is the Doctor of Philosophy in the same department.

Nuclear Engineering and Science

GEORGE WHEELER HINMAN, COORDINATOR

An interdepartmental program of study is offered in Nuclear Engineering and Science leading to the degrees of Master of Science and Doctor of Philosophy in Nuclear Engineering or Nuclear Science. The program is open to qualified students of all engineering and science departments, but is administered through the Department of Mechanical Engineering.

Facilities avaliable for study and research include a water-moderated natural uranium subcritical assembly, a Bendix digital computer, a 450 MEV synchrocyclotron, a nuclear engineering and science laboratory, and extensive radio-chemical laboratory facilities.

MASTER'S DEGREE

In addition to the general requirements for the master's degree (page 8), candidates for the degree of Master of Science in Nuclear Engineering or Nuclear Science are required to complete at least 96 units of work, distributed as follows:

	First Semester	Units
GE585	Fluid Mechanics	12
GE587	Heat Transfer	12
GE599	Nuclear Reactor Analysis	9
S260	Higher Mathematics for Engineering & Science Students II or electives	15
	Second Semester	
GE582	Engineering Analysis II	12
GE586	Thermodynamics	12
GS156	Radiochemical Techniques or Elective	9
GS468	Experiments in Nuclear and Neutron Physics or elective	9
S444	Nuclear Physics	9

The choice of electives must be approved by the Coordinator. Depending on the background of the student, substitutions in the above program may be permitted with the approval of the Coordinator.

DOCTOR'S DEGREE

In addition to the general requirements for the master's degree (page 9), candidates for the degree of Doctor of Philosophy in Nuclear Engineering or Nuclear Science must complete the following:

1. Research experience equivalent to at least 6 units of work in one of the engineering or science departments before taking the qualifying examination.
2. Courses to be determined by the Interdepartmental Committee on Nuclear Engineering and Science on the basis of the student's chosen field of work. The courses shall total at least 150 units of work beyond the bachelor's degree plus at least one year of research. The course program must not be restricted to one department but shall include selections from at least one other department. No more than 120 units of the 150 units required may be from a single department.

3. Satisfactory performance on the language requirement. For the Nuclear Science degree, the student must pass an examination in one foreign language and show competence in another. For the Nuclear Engineering degree, the student must pass an examination in one foreign language only.
4. Satisfactory performance on a qualifying examination. The examination will cover the subjects taken by the student during his first two years of graduate work and will cover:

Atomic and Nuclear Physics	
Radiation Transport	
Fluid Mechanics	}
Heat Transfer	}—Nuclear Engineering
Radiochemistry	
Wave Mechanics	}
Advanced Nuclear Physics	}—Nuclear Science

5. Completion of a doctoral thesis acceptable to the Interdepartmental Committee on Nuclear Engineering and Science.

Systems and Communication Sciences

ALLEN NEWELL AND ALAN JAY PERLIS, COORDINATORS

An interdepartmental program of study is offered in Systems and Communication Sciences leading to the degree of Doctor of Philosophy in Electrical Engineering, Industrial Administration, Mathematics, or Psychology depending on the candidate's department of enrollment. A student so enrolled will have the Systems and Communication Sciences as a major area of specialization. This major will be common to all participating departments and will be administered by the Committee on the Systems and Communication Sciences.

All candidates will take a common written qualifying examination administered by the committee, which will constitute the prime evidence of general competence in the field. The examination will focus on the candidate's integrated ability to analyze and synthesize systems involving information processing, communication, and control.

In addition to the general requirements for the doctor's degree (page 9), the candidate is, of course, required to satisfy the requirements of his department which are listed elsewhere in this catalog and in the catalog of the Graduate School of Industrial Administration.

Detailed information concerning the program along with applications for admission and for financial assistance may be obtained from the Office of Graduate Studies, College of Engineering and Science.

Course Descriptions

Each department in engineering and science lists on the following pages a description of the graduate and advanced undergraduate courses offered.

The courses listed in each curriculum are numbered to refer to the course descriptions given by the department offering the course, according to the following plan:

UNDERGRADUATE COURSE NUMBERS	DEPARTMENT	GRADUATE COURSE NUMBERS
M19—M50	Biological Sciences	GM51—GM99
E700—E749	Chemical Engineering	GE750—GE799
S100—S149	Chemistry	GS150—GS199
E200—E249	Civil Engineering	GE250—GE299
E400—E449	Electrical Engineering	GE450—GE499
S200—S299	Mathematics	GS300—GS399
E500—E549	Mechanical Engineering	GE550—GE599
E600—E649	Metallurgical Engineering	GE650—GE699
S400—S449	Physics	GS450—GS499

The amount of credit given for each course is measured in "units." A "unit" represents one hour a week, either of class attendance or of outside preparation, throughout a semester of 16 weeks. A "unit" is equivalent to one-third of a "semester credit" or "semester hour," as credit is evaluated at some other institutions.

Carnegie Institute of Technology reserves the right to withdraw any announced course if the enrollment is too small to warrant its continuance. Carnegie Institute of Technology also reserves the right to make changes in the schedules of hours, units, or in instructional staff when such changes seem necessary or advisable.

DEPARTMENT OF BIOLOGICAL SCIENCES

Duane Thayer Maunder, Head

Associate Professor Maunder; Assistant Professors Chmura and Efthymiou.

GRADUATE COURSES

GM51 Microbial Physiology — **First semester, 12 units**

Study of the influence of chemical and physical agents in the environment; the biochemistry of bacterial metabolism. Prereq., M21, S118. 3 hrs. lec., 4 hrs. lab.

GM52 Bacterial Genetics — **Second semester, 9 units**

The principles and methodology of genetics as applied to micro-organisms. Application of these principles to the study of bacterial physiology, pathogenesis, and taxonomy. Prereq., M21, M27. 1 hr. lec., 6 hrs. lab.

GM53 Special Topics in Microbiology — **First semester, 6 units**

GM54 Special Topics in Microbiology — **Second semester, 6 units**

Lectures and discussions concerning fundamental and specialized problems in the field of microbiology not ordinarily emphasized in other courses. Content of course differs each semester depending upon student interests and specialized areas of staff or visiting lecturer. 2 hrs.

GM56 Graduate Seminar — **First and second semester**

Recent advances in microbiology are discussed by students and staff. 1 hr.

GM60 **Research** **First and second semester, units to be assigned**
Research work on a selected topic in the field of microbiology, culminating in a thesis. The credit received depends upon the amount of work elected.

ADVANCED UNDERGRADUATE COURSES

The following are advanced undergraduate courses in the Department of Biological Sciences that may be taken for credit by graduate students, if approved by their departments.

M22	Food and Sanitary Microbiology	12 units
M23	Pathogenic Microbiology	12 units
M46	Immunology and Serology	12 units
M50	Industrial Microbiology	12 units

DEPARTMENT OF CHEMICAL ENGINEERING

Carl Corydon Monrad, Head

Professors Canjar, Monrad, Rothfus and Toor; Associate Professor Li; Assistant Professors Converse, Kermode, Kostecki and Manning.

GRADUATE COURSES

GE751 **Equilibrium Stage Processes** **First semester, 6 units**
Advanced treatment of the theory and application of equilibrium stages. Binary and multicomponent distillation; multicomponent absorption; extraction. Prereq., E704. 2 hrs. rec.

GE752 **Advanced Applied Reaction Kinetics** **Second semester, 9 units**
Advanced application of engineering and scientific principles to the study of complex chemical reaction systems. Catalytic and non-catalytic reactions in homogeneous and heterogeneous systems, with and without simultaneous heat and mass transfer, are treated. Prereq., E711. 3 hrs. rec.

GE753 **Advanced Fluid Dynamics** **First semester, 9 units**
Motion of ideal, Newtonian and non-Newtonian fluids; continuity and Navier-Stokes equations; boundary layer theory; mechanics of turbulence; flow through conduits and equipment. Prereq., E707. 3 hrs. rec.

GE754 **Advanced Heat and Mass Transfer** **Second semester, 12 units**
Treatment of heat and mass transfer theory and applications from the viewpoint of the basic transport equations; transfer in non-turbulent and turbulent binary and multicomponent systems; transfer coefficients, stage efficiencies, models, analogies, interfacial phenomena, multiphase systems; transfer with chemical reactions; coupled transport processes. Prereq., E709. 4 hrs. rec.

GE755 **Applied Chemical Engineering Thermodynamics** **First semester, 12 units**
Advanced application of the general thermodynamic method to chemical engineering problems. Second law consequences; estimation and correlation of thermodynamic properties; chemical and phase equilibria. Prereq., E706. 4 hrs. rec.

GE756 **Advanced Process Engineering and Design** **Second semester, 9 units**
A coordinating course consisting of chemical engineering problems of considerable complexity which require for their solutions the application of thermodynamics, unit operations and applied kinetics, the selection of materials of construction, and the consideration of economic factors. Prereq., GE751, GE753, GE755; GE754, GE752 concurrently. 3 hrs rec.

GE760 **Graduate Seminar** **First or second semester, 1 unit**
Discussion of current advances and research in chemical engineering. Presented by graduate students and staff. 1 hr.

GE762 **Advanced Process Dynamics and Control** **Second semester, 9 units**
Analysis of open and closed control loops and their elements; dynamic response of processes; choice of variables and linkages; dynamic testing and synthesis; noise and drift; strategies for optimum operation. Prereq., E721 or equivalent, 3 hrs. rec. Offered in alternate years; offered in 1963-64.

GE763 **Elements of Process Analysis** — **First semester, 9 units**

GE764 **Elements of Process Analysis** — **Second semester, 9 units**

A course designed primarily for graduate students majoring in fields other than Chemical Engineering. Application of scientific principles to the analysis of industrial chemical processes and the solution of chemical engineering problems. Topics include industrial stoichiometry; energy relationships; chemical, phase and mechanical equilibria; fluid and fluid-solid dynamics; transfer of heat and mass; reaction kinetics; control of dynamic processes; chemical engineering economics; technical judgment in process design and development. Prereq., S102, S224, S421, S422 or their equivalent. 3 hrs. rec. Offered when there is sufficient demand.

GE770 **Research** — **First or second semester, units to be assigned**

Research work on a selected topic in the field of Chemical Engineering. The credit received depends on the amount of work elected. Prereq., graduate standing in Chemical Engineering.

GE781 **Advanced Topics in Reaction Kinetics and Catalysis** — **First semester, 9 units**

Prereq., GE755. 3 hrs. rec. Offered in alternate years; offered in 1963-64.

