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Graduate Division Programs for the Academic Year 1976-77 New Jersey Institute of Technology

New Jersey Institute of Technology

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**Graduate
Division
Programs
for the 1976-77
Academic Year**

**New Jersey
Institute
of Technology**

NIJIT

Directory for correspondence

Mailing Address: 323 High Street, Newark, N.J. 07102.

Telephone: Area Code 201, 645-5321

Matters of General College Interest:

Address the President.

Admissions and Fellowships:

Address the Dean, Graduate Division. Telephone: 645-5160.

Foreign Students:

Address the Assistant Dean, Graduate Division. Telephone: 645-5161.

Registration:

Address the Registrar. Telephone: 645-5144.

Alumni Activities:

Address Alumni Secretary. Telephone: 645-5441.

Continuing Education Studies:

Address the Director. Telephone: 645-5235.

Division of Technology:

For information concerning non-credit courses and certificate programs, address the Director. Telephone: 645-5231.

Financial Matters:

Address the Business Manager. Telephone: 645-5106.

Placement of Seniors and Alumni:

Address the Director of Placement. Telephone: 645-5200.

Counseling:

Address the Counseling Center. Telephone: 645-5190.

Transcripts:

For transcripts and student grades, address the Recorder. Telephone: 645-5139.

Veterans:

For information on veteran Certification of Registration, address the Registrar. Telephone: 645-5146. For information on other veteran affairs, address the Director of Veteran's Affairs. Telephone: 645-5103.

The Foundation at New Jersey Institute of Technology:

Address the Administrator. Telephone: 645-5211.

Plant, Equipment, and Utilities:

Address the Plant Engineer. Telephone: 645-5151.

The business and administrative offices of the Institute are open between the hours of 9:00 A.M. and 5:00 P.M. Monday through Friday during the school year. The Registrar's office and the Finance office are also open evenings, Monday through Thursday, the former until at least 6:30 P.M., the latter between the hours of 5:30 P.M. and 8:30 P.M. During the summer program, the business and administrative offices remain open until 4:00 P.M., Monday through Friday. The Registrar's office will provide summer evening coverage between 5:00 P.M., and 7:00 P.M. on Monday, Tuesday and Thursday evenings during the first, fifth and sixth weeks of the Summer Session. The Finance office will be open between the hours of 4:30 P.M. and 7:30 P.M., Monday through Thursday, during the summer.

New Jersey Institute of Technology Catalog of Graduate Programs 1976-1977



GRADUATE DIVISION CALENDAR: 1976-77

The Institute reserves the right to make changes in this calendar.

Registration — Fall Semester	August 23 through August 27, inclusive, in accordance with instructions to be issued.
Fall Semester Begins	August 30
Labor Day Holiday	September 6
Last date on which all requirements are to be completed and "Application for Candidacy" filed for October 1 degree	September 13
Awarding of October Degrees in absentia	October 1
Columbus Day (Not a holiday)	October 11
Veterans' Day (Not a Holiday)	November 11
Thanksgiving Holidays	November 25 to 28, inclusive
Fall Semester Ends	December 23
Registration — Spring Semester	January 10 through January 14, inclusive, in accordance with instructions to be issued.
Spring Semester Begins	January 19
Last date on which graduates may file "Application for Candidacy" for Spring Commencement	January 31
Washington's Birthday Holiday	February 21
Spring Vacation	March 21 to 27, inclusive
Good Friday Holiday	April 8
Spring Semester Ends	May 19
Commencement	May 27
Registration — Summer Session	To be announced.
Summer Session Begins	June 6
Independence Day Holiday	July 4
Summer Session Ends	July 28





General Information



General information

A NEW NAME

On January 1, 1975, Newark College of Engineering became one of the academic units of the newly named New Jersey Institute of Technology. This name change symbolized the growing mission of the institution to serve an expanding professional population with and increasing diversity of educational needs.