GE783 **Advanced Topics in Fluid Mechanics** — **First semester, 9 units**

Prereq., GE753. 3 hrs. rec. Offered in alternate years; offered in 1964-65.

GE784 **Advanced Topics in Mathematical Applications** — **Second semester, 9 units**

Prereq., GE754. 3 hrs rec. Offered in alternate years; offered in 1964-65.

GE785 **Qualifying Examination for the Degree of Doctor of Philosophy**

GE790 **Doctoral Dissertation** — **First or second semester, units to be assigned**

Research on a topic in Chemical Engineering leading to the dissertation for the Ph.D. degree. May be elected only with the permission of the staff.

GE795 **Final Public Oral Examination for the Degree of Doctor of Philosophy**

ADVANCED UNDERGRADUATE COURSES

The following are advanced undergraduate courses in the Department of Chemical Engineering that may be taken for graduate credit by graduate students, if approved by their departments.

E707	Transport Process I	9 units
E708	Transport Process II	9 units
E709	Transport Process III	9 units
E711	Applied Reaction Kinetics	6 units
E712	Process Engineering and Design	9 units
E721	Process Dynamics and Control	6 units
E722	Mathematical Techniques in Chemical Engineering	6 units
E723	Statistics	6 units
E724	Chemical Engineering Economics	6 units
E726	Process Thermodynamics	6 units

DEPARTMENT OF CHEMISTRY

Robert Burnell Carlin, Head
David Scroggs McKinney, Associate Head
Professors Carlin, Fugassi, Kohman, McKinney and Southwick; Associate Professors Douglas, Hepler, Holmes, Mains, and Miller; Assistant Professors Bishop, Caretto, Colter, Ellison, Kurland, Manch, Rubin, Shedlovsky, and Wenaas; Lecturer Mair.

GRADUATE COURSES

GS151 **Graduate Physical Chemistry** — **First semester, 9 units**

GS152 **Graduate Physical Chemistry** — **Second semester, 9 units**

Fundamental laws and relations of chemical thermodynamics applied to systems involving homogeneous and heterogeneous equilibria. Thermodynamic properties of solutions. Modern theories of non-electrolytes and of electrolytes. Chemical kinetics; homogeneous gas reactions, surface and other heterogeneous reactions, introduction to photochemistry. The course is designed for graduate students in the departments of Physics, Metallurgical Engineering, and Chemical Engineering. Prereq., A-D*; S126. 3 hrs. lec.

*See prerequisites for admission to graduate work, page 16.

GS153 **Solutions** — **First semester, 9 units**

Non-electrolytic solutions; departure from ideal behavior; modern theories; dielectric properties of gases, liquids and solutions; polarity and molecular structure; orientation and interaction in solutions; intermolecular forces. Electrolytic solutions; applications of thermodynamics; modern theories of acids and bases; activity coefficients and electrolytic conductance. Prereq., A-D*; knowledge of electrochemistry, organic chemistry and elementary chemical thermodynamics desirable. 3 hrs. lec. Offered every three years and in evening school only; offered in 1964-65.

GS155 **Colloids** — **First semester, 6 units**

GS156 **Colloids** — **Second semester, 6 units**

Physical and chemical properties of interfaces. Capillary electric phenomena. Chemical properties of suspensoid sols. The colloidal particle as a kinetic molecular unit. Properties of emulsoid sols. Gels. Prereq., A-D.* 1½ hrs. lec. Offered every three years and in evening school only; offered in 1963-64.

GS157 **Fractionating Processes** — **First semester, 6 units**

Discussion of theoretical principles and applications in distillation (regular, azeotropic, extractive, and "molecular"), adsorption (regular, with added components, with "molecular sieves"), ion exchange, solvent extraction, crystallization, clathrate compounds, thermal diffusion. 2 hrs. lec. Offered every three years and in evening school only; offered in 1964-65.

GS158 **Radiochemical Techniques** — **Second semester, 9 units**

Introduction to the techniques and applications of radiochemistry. Properties of nuclear radiations, safe handling of radioactive substances, instruments and techniques for measurement of radioactivity, radiochemical separations, applications of isotopic tracers, microscale techniques in radiochemistry. This course, emphasizing practical applications of radioactivity, complements the nuclear part of GS167 and GS168 which are concerned mainly with nuclear phenomena themselves. Prereq., A-D.* 1 hr. lec., 6 hrs. lab. Offered every year in day school. Offered in alternate years in evening school; offered in 1963-64.

GS161 **Advanced Physical Chemistry** — **First semester, 12 units**

GS162 **Advanced Physical Chemistry** — **Second semester, 12 units**

Thermodynamics, molecular structure, chemical kinetics. Introduction to statistical mechanics. Prereq., A-E.* 4 hrs. lec.

GS161A‡ **Advanced Physical Chemistry** — **First semester, 6 units**

GS162A‡ **Advanced Physical Chemistry** — **Second semester, 6 units**

Chemical thermodynamics (GS161A) and molecular structure (GS162A). Prereq., A-E.* 2 hrs. lec. Offered in evening school in alternate years; offered in 1964-65.

GS161B‡ **Advanced Physical Chemistry** — **First semester, 6 units**

GS162B‡ **Advanced Physical Chemistry** — **Second semester, 6 units**

Chemical kinetics (GS161B) and elementary statistical mechanics (GS162B). Prereq., A-E.* 2 hrs. lec. Offered in evening school in alternate years; offered in 1963-64.

GS165 **Advanced Organic Chemistry** — **First semester, 9 units**

GS166 **Advanced Organic Chemistry** — **Second semester, 9 units**

An intensive study of the methods of synthesis, properties, and structures of organic compounds designed to give the student a comprehensive working knowledge of organic chemistry. Prereq., C, E*; four semester hours of physical chemistry. 3 hrs. lec. Offered in evening school in alternate years; offered in 1963-64.

GS167 **Advanced Inorganic and Nuclear Chemistry** — **First semester, 9 units**

GS168 **Advanced Inorganic and Nuclear Chemistry** — **Second semester, 9 units**

Nuclear, atomic, molecular, and crystal structure, properties, and reactions. The emphasis is on the quantum mechanical interpretation and other modern concepts and theories. Topics include various types of chemical bonding, acids and bases, reactions in aqueous and non-aqueous media, mechanisms of inorganic reactions, various classes of inorganic compounds of current interest, isotopes, radioactivity, nuclear reactions, radiochemistry, and chemical applications of nuclear phenomena. Prereq., A-E.* 3 hrs. lec. Offered in evening school in alternate years; offered in 1964-65.

*See prerequisites for admission to graduate work, page 16.
‡Evening school courses GS161A, GS162A, GS161B, and GS162B in sum are the equivalent of the regular day school courses GS161 plus GS162.

GS171 **Quantum Mechanics** — **First semester, 9 units**

Quantum mechanics and its chemical applications. Prereq., GS161, GS162, S251, S436. 3 hrs. lec.

GS172 **Statistical Mechanics** — **Second semester, 9 units**

Classical and quantum statistical mechanics and their chemical applications. Non-equilibrium processes. Prereq., GS171. 3 hrs. lec.

GS173 **Special Topics in Physical Chemistry** — **First semester, 6 units**

GS174 **Special Topics in Physical Chemistry** — **Second semester, 6 units**

Discussion of problems of current interest and importance. Prereq., consent of instructor. 2 hrs. lec.

GS175 **Chemistry of Natural Products** — **First semester, 9 units**

A discussion of recent advances in the knowledge of natural products of physiological interest. Methods used in the determination of structure and the synthesis of vitamins and hormones will be emphasized. Prereq., GS165, GS166; or permission of instructor. 3 hrs. lec. Offered in alternate years; offered in 1964-65.

GS176 **Physical Organic Chemistry** — **Second semester, 9 units**

This course deals with the bond structure of organic compounds as revealed by the physical methods of electron diffraction, absorption spectra, molecular refraction, dielectric constant, and thermodynamic properties. It is principally concerned with a description of the mechanisms of various organic reactions as shown by bond structure, reaction kinetics, and tracer techniques. Prereq., A-E,* GS165, GS166. 3 hrs. lec. Offered in alternate years; offered in 1963-64.

GS177 **Special Topics in Organic Chemistry** — **First semester, 9 units**

An extension of the study of organic chemistry to certain important special topics not fully discussed in the advanced survey course. Among the subjects to be treated are special synthetic methods, stereochemistry, and photochemically induced transformations of organic compounds. Prereq., GS165, GS166; or permission of instructor. 3 hrs. lec. Offered in alternate years; offered in 1963-64.

GS178 **Chemistry of High Polymers** — **Second semester, 9 units**

Focus is on polymerization reactions. Condensation polymerization is considered first, then methods of molecular weight determination are surveyed, and finally addition polymerization is reviewed. Reaction mechanisms for additional polymerization and copolymerization are discussed. Consideration is given to effects on polymer properties of monomer structure, gross polymer structure and molecular weight. Prereq., GS165, GS166; S142, or equivalent. Offered in alternate years; offered in 1964-65.

GS179 **Geochemistry** — **First semester, 9 units**

Survey of the chemical composition and processes of the earth, its environment, and its constituent parts, with emphasis on the underlying physico-chemical principles. Prereq., GS167, GS168. 3 hrs. lec. Offered in alternate years; offered in 1964-65.

GS181 **Special Topics in Nuclear Chemistry** — **First semester, 6 units**

Discussions of selected areas of current interest in nuclear chemistry. Typical topics: nuclear structure, nuclear spectroscopy, theory of nuclear reactions, nuclear and isotope geology, nuclear aspects of astronomy and cosmology, radiochemical separations, isotopic tracer studies. Prereq., GS167, GS168. 2 hrs. lec.

GS182 **Recent Advances in Inorganic Chemistry** — **Second semester, 6 units**

Discussions of selected areas of current interest in inorganic chemistry. Typical topics: phosphonitrilic compounds, lattice energies, ligand field theory and applications, mechanisms of inorganic reactions, boron hydrides. Prereq., GS167, GS168. 2 hrs lec. Offered every three years and in evening school only; offered in 1964-65.

GS192 **Graduate Seminar** — **First and second semester**

Recent advances in chemistry are discussed by advanced graduate students.

GS194 **Chemical Research** — **First and second semester, units to be assigned**

Opportunities for research are offered to graduate students in the major fields of chemistry.