THE NJIT CAMPUS

Drive north along High Street past the imposing Essex County Court House, or south past the St. Michael Medical Center and you will see the usual facade of weathered town houses and store fronts that are typical of our older American cities.

Then you will come upon NJIT's "castle," set on a slight rise above its tree-shaded lawn. The oldest building on NJIT's campus, Eberhardt Hall was once an orphanage, later bought by the Institute and modernized to house administrative offices. Built in 1856, it was designated as an historical landmark in 1973.

The campus is situated close to the Newark business district and to NJIT's sister institutions of Essex County College, the Newark Colleges of Rutgers University, and the College of Medicine and Dentistry of New Jersey. Located a few blocks from the newly-completed Interstate Highway 280, the campus is also easily accessible by public transportation from many points in New Jersey.



Of NJIT's original buildings, the oldest still in use is Colton Hall, built in 1911. Then came Campbell Hall (1926), and an Annex (1930). Rapid growth after World War II led to Weston Hall and Cullimore Hall in 1958.

Then, in 1966, NJIT's "new campus" was dedicated, an event which saw the Institute's total land area jump from hardly more than two acres to twenty, and its number of buildings increase from six to eleven.

Opened simultaneously were an electrical engineering building, a student center, an alumni center, an operations building, and a complete physical education plant which includes a large gymnasium, a swimming pool, specialized sports areas, an athletic field, and several tennis courts.

Most recently, a handsome library-humanities center, and a new chemical engineering-chemistry complex have been added to bring to thirteen the number of facilities on the campus as a whole.

The buildings themselves and the handsome, landscaped campus with its Institute Green that holds and unifies them, are both representative of NJIT's long traditions, and are the scene today of a spirited educational and extracurricular life that looks eagerly to the future.

HISTORY

Since 1919 New Jersey Institute of Technology has offered courses leading to the degrees of Bachelor of Science in Chemical, Civil, Electrical and Mechanical Engineering. In 1960 the degree of Bachelor of Science in Industrial Engineering was added.

The increasing complexity and diversity of expanding scientific knowledge coupled with rapid changes in the state of the art in engineering application have placed new demands on the engineer and scientist in the practice of his profession. Undergraduate programs can at best provide the fundamental base for the true professional who would meet the demands of a more and more sophisticated technology. Graduate work in science and engineering has in recent years come to be recognized by a significant sector of the technical community as one important way of developing the new capabilities beyond the fundamental base required of engineers and scientists. Consequently, the demand for quality graduate programs has escalated. The Graduate Division of the Institute was organized and is maintained to meet this demand; to fulfill its academic obligations to the field of science and technology and to fulfill, to an equal extent, its obligations to the public and industrial community of the city, state and nation.

DEGREES AUTHORIZED

By authorization of the New Jersey Board of Higher Education, the Board of Trustees of the Institute is empowered to confer the degrees of Master of Science in Chemical, Civil, Electrical, Environmental, Industrial, Management, and Mechanical Engineering and in Computer Science. In addition, the Board is further empowered to confer the M.S. degree upon successful candidates who elect to undertake graduate studies with a major emphasis in the engineering sciences, or applied mathematics, or who wish to diversify their engineering studies into the two engineering areas.

The Institute has also been authorized to offer the degree of Doctor of Engineering Science in the Departments of Chemical, Civil and Environmental, Electrical, and Mechanical Engineering. Also offered are programs leading to the degrees Chemical Engineer, Civil Engineer, Electrical Engineer, and Mechanical Engineer. Applicants for admission to these programs are presently restricted to students who hold a Master's degree in the appropriate field.

Daytime, late-afternoon, and evening courses are offered in the various departments of the Institute, so that course work requirements for the degree programs described can, in general, be completed on either a part-time or a full-time basis.

In addition to the degrees described above, the Graduate Division offers a formal master's degree program as well as in-service institutes for secondary and junior-high school teachers of mathematics and the sciences.

FOUNDATION AT NJIT

The Foundation, a privately incorporated and financed organization, has as its goal the development of a center of excellence in graduate study and research at New Jersey Institute of Technology. This goal is being met by developing, to the utmost, opportunities for professional development for graduate students and faculty. The Foundation provides these opportunities by funding graduate student fellowships, awarding academic year and summer grants to faculty, assisting with the preparation of research proposals, directing proposals to agencies most likely to fund them, administering existing grants, and supporting seminar and visiting scholar programs.

FACILITIES

LIBRARY

The Robert W. Van Houten Library, centrally located on the campus, provides facilities for study, research and browsing. A collection of more than 103,000 volumes is available for student use, and 1,450 periodicals are regularly received, as



well as many indexing and abstracting services which give access to the literature of engineering, science, management and other subject areas.

To supplement the resources of the Institute Library, students have the privilege of borrowing material from the Newark Public Library and the Newark-Rutgers Library as well as the libraries of the other nearby institutions of higher learning. Other libraries in the area, such as those of the Chemists' Club and the Engineering Societies, may be used for reference purposes. Inter-library loan arrangements with more distant institutions are also available.

Memorial gifts from the personal libraries of men formerly associated with the College have been received. Foremost among these gifts are books and periodicals from the collections of former Trustee Dr. Edward Weston and State Senator Roy V. Wright. The rare book collection of Dr. Edward F. Weston, who was also a Trustee of the Institute, is maintained by the Library and is available to scholars and others interested in the history of science and technology.



COMPUTING CENTER

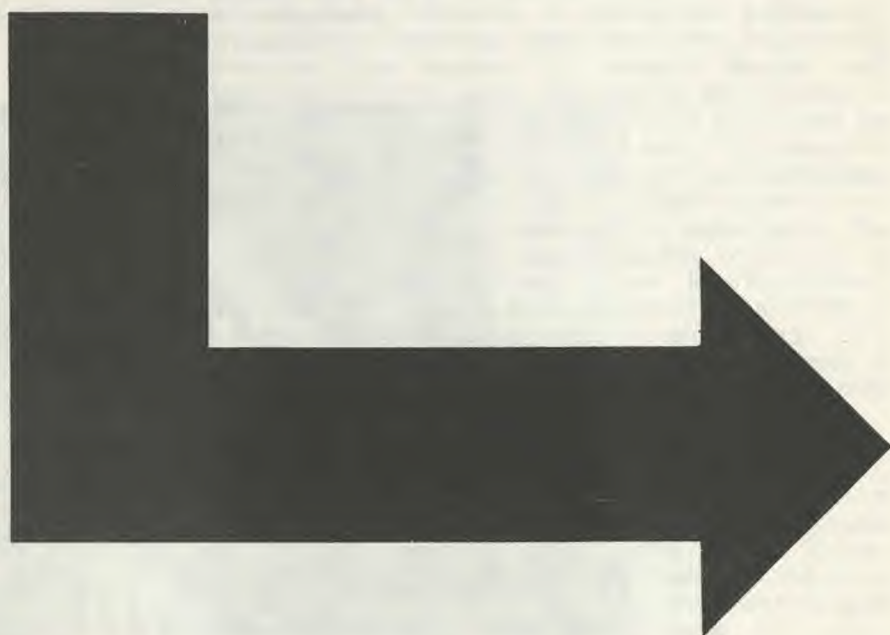
A modern, centralized computing system is maintained at the Computing Center for use by all students and faculty. Remote access to the computing facility is available from terminals located at various sites on the campus for on-line timesharing, as well as from non-centralized peripherals for job entry into open batch.

Graduate students are normally expected to integrate computer use in their course work and in research carried out by them in connection with their master's projects and thesis, or doctoral dissertations. Many courses are offered at the Institute for training in computer use.

A large library of selected applications programs and program preparation facilities has been collected and is available on-line to the computer system for easy accessing. The staff at the Center can be consulted on the use of the computer facilities and for help in determining appropriate solution methods for particular problems.