GS196 **Cumulative Examinations for the Degree of Doctor of Philosophy**

GS198 **Final Public Oral Examination for the Degree of Doctor of Philosophy**

*See prerequisites for admission to graduate work, page 16.

ADVANCED UNDERGRADUATE COURSES

The following are advanced undergraduate courses in the Department of Chemistry that may be taken for graduate credit by graduate students, if approved by their departments.

S117	Organic Chemistry I	12 units
S118	Organic Chemistry II	12 or 15 units
S123	Physical Chemistry I	9 or 12 units
S124	Physical Chemistry II	9 or 15 units
S135	Organic Qualitative Analysis	6, 9, or 12 units
S136	Instrumental Analysis	6, 9, or 12 units
S137	Inorganic and Nuclear Chemistry	9 units

DEPARTMENT OF CIVIL ENGINEERING

Thomas Eugene Stelson, Head

Professor Stelson; Associate Professors Au, Romualdi and Stewart; Assistant Professors Anderson, Bugliarello, Hribar, Wenzel and Yoshimi; Lecturers D'Appolonia, DiGioia and Richmond.

GRADUATE COURSES

GE253 Civil Engineering Analysis — **First semester, 9 units**

Application of mathematical and numerical methods to the systematic analysis and development of problems in the field of civil engineering, including equilibrium, eigenvalue and propagation problems in lumped-parameter and continuous systems. 3 hrs. rec.

GE254 Stability Problems — **Second semester, 9 units**

Buckling of prismatic and non-prismatic bars subjected to axial and lateral loads. Buckling of compressed rings and curved bars. Bending and buckling of thin plates and shells. Prereq., GE253, GE255. 3 hrs. rec. Offered in alternate years; offered in 1964-65.

GE255 Applied Elasticity — **First semester, 9 units**

General stress and strain-relationships; basic equations of elasticity. Plane stress and plane strain. Three dimensional stress analysis. Photoelastic, mechanical, and electrical measurement of stress-strain conditions. Prereq., GE253, or concurrently. 3 hrs. rec.

GE258 Vibration Problems — **Second semester, 9 units**

Analysis of vibrating systems having one or more degrees of freedom; torsional and lateral vibrations; vibration of elastic bodies. Prereq., GE253. 3 hrs. rec. Offered in alternate years; offered in 1963-64.

GE259 Plates and Shells — **First semester, 9 units**

Analysis of circular and rectangular plates under various conditions of loading and boundary; large deflections of plates; membrane theory and general theory of shells of revolution. Prereq., GE255. 3 hrs. rec. Offered in alternate years; offered in 1964-65.

GE262 Hydraulic Engineering — **Second semester, 9 units**

The control and utilization of natural waters. Analysis of rainfall data. Effect of evaporation, transpiration, retention, and infiltration on runoff. Flood prediction and routing. Groundwater flow. Hydraulic systems and multipurpose projects. 3 hrs. rec.

GE263 Hydraulic Design Problems — **First semester, 9 units**

Application of hydrology and hydraulics to problems of design and operation of hydraulic engineering works. Technical and economic aspects of single and multiple purpose projects. 3 hrs. rec. Offered in alternate years; offered in 1964-65.

GE264 Advanced Hydrology — **Second semester, 9 units**

Hydrometerology, surface-water and groundwater hydrology; survey of data, theories and experimental techniques; application of computers to selected problems. 3 hrs. rec. Offered in alternate years; offered in 1964-65.

GE266 Flow of Liquid-Solid-Gas Mixtures — **Second semester, 9 units**

Basic relationships in hydraulic and pneumatic transport of solids and the flow of liquid-gas mixtures including air binding in pipe lines and sediment transport in streams. Considerations of concentrations, velocities, pressure losses, and characteristics of flow. Prereq., GE241. 3 hrs. rec. Offered in alternate years; offered in 1963-64.

GE267 **Advanced Fluid Mechanics** — **First semester, 9 units**

Analysis of potential flow by exact, numerical, and graphical methods. Characteristics of real fluids. Fluid flow around bodies and past obstacles. Flow in conduits and channels. 3 hrs. rec. Offered in alternate years; offered in 1963-64.

GE268 **Modern Flow Theories** — **Second semester, 9 units**

Molecular structure of gases, solids, and liquids; fluid properties; nature of fluidity; Newtonian and non-Newtonian flows; kinetic theories of gases and liquids; flow in gravitational, magnetic, and electrical fields; flow and sound; flow and heat; experimental techniques. 3 hrs rec. Offered in alternate years; offered in 1964-65.

GE273 **Advanced Structural Design (Concrete)** — **First semester, 9 units**

Principles in the advanced design of reinforced concrete members or structures such as prestressed concrete beams and box girders, lift slabs and folded plates. 3 hrs. rec. Offered in alternate years; offered in 1963-64.

GE274 **Advanced Structural Design (Metal)** — **Second semester, 9 units**

Principles in the advanced design of metal structures. Orthotropic plate bridges. Brittle fracture and crack propagation in sheet metals and welds. Design problems in aircraft structures. 3 hrs. rec. Offered in alternate years; offered in 1963-64.

GE276 **Advanced Structural Analysis** — **Second semester, 9 units**

The formulation and solution of complex problems in the analysis of statically indeterminate structures. Matrix structural analysis. 3 hrs. rec.

GE278 **Plastic Analysis of Structures** — **Second semester, 9 units**

Basic concepts of yield conditions and plastic flow in solids. Applications of the theory of perfectly plastic solids to structures. Structures under combined stresses. Prereq., GE255. 3 hrs. rec. Offered in alternate years; offered in 1964-65.

GE279 **Structural Dynamics** — **First semester, 9 units**

Study of the response of structures under dynamic loads including shock, impact, blast, and earthquake. Analysis of force-displacement-time components and impulse-momentum changes. 3 hrs. rec. Offered in alternate years; offered in 1964-65.

GE281 **Foundation Design Problems** — **First semester, 9 units**

The application of basic concepts in soil mechanics, geologic investigations and hydraulic conditions to the solution of selected problems in foundation and earth structure design and construction. 3 hrs. rec. Offered in alternate years; offered in 1963-64.

GE282 **Advanced Soil Mechanics** — **Second semester, 9 units**

Stress-strain-failure relationships for soils with applications to bearing pressures, movements and stability. Hydraulic properties, permeability, seepage, and consolidation. 3 hrs. rec.

GE283 **Dynamics of Soils** — **First semester, 9 units**

The influence of time dependent loads on the significant physical properties of cohesive and granular soils. Methods of analysis and design for foundations and soil structures subjected to vibratory and blast loads. 3 hrs. rec. Offered in alternate years; offered in 1964-65.

GE288 **Advanced Topics in Materials I** — **Second semester, 9 units**

Dislocations and slip in crystalline solids. Theories of yield strength, work hardening, annealing, creep, and fatigue. 3 hrs. rec. 1963-64.

GE289 **Advanced Topics in Materials II** — **First semester, 9 units**

An extensive examination of the nature of the flow process in liquids, gases and solids; phenomenological, molecular, and rheological theories; the problem of a general rheological equation. Prereq., GE288. 3 hrs. rec. 1964-65.

GE296 **Qualifying Examination for the Degree of Doctor of Philosophy**

GE297 **Final Public Oral Examination for the Degree of Doctor of Philosophy**

GE298 **Graduate Projects** — **First and second semester, units to be assigned**

Analysis, design, research, or other independent investigation and comprehensive report on projects selected, with the advice and approval of the head of the department, in the fields of fluid mechanics and hydraulic engineering, mechanics and materials, soil mechanics and foundation engineering, solid mechanics and structural engineering. Required of candidates for the degrees of Master of Science and Doctor of Philosophy in Civil Engineering.

GE299 **Thesis** **First and second semester, units to be assigned**
Required of candidates for the degree of Doctor of Philosophy in Civil Engineering.

ADVANCED UNDERGRADUATE COURSES

The following are advanced undergraduate courses in the Department of Civil Engineering that may be taken for graduate credit by graduate students, if approved by their departments.

E221	Structural Mechanics II	12 units
E225	Soil Mechanics	9 units
E231	Fluid Mechanics II	9 units
E243	Systems Engineering	12 units
E244	Structural Engineering	12 units

DEPARTMENT OF ELECTRICAL ENGINEERING

Everard Mott Williams, Head

Professors Finzi, Longini, Milnes, Newell, Penney, Schatz, Teare and Williams; Associate Professors Hughes, Jordan, and Young; Assistant Professors Fehrle, Feldman, Gupta, Konnerth, Lavi, Mott, Pierce, Smith, Voshall, and Wallach; Instructors Acker, Snelsire, and Williams.

GRADUATE COURSES

GE451-2 Seminar **First and second semester, 0-3 units**
GE453-4 Seminar **First and second semester, 0-3 units**
GE455-6 Seminar **First and second semester, 0-3 units**
A series of seminars in which students discuss progress in research and invited distinguished scientists present papers on topics of interest. The seminar program is divided into general meetings and meetings of particular interest to students in specialized options such as materials sciences, magnetohydrodynamics, etc. Attendance is expected of each electrical engineering graduate student in all general meetings and in the meetings appropriate to his option. 1 hr. rec.

GE461 **Advanced Topics in the Science of Materials** **First semester, 12 units**
GE462 **Advanced Topics in the Science of Materials** **Second semester, 12 units**
Macroscopic properties of solids in terms of modern atomic theory of metals, semiconductors and insulators. Discussion of special topics in semiconductor theory such as surface phenomena, diffusion, traps and impurity phenomena, crystal growth, zone refining, optical and thermoelectric effects. 3 hrs. rec., 3 hrs. lab. Professors Jordan and Milnes.

GE463 **Plasma Dynamics and Magnetohydrodynamics** **First semester, 12 units**
GE464 **Plasma Dynamics and Magnetohydrodynamics** **Second semester, 12 units**
Fundamental equations of magnetohydrodynamics; flow of gases and viscous liquids and applications; magnetohydrodynamic waves; plasma physics; application to fusion reactors, confinement and stability. 4 hrs. rec. Professors Hughes and Young.

GE471 **Advanced Engineering Analysis** **First semester, 12 units**
An integration of the fundamental methods and principles of mathematics, physics, mechanics, and thermodynamics, and their utilization in a rigorous training in methods of analysis. 4 hrs. rec.

GE473 **Linear Network Theory** **Second semester, 12 units**
Generalized linear-network analysis; driving-point and transfer network functions, matrix methods, topology, signal-flow graphs. Introduction to the synthesis of passive one-port and two-port networks. Positive real functions, physical realizability criteria, the potential analog, LC, RC, RL and RLC networks. 4 hrs. rec. Professor Konnerth.

GE474 **Theory of Systems** **Second semester, 12 units**
Concepts of state, state representation of systems, impulse function, transform theory, kernels, time-varying systems, probability distributions, stability, nonlinear system concepts. Prereq., S266, S256. 4 hrs. rec. Professor Gupta.

GE475 **Electromagnetic Field Theory I** — **First semester, 12 units**

Introduction to the advanced mathematical treatment of vector fields; vector calculus; solutions of Laplace's equation for static electric and magnetic fields; the physical basis of the properties of simple dielectric and magnetic materials. 4 hrs. rec. Professor Feldman.

GE476 **Electromagnetic Field Theory II** — **Second semester, 12 units**

Development of Maxwell's equations for time varying fields; solutions of D'Alembert's equation; propagation of electromagnetic fields in various structures; induced voltages and skin effects; variation of the electromagnetic constants of simple materials as a function of frequency. 4 hrs. rec. Professor Feldman.

GE478 **Advanced Electromagnetic Field Theory** — **Second semester, 12 units**

Functions of a complex variable in solutions of electromagnetic field problems; Schwarz-Christoffel transformation; Green's function; Maxwell's stress tensor; resonant cavities; interaction between electron beam and fields; relativistic effects. Prereq., GE476, S271. 4 hrs. rec. Usually offered in alternate years.

GE480 **Qualifying Examination for the Degree of Doctor of Philosophy**

GE481 **Power System Stability** — **First semester, 12 units**

A study of electric power systems in the transient state. Symmetrical components and applications to faults. Selected problems and tests in the Power System Stability Laboratory. Prereq., GE482, 4 hrs. rec., or 3 hrs. lab. Offered when there is sufficient demand.

GE482 **Analysis of Nonlinear Magnetic and Dielectric Systems** — **Second semester, 12 units**

Magnetic and dielectric nonlinearities; first-order problems; analog, operational, memory and logic devices; high order systems, ferroresonance, regulators, subharmonic generators, parametric amplifiers and oscillators. General energy relations; small and large signal analysis; system performances and stability. 4 hrs. rec. Professors Finzi and Lavi.

GE483 **Advanced Problems in Machine Analysis** — **First semester, 12 units**

Advanced general study of electric machines in the transient state. Various approaches and methods of analysis as applied to synchronous, asychronous, and commutator machines. Prereq., GE482, GE484. 4 hrs. rec. Offered when there is sufficient demand.

GE484 **Advanced Synchronous Machines** — **Second semester, 12 units**

A study of synchronous machines in transient and steady-state operation. Machine reactances, their physical origin, analytical evaluation, determination by tests, and use in selected problems and tests in the Power System Stability Laboratory. 4 hrs. rec., 6 hrs. lab. Offered when there is sufficient demand.

GE488 **Graduate Projects** — **First and second semester, units to be assigned**

Training in research; a series of investigations under the student's initiative culminating in comprehensive reports, with special emphasis on orderly presentation. Professors Finzi, Longini, Milnes, Newell, Penney, Williams, Hughes, Jordan, Young, Fehrle, Pierce, Smith, Voshall, Wallach.

GE489 **Research** — **First and second semester, units to be assigned**

A limited number of properly qualified students may elect to do research work culminating in a thesis. The particular topic of investigation must be selected with the advice and approval of the Head of the Department. Professors Finzi, Longini, Milnes, Newell, Penney, Williams, Hughes, Jordan, Young, Fehrle, Feldman, Feucht, Gupta, Konnerth, Lavi, Mott, Pierce, Smith, Voshall, Wallach.

GE490 **Final Public Oral Examination for the Degree of Doctor of Philosophy**

GE491 **Information Theory and Noise** — **First semester, 12 units**

Generalized harmonic analysis; random variables, ensembles, distributions, and averages. Correlation and power density spectra; noise in devices and networks. Sampling theory, error reducing codes, information measure, rates and channel capacity. Analysis of systems with random inputs. 4 hrs. rec. Professor Pierce.

GE492 **High-Frequency Engineering** — **Second semester, 12 units**

High-frequency measurements, modulation theory, travelling wave and beam tubes, magnetrons and klystrons. Modern amplifier-analysis and synthesis including parametric amplification, masers and solid state devices. Principles of communication systems and radar. Prereq., GE491. 3 hrs. rec. 3 hrs. lab. Professor Jordan.

GE494 **Feedback Control Systems** — **Second semester, 12 units**

Analysis and synthesis of linear and nonlinear feedback control systems based upon classical methods of servomechanisms (continuous and discrete), signal flow graphs, transfer function, stability criteria, performance of systems and corrective network synthesis. Prereq., S271. Professor Lavi.

GE495 **Advanced Topics in Control Systems** — **First semester, 12 units**

Multivariable systems; methods of analysis of nonlinear control systems; discrete systems; self-optimizing control systems; optimization of continuous and discrete systems with deterministic and statistical inputs.

GE496 **Information Processing Systems** — **Second semester, 12 units**

Boolean algebra and logic, applications; memory and logic circuits; automata theory, Turing machines; pattern recognition; reliability; redundancy; stability of self-organizing systems. Prereq., S256, S266. 4 hrs. rec. Professor Pierce.

GE493 **Selected Problems in Electrical Engineering** — **First semester, 12 units**

GE498 **Selected Problems in Electrical Engineering** — **Second semester, units to be assigned**

Problems of current interest in electrical engineering in the fields of servomechanisms and communication systems. The emphasis is on the intelligent use of analytical and laboratory work in the solution or realistic problems. 4 hrs. rec. Staff.

ADVANCED UNDERGRADUATE COURSES

The following are advanced undergraduate courses in the Department of Electrical Engineering that may be taken for graduate credit by graduate students, if approved by their departments.

E407	Electrical Engineering III	12 units
E408	Electrical Engineering IV	12 units
E409	Electrical Engineering V	12 units
E410	Electrical Engineering VI	9 units
E411	Systems I	12 units
E412	Systems II	12 units
E413	Physical Electronics	12 units
E414	Circuit Electronics	18 units

DEPARTMENT OF MATHEMATICS

Alan Jay Perlis, Head

David Moskovitz, Associate Head

Professors Duffin, Moskovitz, Nehari, Noll, and Perlis; Associate Professors Hoover, MacCamy, Martin, Moore, and Strehler; Assistant Professors DeGroot, Leonard, Mizel, Pederson, and Rao; Instructors Karlovitz and Winter.

GRADUATE COURSES

GS301 **Theory of Functions of a Complex Variable I** — **First semester, 12 units**

GS302 **Theory of Functions of a Complex Variable II** — **Second semester, 12 units**

The techniques and classical theorems of analysis are developed and studied with emphasis on general theory. Point-set and real variable introduction, complex numbers, differentiation and analytic functions, integration and Cauchy's theorem, Taylor's series, singularities, multiple-valued functions and Riemann surfaces, uniform convergence, calculus of residues, analytic continuations, gamma function, Riemann zeta function, maximum modulus theorem, conformal mapping, integral functions, power series, Dirchlet series, elliptic functions. 3 hrs. rec.

GS303 **Theory of Measure and Integration** — **First semester, 12 units**

Special emphasis on Lebesgue measure and integration as prototypes; set functions; general measure; applications in probability theory, potential theory, trigonometric series. 3 hrs. rec.

GS304 Fourier Series and Integrals — Second semester, 12 units

Convergence in mean, summability, Parseval's formula, Poisson's summation formula, probability, and characteristic functions; selected topics from recent developments such as the work of Wiener. Prereq., GS303. 3 hrs. rec.

GS305 Theory of Differential Equations I — First semester, 12 units

GS306 Theory of Differential Equations II — Second semester, 12 units

First order equations, types solvable by quadratures, Clairaut's equation, envelopes, integrating factors, existence proofs; systems of first order equations; linear second order equations, constant coefficient, Euler's equation; Riccati's equation. Equations of the Sturm-Liouville type, eigen-value problems and oscillation theory, the expansion theorem, connections with the calculus of variations; linear second order equations in the complex domain, singularities, Fuch's theory of non-essential singular points; equations of Legendre and Bessel, the hyper-geometric equation, Whittaker's equation; integration by means of definite integrals; the Laplace transform. 3 hrs. rec.

GS307 Theory of Relativity — Second semester, 12 units

Pseudo-Euclidean spaces; kinematics, dynamics, and electromagnetism in Minkowski space; differentiable manifolds, Riemannian geometry; the field equations of Einstein's theory of gravitation, special solutions; selected topics from recent developments. Prereq., S267, or equivalent. 3 hrs. rec.

GS308 Selected Topics in Analysis — 12 units

Additional topics of analysis not covered in other courses. 3 hrs. rec. Offered when there is sufficient demand.

GS309 Continuum Mechanics — First semester, 12 units

GS310 Continuum Mechanics — Second semester, 12units

Elasticity and hydrodynamics. Kinematics, strain, rate of strain, vorticity; forces and stresses. The fundamental principles of classical mechanics, Cauchy's equations of motion. Thermostatics of continuous media, perfect fluids, perfectly elastic materials. Linear elasticity; Newtonian fluids. The general theory of materials, rheology. The partial differential equations of elasticity and hydrodynamics; irrotational flow of perfect fluids; problems in linear elasticity; applications. 3 hrs. rec.

GS311 Mathematical Logic — First semester, 12 units

Propositional calculus, intuitive treatment; Boolean logics; propositional calculus, formal treatment; logics with quantifiers; predicate calculus; mathematical models; consistency and completeness; classes and types. 3 hrs. rec.

GS312 Probability — Second semester, 12 units

Properties of Lebesgue-Stieltjes measures; axiomatic theory of probability; characteristic functions, sequences of distributions, and general convergence theorems; weak and strong laws of large numbers; problems of moments; central limit theorem; Markov chains; Gram-Charlier and Edgeworth series; combinatorial problems. Prereq., S295, S296, GS303. 3 hrs. rec.

GS313 Differential and Integral Equations of Mathematical Physics I — First semester, 12 units

GS314 Differential and Integral Equations of Mathematical Physics II — Second semester, 12 units

Mathematical theory of the linear partial differential and integral equations of mathematical physics with examples and applications; classification of second order partial differential equations; hyperbolic equations, characteristic curves and the Cauchy problem, the wave equation; eigen-values; eigen-functions, and general Fourier expansions; Fourier and Laplace transforms, the heat equation; elliptic equations and boundary value problems, potential theory and harmonic functions, variational principles and methods; integral equations of the first and second kind. 3 hrs. rec.