Degree Programs



Degree programs

MASTER'S DEGREE PROGRAMS

Programs offered by the Graduate Division are designed to meet the varied needs for advanced education required for success in work of a professional nature in an era of rapidly expanding technology. Success in this endeavor is likely only for the student with a demonstrated aptitude for academic work in an engineering or technical field and with adequate undergraduate preparation for graduate work.

DEGREES AWARDED

Academic programs are available which lead to the following master's degrees:

Designated Master's Degrees

Master of Science in Chemical Engineering
Master of Science in Civil Engineering
Master of Science in Electrical Engineering
Master of Science in Environmental Engineering
Master of Science in Industrial Engineering
Master of Science in Management Engineering
Master of Science in Mechanical Engineering
Master of Science in Computer Science

Undesignated Master's Degrees:

The degree, *Master of Science in*

Applied Mathematics

Applied Science (for High School Teachers)

Engineering Science

Interdisciplinary Studies in Engineering-related areas.



PROGRAMS OF STUDY



ENGINEERING PROGRAMS

Two broad program options are available within the engineering fields:

- A. *Programs leading to designated master's degrees*—A student with an undergraduate degree in chemical, civil, electrical, industrial or mechanical engineering who wishes to continue within the same engineering discipline may receive the master's degree with designation of the major engineering department. A student wishing to change engineering fields may be admitted to a program leading to a designated master's degree by completing appropriate undergraduate and/or graduate prerequisites in addition to the normal graduate degree requirements of the department. The program leading to the degree, Master of Science in Environmental Engineering, is an interdisciplinary engineering program open to students from a variety of undergraduate engineering backgrounds. The program leading to the degree, Master of Science in Management Engineering, is intended for students from a range of engineering disciplines.
- B. *Programs leading to the degree, Master of Science*—Students with undergraduate backgrounds in physics, chemistry or mathematics or with a quantitative background in the social sciences or planning or those with engineering backgrounds may pursue cross-disciplinary programs with major interest in the work offered by one of the engineering departments and leading to the degree, *Master of Science*.

PROGRAMS IN ENGINEERING AND SCIENCE

- A. *Program leading to the degree, Master of Science in Computer Science*—This program with major interest in the work offered by the Department of Computer Science is open to qualified students with undergraduate backgrounds in engineering, computer science, the physical sciences, and mathematics or with quantitative background in the social sciences or planning.
- B. *Programs leading to the degree, Master of Science.*
1. *Program in Applied Mathematics*—This program, administered by the Department of Mathematics, emphasizes the interdisciplinary aspects of applied mathematics. It is open to students with undergraduate training in mathematics, engineering, computer science and the physical sciences.
 2. *Program in Engineering Science*—A student with appropriate undergraduate background whose major interest is in work within the engineering sciences will be assigned an adviser from the field most related to his or her academic goals. Although the Engineering Science program is designed to be flexible in meeting the needs of the individual student in the selection of his field of interest and in the design of his course of study, certain patterns of major interest exist within the departmental framework. Thus, specific departmental degree requirements may be found in the section of this catalog covering chemistry. As individual student need dictates and as interest develops, adviser assignment and program design may be planned on a cross-departmental basis.

PROGRAM FOR SECONDARY SCHOOL SCIENCE TEACHERS

This program, leading to the degree, Master of Science, is offered in the field of applied science for qualified secondary and junior high school teachers of science and mathematics. A description of the program will be found starting on page 115 of this catalog.

SYSTEMS SCIENCE AND SYSTEMS ENGINEERING

The modern engineer is faced with problems of growing technological complexity in the design and operation of today's industrial and business systems. Often the engineer will make managerial decisions with far-reaching consequences. An engineering system is comprised of a large number of distinct components that are inter-related to achieve some common purpose. As an example, if a city were to consider the construction of an elevated cross-town freeway, it would be necessary to consider in addition to construction costs, the effects of the

proposed highway on mass transit in the city, the effect on the local economy, the environmental impact, the change in property values of the bypassed land, and the human values of the people in the area near the road. Thus, the decision as to where the road should be built, and its exact alignment, requires that all of these factors be taken into account.