GS315 Partial Differential Equations I — First semester, 12 units

GS316 Partial Differential Equations II — Second semester, 12 units

Existence and uniqueness theorems for hyperbolic systems. Classical theory of linear equations including Riemann's method, potential theory and fundamental solutions. A discussion of the Dirichlet problem and other boundary-value problems for elliptic equations. An introduction to recent developments in the application of functional analysis to partial differential equations. 3 hrs. rec.

GS317 **Advanced Programming I** — **First semester, 12 units**

GS318 **Advanced Programming II** — **Second semester, 12 units**

Examples and analysis of the properties of representative programming languages; symbolic methods for defining programming languages; techniques for constructing language processors; systems and collections of programming languages; mathematical models of programming languages. 3 hrs. rec.

GS319 **The Calculus of Variations** — **First semester, 12 units**

First variation, Euler-Lagrange equations; free endpoint problems, isoperimetric problems; geodesics; second variation, Legendre's and Jacobi's conditions; conjugate points, sufficient conditions, Weirstrass' E-function; higher-dimensional problems; the Rayleigh-Ritz method; Hamilton-Jacobi theory. 3 hrs. rec.

GS321 **Elements of Topology I** — **First semester, 12 units**

GS322 **Elements of Topology II** — **Second semester, 12 units**

Standard notions in point set topology; equivalence of the axiom of choice, the well-ordering theorem, and Zorn's lemma; Tychonoff theorem; Tietze extension theorem; compactification and metrization by imbedding in a cube; topological groups and coset spaces; characterization of finitely generated abelian groups by torsion and Betti numbers; simplicial complexes; simplicial approximation theorem; chain complexes; universal coefficient theorem; Brower fixed-point theorem; invariance of domain; degree of maps of spheres and the fundamental theorem of algebra. 3 hrs. rec.

GS325 **Algebraic Theories I** — **First semester, 12 units**

GS326 **Algebraic Theories II** — **Second semester, 12 units**

Vectors and linear systems; determinants; linear transformations and matrices: the characteristic equation, invariant factors and elementary divisors, similarity, canonical forms, geometric applications. Group theory through the Sylow theorems; field theory, polynomials, algebraic extension fields, Galois theory. 3 hrs. rec.

GS327 **Algebraic Theories III** — **First semester, 12 units**

GS328 **Algebraic Theories IV** — **Second semester, 12 units**

Euclidean rings, polynomial rings, ideals in commutative rings, principal ideal rings, the decomposition of ideals. Theory of algebraic numbers: quadratic domains, the Gaussian domain, the field of all algebraic numbers, integral algebraic numbers, discriminant, basis, unique factorization of ideals. 3 hrs. rec.

GS331 **Selected Topics in Geometry** — **12 units**

3 hrs. rec. Offered when there is sufficient demand.

GS332 **Selected Topics in Algebra** — **12 units**

3 hrs. rec. Offered when there is sufficient demand.

GS345 **Numerical Analysis and Methods** — **First semester, 12 units**

Numerical solutions of partial differential equations and integral equations, matrix methods with application to systems of linear equations and linear inequalities, high speed computing devices, punch-card computers, digital computers, analog computers. 3 hrs. rec.

GS355 **Linear Vibrations** — **First semester, 12 units**

Free and forced vibrations of continuous systems: strings, beams, membranes, and plates. Exact and various approximate solutions such as Rayleigh-Ritz, Weinstein, Method of Finite Differences, Collocation, Galerkin, etc. 3 hrs. rec.

GS356 **Nonlinear Vibrations** — **Second semester, 12 units**

Free and forced vibrations of systems with nonlinear restoring forces, with and without damping. Graphical and geometrical methods, various analytical methods. Self-sustained vibrations, subharmonic resonance. Stability of nonlinear vibrations. 3 hrs. rec.

GS361 **Selected Topics in Hydrodynamics** — **12 units**

3 hrs. rec. Offered when there is sufficient demand.

GS371 **Selected Topics in Elasticity** — **12 units**

3 hrs. rec. Offered when there is sufficient demand.

GS374 **Theory of Linear Operators** — **Second semester, 12 units**

Topics from Hilbert spaces, Banach spaces, spectral theory, operator algebra; with applications. 3 hrs. rec.

GS375 Function Spaces I — First semester, 12 units

GS376 Function Spaces II — Second semester, 12 units

Review of Lebesgue integration and topology. Linear spaces; functionals; Hilbert space; Banach space; bounded linear operators; spectral theory. Unbounded operators; integral equations and other applications. 3 hrs. rec.

GS387 Qualifying Examination for the Degree of Doctor of Philosophy

GS388 Final Public Oral Examination for the Degree of Doctor of Philosophy

GS389 Graduate Seminar in Mathematics I — First semester, units to be assigned

GS390 Graduate Seminar in Mathematics II — Second semester, units to be assigned

GS391 Advanced Mathematical Statistics I — First semester, 12 units

GS392 Advanced Mathematical Statistics II — Second semester, 12 units

Sampling distributions; tests of goodness of fit; theory of estimation; general theory of testing statistical hypotheses; topics in regression and analysis of variance, combinatorial statistical theory. Prereq., S295, S296. 3 hrs. rec.

GS393 Normal Sampling Theory I — First semester, 12 units

GS394 Normal Sampling Theory II — Second semester, 12 units

Density functions and their properties; tests of hypotheses; properties of the normal and allied distributions; the canonical test of linear hypotheses with applications to regression, analysis of variance and covariance, systematic and randomized models; the relation between regression and correlation in normal distributions; correlation models and an introduction to multivariate analysis. Prereq., S241, S295, S296. 3 hrs. rec.

GS395 Statistical Analysis I — First semester, 12 units

GS396 Statistical Analysis II — Second semester, 12 units

Sequential analysis; order statistics; rank correlation; non-parametric tests; study of selected papers from current statistical literature; critical analysis of contributed problems. Prereq., S295, S296. 3 hrs. rec.

GS397 Selected Topics in Statistics — 12 units

3 hrs. rec. Offered when there is sufficient demand.

GS398 Reading and Research I — Units to be assigned

GS399 Reading and Research II — Units to be assigned

ADVANCED UNDERGRADUATE COURSES

The following are advanced undergraduate courses in the Department of Mathematics that may be taken for graduate credit by graduate students, if approved by their departments.

S249	Combinatorial Analysis	9 units
S251	Differential Equations	9 units
S255	Advanced Calculus I	12 units
S256	Advanced Calculus II	12 units
S259	Higher Mathematics for Engineering and Science Students I	9 units
S260	Higher Mathematics for Engineering and Science Students II	9 units
S265	Probability and Statistics I	9 units
S266	Probability and Statistics II	9 units
S267	Vector and Tensor Analysis	9 units
S268	Partial Differential Equations	9 units
S271	Functions of a Complex Variable	9 units
S272	Operational Calculus	9 units
S273	Modern Algebra I	12 units
S274	Modern Algebra II	12 units
S275	Fourier Series and Orthogonal Functions	9 units

S281	Hydrodynamics	9 units
S282	Elasticity	9 units
S287a	Experimental Design I	9 units
S287b	Experimental Design II	9 units
S289	Numerical and Graphical Analysis I	9 units
S290	Numerical and Graphical Analysis II	9 units
S291	Statistical Quality Control I	9 units
S292	Statistical Quality Control II	9 units

DEPARTMENT OF MECHANICAL ENGINEERING

Milton Clayton Shaw, Head

John Fletcher Osterle, Associate Head

Professors Forstall, Osterle, and Shaw; Associate Professors Gaylord, Hinman, Hughes, Rouleau, Stokey, and Weinstein; Visiting Associate Professor Peklenik; Assistant Professors Hawk, Hornbeck, and Johnson; Instructors McLennan, Murphy, and Walker.

GRADUATE COURSES

GE565 Advanced Strength of Materials I — First semester, 8 units

GE566 Advanced Strength of Materials II — Second semester, 8 units

Brief review of elementary strength of materials. Statically indeterminate problems in bending; general case of bending; energy of strain; general expression for strain energy; theorem of Castigliano and its application to statically indeterminate problems; the reciprocal theorem and influence lines; theory of curved bars; bending of a curved bar out of its plane of initial curvature; semi-infinite and finite beam on elastic foundations; combined direct compression and lateral loaded beams; continuous struts; representation of deflection curve by a trigonometrical series; elementary theory of thin plates; bending of rectangular plates; local bending stresses in these vessels. Prereq., E517 or equivalent. 2 hrs. rec.

GE567 Advanced Strength of Materials III — First semester, 8 units

GE568 Advanced Strength of Materials IV — Second semester, 8 units

Lateral buckling of bars; energy method of calculating critical compressive loads; buckling of latticed struts; buckling of circular rings and tubes under external pressure; buckling of a circular arch; buckling of beams without lateral supports; thick wall cylinders; torsion of shafts of non-circular cross section; membrane analogy; torsion of rolled profile sections; torsional buckling of thin-walled compression members; combined bending and torsion of thin-walled members of open cross section; structures of perfectly plastic materials ultimate strength of structures; pure bending of beams of material which does not follow Hooke's law; torsion beyond the elastic limit; mechanical properties of materials; various strength theories. Prereq., E517, or equivalent. 2 hrs. rec. These subjects may be taken before GE565 and GE566.

GE570 Nuclear Design of Power Reactor Cores — Second semester, 9 units

A study of the engineering aspects of the nuclear design of power reactors, emphasizing the use of digital computers. Those areas of nuclear design leading to quantities used in other design fields (hot channel factors, lattice optimization, control requirements, etc.) are stressed. Among the specific topics will be the solution of the neutron distribution equation by various computer approximations, studies of reactivity and core loading, lifetime and fuel burnup, power distributions and control programming, and transients and spatial oscillations. Prereq., S445, S446, or equivalent. 3 hrs. rec.

GE572 Thermal and Hydraulic Design of Power Reactor Cores — Second semester, 9 units

This course is to introduce and analyze the thermal and hydraulic problems in design of a nuclear reactor core. The problems related with two phase flow and boiling heat transfer will be emphasized. Thermal and hydraulic design of a core at steady state will be discussed. Transient analysis will be introduced. 3 hrs. rec.

GE580 Graduate Projects — First and second semester, units to be assigned

Training in research: a series of investigations under the student's initiative culminating in comprehensive reports, with special emphasis on orderly presentation and effective English composition. Participation in graduate seminar.

GE581 **Advanced Engineering Analysis I** — **First semester, 12 units**

An integration of the fundamental facts and principles of mathematics, physics, mechanics, electric circuits, and thermodynamics, and their utilization in a rigorous training in methods of analysis of engineering problems. The mathematical level attained includes ordinary differential equations. 4 hrs. rec.

GE582 **Advanced Engineering Analysis II** — **Second semester, 12 units**

Extension of GE581 to engineering problems involving distributed systems, especially in the fields of thermal conduction and mechanical vibration. Formulation of partial differential equations and solution by analytical and numerical methods. Prereq., GE581; or E515, or equivalent. 4 hrs. rec.

GE583 **Engineering Elasticity** — **First semester, 12 units**

General analysis of stress and strain; equations of equilibrium and compatability; stress-strain relations; two-dimensional stress problems; theory of unsymmetrical beams; torsion of non-circular sections; elastic energy principles with application to indeterminate structures; thermoelastic problems; instability of columns and beam columns; introduction to plate theory. 4 hrs. rec.

GE584 **Dynamics of Machinery I** — **Second semester, 12 units**

A study of the principles of dynamics and kinematics in terms of their application to the design and operation of machinery. Rigid body motion in systems with several degrees of freedom; rotating and accelerating frames of reference; use of energy methods, and Lagrange's equations, as well as Newton's laws in setting up equations of motion. Free and forced vibrations; Fourier analysis of vibrations; vibration absorption and isolation; dynamic forces and stresses; balancing, critical speeds, governors, and feedback systems. 4 hrs. rec.

GE585 **Fluid Mechanics** — **First semester, 12 units**

Equations of continuity, momentum, and energy; kinematics of fluids; dynamics of non-viscous fluids; viscous flow; Navier-Stokes equations; turbulence; boundary layer theory; convention heat transfer; flow about immersed bodies and in closed conduits. 4 hrs. rec.

GE586 **Thermodynamics** — **Second semester, 12 units**

Review of the first and second laws of thermodynamics. Introduction of the concepts of entropy generation and dissipation with applications. Kinetic theory and an introduction to statistical mechanics. The thermodynamics of coupled irreversibilities and applications to direct energy conversion devices. The thermodynamics of reactive systems. 4 hrs. rec.

GE587 **Heat Transfer** — **First semester, 12 units**

Primary consideration is given to topics in steady-state and transient conduction heat transfer emphasizing techniques used in the solution of practical engineering problems. The solutions of Bessel and Legendre equations together with the Laplace transforms are utilized. Convection and radiation heat transfer are considered primarily from the viewpoint of boundary conditions. 4 hrs. rec.

GE588 **Qualifying Examination for the Degree of Doctor of Philosophy**

GE589 **Final Public Oral Examination for the Degree of Doctor of Philosophy**

GE590 **Research** — **First and second semester, units to be assigned**

GE591 **Plasma Dynamics and Magnetohydrodynamics** — **First semester, 12 units**

GE592 **Plasma Dynamics and Magnetohydrodynamics** — **Second semester, 12 units**

Study of the basic equations of magnetohydrodynamics with emphasis on the rigorous development of electrodynamics. Flow of gases and viscous liquids and applications. Magnetohydrodynamic waves, shocks, and acoustics. The Boltzmann equation and plasma physics. Applications to fusion reactors. Study of confinement and stability. Prereq., permission of the instructor. 4 hrs. rec.

GE594 **Fluid Mechanics II** — **Second semester, 12 units**

Analysis of compressible flow in ducts with area change, friction, and heat transfer. Two-dimensional compressible flow. Method of small perturbations. Compression shocks and expansion waves. Method of characteristics. Prereq., GE585. 4 hrs. rec.

GE595 **Dynamics of Machinery II** — **First semester, 9 units**

A study of selected topics in dynamics of machinery such as: three-dimensional motion, gyroscopes, and gyroscopic effect in rotating disks; nonlinear systems; methods of analyzing free and forced vibration of systems having many degrees of freedom such as beams, turbine blades, and plates; mechanical servomechanisms. Prereq., GE584. 3 hrs. rec. and lab.

GE598 Engineering Plasticity — **Second semester, 9 units**

A mathematical study of the theory and applications of ideally plastic solids. Critical examination of the limitations of present theory in describing materials. Applications to mechanical testing methods, metal forming processes, structural collapse, and soil mechanics. Prereq., GE583, or equivalent. 3 hrs. rec.

GE599 Nuclear Reactor Analysis — **First semester, 9 units**

The equations of neutron transport and neutron slowing down are developed. These equations are applied to problems of determining the spatial and energy distributions of neutrons in non-multiplying and multiplying media. Also treated is the multiplication constant for a homogeneous and/or a heterogeneous system, including the evaluation of the thermal utilization, resonance escape probability, fast effects, and leakages. Other special topics include reactor dynamics, control rod calculations, burnup and conversion, and temperature coefficients of reactivity. Prereq., GS467, or S445, S446; S260. 3 hrs. rec.

ADVANCED UNDERGRADUATE COURSES

The following are advanced undergraduate courses in the Department of Mechanical Engineering that may be taken for graduate credit by graduate students, if approved by their departments.

E515	Engineering Analysis	12 units
E516	Viscous Fluids and Transfer Processes	9 units
E517	Stress Analysis	9 units
E519	Thermodynamics I	9 units
E520	Thermodynamics II	12 units
E531	Thermal Systems Analysis	12 units
E532	Servomechanisms and Control	9 units
E535	Dynamics of Machinery	9 units
E536	Mechanical Design	12 units
E538	Numerical and Energy Methods	9 units
E542	Potential Flow and Gas Dynamics	9 units
E544	Nuclear Reactor Analysis	9 units

DEPARTMENT OF METALLURGICAL ENGINEERING

Charles Law McCabe, Head

Richard Holland Lambert, Assistant Head

Professors Derge, McCabe, Paxton, Philbrook, and Pound; Associate Professors Horne, Lambert, Mullins, and Shewmon; Assistant Professors Bauer, Camp, Mills, and Robinson.

GRADUATE COURSES

GE655 Metallurgical Problems — **First and second semester, units to be assigned**

Individual problems, including laboratory, library, or design work with comprehensive report on some specific phase of work in modern metallurgy.

GE658 Advanced Metallurgical Operations — **First semester, 8 units**

Analysis of smelting and refining processes for evaluation of limiting factors; e.g., equilibrium limitations, reagent supply, energy supply, kinetics or transport steps. Applications to representative processes involving shaft, pneumatic, reverberatory and electric furnaces, including recent industrial innovations and problems of devising mathematical models for process simulation and control by computers. Prereq., undergraduate physical chemistry; E622, E625 and E626, or equivalent in chemical or mechanical engineering courses and industrial experience; S205 or computer experience desirable. 2 hrs. lec. Offered in alternate years; offered in 1964-65. Professor Philbrook.

GE659 Heat Flow in Metallurgical Processes — **Second semester, 8 units**

An engineering treatment emphasizing understanding and application rather than mathematical derivation of solutions. Steady and unsteady conduction by analytical, numerical and graphical methods; radiation, including complex geometry; and convection heat transfer. Problems and applications in heating and quenching of metals, pyrometry and metallurgical furnaces and heat exchangers. Prereq., E622, or equivalent. 2 hrs. lec. Offered in alternate years; offered in 1963-64. Professor Philbrook.

GE660 **Physical Chemistry of Metallurgical Reactions** — **Second semester, 8 units**

The application of physical chemistry and thermodynamics to a theoretical study of the kinetics and equilibria involved in metal refining processes. Special attention is paid to slag constitution and to the gas-liquid slag, and liquid metal-liquid slag reactions. Prereq., GS151, GS152; or equivalent. 2 hrs. lec. Offered in alternate years; offered in 1963-64.

Professor Derge.

GE661 **Introduction to the Science of Process Metallurgy** — **First semester, 8 units**

This course deals principally with the use of thermodynamics and kinetic theory in understanding the behavior of systems of interest in process metallurgy. Topics not covered in the basic courses in chemical thermodynamics but needed for this field, will be developed. Emphasis is placed on building a sound scientific background for further study in process metallurgy. Prereq., undergraduate physical chemistry. 2 hrs. lec. Offered in alternate years; offered in 1964-65.

Professor McCabe.

GE663 **Crystallography** — **First semester, 8 units**

The essential aspects of space lattice theory including symmetry operators, point groups, and Bravais lattices will be developed. The concept of the reciprocal lattice will be introduced and used extensively throughout the course in dealing with various diffraction phenomena and techniques. The physical theory of the diffraction of x-rays will be presented at a level sufficient for the understanding of the interference conditions, the meaning of the atomic scattering factor, and various geometrical factors which determine the intensities of diffracted beams. A discussion of those x-ray techniques most important to metallurgists will be given. The theory of electron diffraction and electron diffraction microscopy (i.e. transmission electron microscopy) will be given. Prereq., B.S. in engineering or science. 2 hrs. lec.

Professor Robinson

GE674 **Seminar** — **First and second semester**

Review by graduate students of recent articles in the metallurgical field. Open to all students registered in graduate studies. 1 hr.

GE675 **Thesis** — **First and second semester, units to be assigned**

GE681 **Diffusion in Solids** — **First semester, 8 units**

Solutions to diffusion equations for various problems. Atomistic approach to diffusion. Detailed discussion of diffusion in alloys. Special topics: surface diffusion, diffusion in ionic materials and oxidation, liquid diffusion. Prereq., B.S. in metallurgy, chemistry, or physics; one mathematics course past integral calculus recommended. 2 hrs. lec.

Professor Shewmon.

GE682 **Introduction to the Kinetics of Phase Transformations** — **Second semester, 8 units**

Introduction to rate theory; kinetics of nucleation and growth reactions in vapor-liquid, vapor-solid, liquid-solid, and solid-solid phase changes; applications of rate theory to other metallurgical phenomena such as diffusion and dislocation motion. Prereq., GS151, or equivalent; GS152, or concurrently. 2 hrs. lec.

Professor Pound.

GE683 **Reactions in the Solid State I** — **First semester, 8 units**

GE684 **Reactions in the Solid State II** — **Second semester, 8 units**

Factors influencing stability of phases as a function of composition, temperature, pressure, nucleation in solids. Rate of growth of one phase into another. Typical morphologies and their origin. Selected examples of different types of solid-solid reaction as typified by the formation of austenite and its decomposition. Precipitation from solid solution and its effect on properties. Recovery, recrystallization and grain growth. The approach is primarily theoretical rather than descriptive; a substantial amount of reading will be assigned to familiarize the student with the observations to be discussed. Prereq., undergraduate course in metallography and/or physical metallurgy recommended; GE682; GS151; GS152. 2 hrs. lec.