The systems approach gives the engineer a tool by which he can examine the project in a rational way and make his decisions based on some set of priorities that take into account all of the diverse physical and human aspects of the project.

Each engineering department as well as the departments of Computer and Information Science, and Organizational and Social Science offer a variety of courses appropriate to an interest in systems science and systems engineering. Acceptable programs may be designed with a major in any of these departments.

The programs are intended for the engineering graduate or the holder of a degree in physical science or social science who has an acceptable quantitative background and an interest in pursuing advanced study in the systems area. The courses selected for each program may cut across the boundaries of the formal institute departments.



The courses offered make it possible to study linear and non-linear systems, continuous-time and discrete-time systems, continuous-values and quantitized systems, and deterministic and probabilistic systems. Separate courses deal with the explicit applications of such mathematical tools as simulation, modeling and optimization techniques.

Listed below are areas of systems science and systems engineering in which appropriate academic programs may be planned based on an individual student's interest. By referring to the catalog entries of the department(s) listed opposite a given systems category, the student will find information on specific systems programs.

<i>Systems Area</i>	<i>Department</i>
Biomedical System	Electrical Engineering Mechanical Engineering
Communications Systems	Computer and Information Science Electrical Engineering
Control Systems	Chemical Engineering Electrical Engineering Industrial and Management Engineering Mechanical Engineering
Computer Application Systems	Computer and Information Science
Information Systems	Computer and Information Science
Management Systems	Industrial and Management Engineering
Man-Machine Systems	Industrial and Management Engineering
Machine Systems	Mechanical Engineering
Power Systems	Electrical Engineering Mechanical Engineering
Processing Systems	Chemical Engineering Computer Science
Transportation Systems	Civil and Environmental Engineering Organizational and Social Sciences
Urban Systems	Civil and Environmental Engineering Organizational and Social Sciences

ENVIRONMENTAL ENGINEERING PROGRAMS

The study of the environment and the design of methods for dealing with man's impact upon it are of concern to almost all of the academic departments of the Institute. In order to meet most effectively the educational needs of students with interest in environmental problems, a broad inter-disciplinary program supervised by an inter-departmental group is available. The program described at the end of the alphabetic listing of departmental programs (see page 112), is open to students from a wide range of scientific and mathematical backgrounds and is taught by faculty of many departments.

APPLIED POLYMER SCIENCE AND ENGINEERING

Prospective students interest in applications work in the plastics field will find a variety of courses in the Departments of Chemical Engineering and Chemistry, and in Mechanical Engineering which may be combined into options in this field within the master's degree programs of those departments.

ADMISSIONS—MASTER'S DEGREE

Applicants for admission to programs leading to a designated master's degree in one of the engineering fields (see Section A, page 10, under the heading "Programs of Study") as minimum qualification should present a baccalaureate degree in engineering from an ECPD accredited program. Applicants for other MS programs should have a baccalaureate degree in physics, chemistry, mathematics, computer science or in the quantitative social sciences or planning from a regionally accredited college or university, or in engineering from an ECPD accredited program.

CONDITIONAL ADMISSIONS

When judged appropriate, conditional admission may be granted to applicants to the various master's degree programs. The meeting of the terms of conditional admission will typically depend upon the attainment of specified passing grades in a number of designated courses as well as upon individual evaluation by the course instructors. Where such designated courses are graduate courses, they may be assigned in addition to the minimum number of courses required for the master's degree.

FOREIGN STUDENTS

Students with degrees from foreign countries or universities are advised to contact the Graduate Division regarding special procedures to be followed. Students applying from abroad must demonstrate the availability of financial resources sufficient to meet the expenses of their anticipated stay at the Institute. In estimating expenses, potential students who would be on visa status during the period of study should note that they will be expected to pay non-resident tuition rates (see page 31.)