Professor Paxton.

GE687 **Mechanics of Deformable Solids** — **Second semester, 8 units**

Analysis of stress, strain; Hooke's law for homogeneous isotropic solids and crystalline solids; equations of equilibrium and compatibility; vibrations; introduction to mathematical plasticity; anelasticity; creep. Prereq., S259. 2 hrs. lec.

Professor Horne.

GE688 **Dislocations in Crystals** — **First semester, 8 units**

The fine structure of plastic deformation of crystals; treatment of full and imperfect static dislocations, geometry, stresses, strains; treatment of moving dislocations; origin of dislocations; applications to yielding, work hardening, fracture, creep, internal friction. Prereq., GE687. 2 hrs. lec.

Professor Mullins.

GE689 Theory of the Properties of Solids I — First semester, 8 units

GE690 Theory of the Properties of Solids II — Second semester, 8 units

An introduction to the principles and applications of quantum mechanics. Exact and approximate solutions to the Schrödinger equation are discussed for various physical systems. The results are then used to understand the theory of the properties of solids. Among the topics discussed are: the free electron approximation, Brillouin zones, cohesion, wave propagation in lattices, specific heat, elastic constants, compressibility, thermal expansion, thermoelectricity, electrical and thermal conductivity, optical properties, semi-conduction, magnetism, and superconductivity. Prereq., S259, S260. 2 hrs. lec. Professor Bauer.

GE691 Qualifying Examination for the Degree of Doctor of Philosophy

GE692 Final Public Oral Examination for the Degree of Doctor of Philosophy

GE693 Mathematical Analysis in Materials Research — Second semester, 8 units

A course dealing with the advanced methods of applied mathematical analysis that are particularly important in metallurgical reasearch. Emphasis will be on practical problems. Topics include solutions of the heat flow or diffusion equation by means of Fourier transforms, Laplace transforms, and Green's functions; the calculus of variations with applications to capillary theory and nucleation theory; the theory of probability with applications to random walk (biased and unbiased), statistical mechanical fluctuations, quantitative metallography and atomistic relaxation processes; matrix theory with applications to crystalline anisotropy, crystalline geometry, stress analysis. Other topics such as topological aspects of metallography, dimensional analysis, etc. may be included depending on class interest. Prereq., S259, S260, GS451, GE681. 2 hrs. lec. Professor Mullins.

GE695 Selected Topics in the Thermodynamics of Solids — Second semester, 8 units

An advanced course on the thermodynamics of solids with particular emphasis on alloys. (a) Statistical thermodynamics of solids; (b) effects of a general state of stress on thermodynamic quantities; and (c) capillarity of solids. Prereq., GS151. 2 hrs. lec. Professor Pound.

ADVANCED UNDERGRADUATE COURSES

The following are advanced undergraduate courses in the Department of Metallurgical Engineering that may be taken for graduate credit by graduate students, if approved by their department.

E622	Engineering Principles of Process Metallurgy	12 units
E625	Process Design I	9 units
E626	Process Design II	9 units
E633	Mechanical Metallurgy I	9 units
E634	Mechanical Metallurgy II	9 units
E642	Advanced Physical Metallurgy	6 units
E643	Metallography I	9 units
E644	Metallography II	9 units

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GRADUATE COURSES

GS450 Qualifying Examination for the Degree of Doctor of Philosophy

GS451 Classical Physics I — First semester, 12 units

Mechanics and electromagnetism. Vectors; Newton's laws of motion; mechanics of mass points and of systems; conservation laws; Lagrange's equations; small vibrations; mechanics of rigid bodies; gyroscopes. Fundamental experiments of electromagnetism and their description by Maxwell's equations in integral form; Maxwell's equations; electromagnetic waves, reflection, and refraction; scalar and vector potentials. Radiation. Prereq., differential equations; also desirable: S255, S256; S259, S260; or S269, S270. 4 hrs. lec.

GS452 **Classical Physics II** — **Second semester, 12 units**

Thermodynamics and mechanics of continuous media. First and second law of thermodynamics; equations of state; phase transitions; chemical potentials; elements of statistical mechanics. Fundamental concepts of elasticity and hydrodynamics. Prereq., differential equations; also desirable: S255, S266; S259, S260; or S270. 4 hrs. lec.

GS453 **Quantum Theory of Matter I** — **First semester, 12 units**

GS454 **Quantum Theory of Matter II** — **Second semester, 12 units**

A course primarily for non-physics students in the quantum theory of matter emphasizing applications to solid state physics and providing the background necessary for advanced study in this field (see for example GS483). The basic experiments of atomic physics are reviewed and the inadequacies of classical and old quantum theories discussed. The principles of wave mechanics are introduced. Schrödinger's equation is solved for such simple systems as the particle in a box, the harmonic oscillator, and the hydrogen atom including electron spin. Perturbation theory and other approximate methods are developed and employed in the treatment of complex atoms, emission and absorption of radiation, molecular binding, etc. The elements of quantum statistical mechanics are introduced as a basis for the treatment of large aggregates of electrons, quanta, and atoms. The above techniques are then applied to various problems in the physics of solids. Among the topics discussed are: the classification of solid types; specific heats; free electron model of metals; elementary band description of insulators, semi-conductors, and metals; semi-conductor behavior; and magnetic properties of solids. When possible, recent practical developments in solid state physics will be described. Prereq., bachelor's degree in science or engineering; differential equations. 4 hrs. lec.

GS455 **Quantum Mechanics I** — **First semester, 12 units**

GS456 **Quantum Mechanics II** — **Second semester, 12 units**

Dual nature of matter and of light; Schrödinger's equation and its application to simple systems such as the harmonic oscillator and the hydrogen atom; uncertainty principle; Hermitian operators; physical interpretation of the wave function and the operators. Time-independent and time-dependent perturbation theory. General theory of spin and angular momentum. Systems of identical particles. Variational method, helium atom, complex atoms, simple molecules. Interaction of atoms and radiation. Prereq., S446; S260 or S256. 3 hrs. lec.

GS457 **Classical Mechanics** — **First semester, 12 units**

Detailed treatment of classical mechanics with emphasis on aspects of modern interest, especially as an introduction to quantum mechanics. Applications of Lagrange's equations, small oscillations, scattering, rigid body motion, and Hamilton's equations. Introduction to relativistic mechanics. Prereq., S436; S260 or S256. 3 hrs. lec.

GS458 **Special Topics in Classical Mechanics** — **Second semester, 12 units**

More advanced topics in classical mechanics will be covered including canonical transformations, Hamilton-Jacobi theory, approximation methods. Special topics such as hydrodynamics, relativity, etc. may be emphasized in different years. Prereq., GS457. 3 hrs. lec.

GS459 **Introduction to Theoretical Physics I** — **First semester, 12 units**

GS460 **Introduction to Theoretical Physics II** — **Second semester, 12 units**

An introduction to the methods of mathematical analysis in use in present day physics, with particular emphasis on differential equations. Throughout the course numerous problems involving vibrations and wave propagation, transport phenomena, and potenital theory serve as the starting points for extensive applications of these methods of analysis. Topics which are studied and applied to the solution of differential equations are as follows: complex variables and analytic functions; Fourier series and integrals; matrices; separation of variables; series solutions; orthogonal systems of functions; Green's functions; and approximation methods. The mathematical formulation of physical problems, involving boundary conditions and approximations appropriate to the physical situations, are stressed. Prereq., S438; advanced calculus: S255, S256, or S259, S260; or consent of instructor. 3 hrs. lec. and rec.

GS461 **Advanced Electricity and Magnetism I** — **First semester, 12 units**

GS462 **Advanced Electricity and Magnetism II** — **Second semester, 12 units**

Emphasis is placed upon the solution of problems. The topics discussed include potential theory and the solution of Laplace's equation; the calculation of forces and torques in the electromagnetic field; the rigorous development of Maxwell's equations; the propagation of free and guided electromagnetic waves; retarded potentials; radiation theory; field of a moving charge; electron theory of the dielectric constant. Prereq., S438, GS459 (may be taken simultaneously). 3 hrs. lec.

GS465 **Statistical Mechanics** — **First semester, 12 units**

Develops methods for calculating from microscopic models the observable properties of macroscopic systems in thermodynamic equilibrium. Systems of weakly interacting elements, distinguishable and indistinguishable, are treated in detail by the methods of the most probable distribution and mean values. Illustrative systems discussed include ideal gases in the classical and quantum degenerate limits, ideal paramagnets, simple crystals, photons, etc. The general theory of ensembles is then developed classically and quantum mechanically to permit treatment of systems of interacting elements. Topics receiving emphasis include the density matrix, the grand canonical ensemble, and fluctuations. The methods are applied to real gases, ferromagnets, and other cooperative systems. Prereq., S441, GS456, GS457. 3 hrs. lec.

GS466 **Special Topics in Statistical Mechanics** — **Second semester, 12 units**

A course devoted to further applications of the methods developed in GS465, more detailed consideration of the foundations of these methods, and attempts at the treatment of systems not in equilibrium. Topics discussed may be drawn from the areas of real gas theory, cooperative behavior and magnetism, fluctuations and noise, irreversible thermodynamics, transport theory, etc. Prereq., GS465. 3 hrs. lec. Offered when there is sufficient demand.

GS467 **Atomic and Nuclear Physics** — **First or second semester, 9 units**

A course directed towards non-physics students as a background for courses on nuclear reactors. Topics covered include: properties of atoms and nuclei; collision problems in center of mass and laboratory coordinate systems; elementary statistical mechanics and kinetic theory including Maxwell's distribution law; quantum effects on an atomic scale including the Bohr theory of the atom; general properties of the nucleus, such as size, binding energy, stability, and nuclear energy levels; interaction of charged particles and radiation with matter; nuclear reactions; radioactivity. Prereq., consent of instructor. 3 hrs. lec.

GS468 **Experiments in Nuclear and Neutron Physics** — **First or second semester, 6 units**

The course emphasizes basic laboratory techniques for making measurements on nuclear radiations. Measurements are carried out on the characteristics of alpha, beta, and gamma rays. Several experiments deal with the properties of neutrons and neutron multiplying media. Principles of radiation protection are also stressed. Prereq., S444 or equivalent, GS467. 1 hr lec., 3 hrs. lab.

GS469 **Quantum Mechanics III** — **First semester, 12 units**

A further development of non-relativistic quantum mechanics with emphasis on scattering theory. Introduction to relativistic quantum mechanics, Dirac equation. Prereq., GS456, GS457. 3 hrs. lec.

GS470 **Quantum Mechanics IV** — **Second semester, 12 units**

Introduction to quantum field theory with applications to the many-body problem, radiation theory, electron scattering, Lamb shift. Further work on transformation theory, invariance principles, formal scattering theory, and the Dirac equation may also be included. Prereq., GS469. 3 hrs lec.

GS476 **Modern Experimental Techniques** — **Second semester, 6 to 12 units**

Survey of the experimental methods used in modern physical laboratories. The student will gain experience in the techniques used in nuclear, low-temperature, and solid state physics research. 3 hrs. lab.

GS479 **Nuclear Physics I** — **First semester, 12 units**

A course on low energy nuclear physics with particular stress on nuclear interactions. The topics include the following: nuclear forces; the deuteron; review of nuclear models; the scattering of nucleons; emission and absorption of gamma rays; and nuclear reactors. Prereq., GS469, or concurrently. 3 hrs. lec.

GS480 **Nuclear Physics II** — **Second semester, 12 units**

A course in high energy and relativistic nuclear physics covering: review of theoretical methods; pi mesons; beta decay; weak interactions of pi and mu mesons; and strange particles. Prereq., GS470, or concurrently; GS479. 3 hrs. lec.

GS481 Advanced Nuclear Theory I — First semester, 12 units

GS482 Advanced Nuclear Theory II — Second semester, 12 units

The topics covered will vary from time to time depending on current interest. The course is primarily intended for those who have had quantum mechanics and nuclear physics. The topics may include the following: nuclear forces; shell model, nuclear many-body problem; scattering; beta theory; nuclear reactions; high energy processes; cosmic rays; and elementary particles. 3 hrs. lec. Offered when there is sufficient demand.

GS483 Theory of Solids I — First semester, 12 units

GS484 Theory of Solids II — Second semester, 12 units

This course is designed to give advanced graduate students a fundamental knowledge of the macroscopic properties of solids in terms of molecular and atomic theory. Modern electronic theory of metals, semi-conductors and insulators. Free electron model, energy bands, electrical conduction, magnetism. Different special topics may be covered in the second semester. Prereq., GS456. 3 hrs. lec.

GS485 Special Topics in Solid State Physics — First or second semester, 12 units

Various topics of current interest in solid state physics will be included. Among these may be the theory of magnetic properties of solids, superconductivity, magnetic resonance, or defects in solids. 3 hrs. lec. Offered when there is sufficient demand.

GS487 Introduction to Solid State Physics I — First semester, 6 units

GS488 Introduction to Solid State Physics II — Second semester, 6 units

A course intended to give a short account of representative aspects of the physics of solids and, whenever possible, to give a discussion of recent practical applications. The elementary theory of well developed models of solids will be stressed. Quantum mechanical and statistical mechanical concepts and techniques will be introduced as required in the treatment of the subject matter. Topics dealt with include: crystal structures; elastic, thermal, and dielectric properties; free electron model of metals; band theory and Brillouin zones; semi-conductors; interaction of radiation with solids; special topics. Prereq., bachelor's degree in science or engineering. 2 hrs. lec. Offered when there is sufficient demand.

GS489 Quantum Field Theory I — First semester, 12 units

GS490 Quantum Field Theory II — Second semester, 12 units

The subject of quantum field theory is developed in detail beyond the introduction provided by GS470. 3 hrs. lec. Offered when there is sufficient demand.

GS491 Special Topics in Quantum Mechanics I — First semester, 12 units

GS492 Special Topics in Quantum Mechanics II — Second semester, 12 units

This course deals with different topics of current interest relating to the foundations or applications of quantum theory. Different topics will be covered in different years. Among the subjects might be the many-body problems, dispersion relations, or elementary particles. 3 hrs. lec. Offered when there is sufficient demand.

GS493 Supervised Reading — First and second semester, units to be assigned

Designed to give the graduate student in physics an opportunity to do investigation in fields not covered in regular courses. Each student admitted will have a weekly conference with the faculty member supervising his reading. Usually offered every year.

GS494 Colloquium — First and second semester

Weekly meeting for the discussion of current problems of physics. Open to graduate students and others interested. 1 hr. lec. alternate weeks.

GS495 Graduate Seminar — First semester

GS496 Graduate Seminar — Second semester

Primarily for advanced graduate students. The subject to be chosen from the fields of thermodynamics, kinetic theory, or quantum physics. 2 hrs.

GS497 **Graduate Laboratory** — **First and second semester, units to be assigned**

This course offers qualified graduate students opportunity to gain first-hand research experience by assisting in research conducted by staff members. 6 units minimum each semester except with special permission. Approximately one unit for each hour per week spent in the laboratories.

GS498 **Thesis Research** — **First and second semester, units to be assigned**

Only graduate students accepted as candidates for the doctorate may enroll.

GS499 **Final Public Oral Examination for the Degree of Doctor of Philosophy**

ADVANCED UNDERGRADUATE COURSES

The following are advanced undergraduate courses in the Department of Physics that may be taken for graduate credit by graduate students, if approved by their department.

S436	Physical Mechanics	10 units
S437	Electricity and Magnetism	12 units
S438	Electricity and Magnetism	9 units
S441	Thermodynamics	9 units
S442	Chemical Physics and Solids	9 units
S443	Optics	12 units
S444	Introduction to Nuclear Physics	9 units
S445	Atomic Physics	9 units
S446	Atomic Physics	9 units
S449	Physical Electronics	12 units

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Terms Expire in 1964

ALFRED S. ANDREWS, *President, Andrews, Bartlett and Associates, Inc.*
LOGAN T. JOHNSTON, *President, Armco Steel Corporation*

Terms Expire in 1965

EDWIN R. BRODEN, *President and Chairman of the Board, SKF Industries, Incorporated*
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JOHN ROYSTON COLEMAN, *Dean Elect, Division of Humanities and Social Sciences*
ROBERT JOSEPH KIBBEE, *Assistant to the President for Planning*
RAYMOND EDWARD PARSHALL, *Assistant to the President; Secretary, Executive Board*

Faculty

JOHN CHRISTIAN WARNER, *President*
A.B., A.M., Ph.D., Indiana University; D.Sc. (Hon.), Northeastern University; D.Sc.(Hon.), Indiana University; D.Sc. (Hon.), University of Maryland; D.Sc. (Hon.), Bucknell University; LL.D. (Hon.), University of Pittsburgh; D.Sc. (Hon.), Worcester Polytechnic Institute; L.H.D. (Hon.), Youngstown University; D.Eng. (Hon.), University of Toledo. Carnegie, 1926—.

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COLLEGE OF ENGINEERING AND SCIENCE

General Officers

BENJAMIN RICHARD TEARE, JR., *Dean of the College of Engineering and Science*
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CHARLES LAW McCABE, *Associate Dean—Graduate Studies of the College of Engineering and Science*
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Committee on Graduate Degrees

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FULL TIME FACULTY 1962-1963

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NEIL RAYMOND JOHNSON, *Assistant Professor of Mechanical Engineering*
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FLORENCE SHIRLEY JONES, *Visiting Assistant Professor of Physics*
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ANGEL GONI JORDAN, *Associate Professor of Electrical Engineering*
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LES ANDREW KARLOVITZ, *Instructor in Mathematics*
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RICHARD IRA KERMODE, *Assistant Professor of Chemical Engineering*
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*TRUMAN PAUL KOHMAN, *Professor of Chemistry*
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JOHN ALBERT KOSTECKI, *Instructor in Chemical Engineering*
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L. GEORGE LANG, *Assistant Professor of Physics*
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JAMES STEPHEN LANGER, *Assistant Professor of Physics*
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ABRAHIM LAVI, *Assistant Professor of Electrical Engineering*
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HENRY SIGGINS LEONARD, JR., *Assistant Professor of Mathematics*
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KUN LI, *Associate Professor of Chemical Engineering*
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GILBERT JOSEPH MAINS, *Associate Professor of Chemistry*
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CLARA EMILIE MILLER, *Associate Professor of Chemistry*
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GERALD MOTT, *Assistant Professor of Electrical Engineering*
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ALAN JAY PERLIS, *Professor of Mathematics; Head of Department of Mathematics; Director of Computation Center*
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Calendar

	1962-63		1963-64	
REGISTRATION, FALL SEMESTER	Sept. 16	Mon.	Sept. 17	Mon.
ALL STUDENTS	Sept. 17	Tue.	Sept. 18	Tue.
CLASSES BEGIN	Sept. 18	Wed.	Sept. 19	Wed.
MID-SEMESTER GRADES DUE	Nov. 11	Mon.	Nov. 12	Mon.
THANKSGIVING RECESS	Nov. 21	Wed.	Nov. 28	Thu.
	Nov. 25	Sun. incl.		
CLASSES RESUME	Nov. 26	Mon.		
CHRISTMAS RECESS	Dec. 21	Fri.	Dec. 21	Sat.
	Jan. 2	Wed. incl.	Jan. 5	Sun.
CLASSES RESUME	Jan. 3	Thu.	Jan. 6	Mon.
CLASSES END	Jan. 19	Sat.	Jan. 21	Tue.
FINAL EXAMINATIONS	Jan. 21	Mon.	Jan. 22	Wed.
	Jan. 29	Tue. incl.	Jan. 29	Wed.
REGISTRATION, SPRING SEMESTER	Feb. 4	Mon.	Feb. 3	Mon.
ALL STUDENTS	Feb. 5	Tue.	Feb. 4	Tue.
CLASSES BEGIN	Feb. 6	Wed.	Feb. 5	Wed.
MID-SEMESTER GRADES DUE	April 1	Mon.	April 8	Wed.
EASTER RECESS	April 12	Fri.	Mar. 26	Thu.
	April 16	Tue. incl.	Mar. 31	Tue. incl.
CLASSES RESUME	April 17	Wed.	April 1	Wed.
CLASSES END	May 28	Tue.	May 26	Tue.
FINAL EXAMINATIONS	May 29	Wed.	May 27	Wed.
	June 5	Wed. incl.	June 3	Wed. incl.
COMMENCEMENT	June 10	Mon.	June 8	Mon.

CARNEGIE