APPLICATION FOR ADMISSION

Application should be made on the Graduate Admission Form, which may be obtained from the Graduate Division. A \$10.00 application fee in the form of a check or money order must accompany the application. Two transcripts from the institution which has conferred the baccalaureate degree and one transcript from each other undergraduate or graduate institution attended are required. To be accepted as official, transcripts must be sent directly to the Graduate Division by the institutions concerned. Applications must be received by August 1 to be eligible for the fall semester and by January 1 to be eligible for the spring semester. Applications received after the dates indicated will be processed for the following semester. Applicants are advised to arrange for transcripts to reach the Graduate Division by the dates indicated in order to avoid delay in processing applications.

GRADUATE RECORD EXAMINATION

To help in the evaluation of the applicant's background it is recommended that he take the aptitude test and advanced portions of the Graduate Record Examination and submit the results of the examination with the application for admission. Information concerning the examination may be obtained and arrangements for taking it made by contacting Educational Testing Service, P.O. Box 592, Princeton, New Jersey.

CONFERENCE WITH ADVISER

Conferences with graduate advisers should be arranged as soon as possible after notification of admission. Appointments may be made by calling the department of major study. The purpose of the conference is to formulate a program of required courses in fulfillment of the academic prerequisites for a degree. Any change in this program of required courses must be approved by the chairman of the major department, or by his representative.

ACADEMIC REQUIREMENTS—MASTER'S DEGREE

MASTER OF SCIENCE PROGRAMS

- A. The degree, *Master of Science in Chemical, Civil, Electrical, Environmental, Industrial, Management, or Mechanical Engineering or in Computer Science* and the *Master of Science* degree program in Applied Mathematics will require of the student the following:
1. Eighteen credits of specialization of which no more than six credits may be in courses numbered from 500 to 599 with the approval of the department of specialization. These courses must form a correlated group within an area of specialization and must include a thesis or other independent work which will require the equivalent of two semesters of *individual* effort on the part of the student.
 2. Twelve credits of electives. These may be chosen from graduate courses offered by any department. Six of these credits must be taken in a related area, normally outside of the department of specialization.
 3. No more than nine credits of courses numbered from 500 to 599 may be included in the minimum of thirty credits required for the degree.
- B. The degree, *Master of Science*, will require of the student the following:
1. Fifteen credits of specialization of which no more than six credits may be in courses numbered from 500 to 599 with adviser's approval. These courses must form a correlated group within an area of specialization and must include a

thesis or other independent work which will require the equivalent of two semesters of *individual* effort on the part of the student.

2. Fifteen credits of electives. These may be chosen from graduate courses offered by any department. Six of these credits must be taken in a related area, normally outside of the department of specialization.
3. No more than nine credits of courses numbered from 500 to 599 may be included in the minimum of thirty credits required for the degree.

Note: More than the minimum of 30 credits may be required to fulfill individual departmental requisites for a degree.

See page 115 for degree requirements in the applied science MS program for junior high and high school teachers of science and mathematics.

TRANSFER CREDIT

Graduate courses completed with a grade equivalent to A or B at other institutions may be offered for transfer credit toward the master's degree with a maximum allowance of nine credits. Graduate courses completed at one of the neighboring publicly supported institutions with prior approval through the inter-institutional cross registration program will not be considered subject to the nine credit limitation. Transfer credit will normally not be granted until twelve credits of graduate course work have been completed at New Jersey Institute of Technology. Requests for transfer credit must be in writing, on the form provided by the Graduate Division office, accompanied by appropriate catalogues of the college describing the courses, and other pertinent information, and addressed to the Dean, Graduate Division, New Jersey Institute of Technology. Official transcripts of the work should be sent directly from the college or institution concerned to the same office. The restrictions described in the section "Time Limitation" apply to courses offered for transfer credit.



MATRICULATION

Admission to studies in the Graduate Division does not imply matriculation. To matriculate for the Master's degree, a student must demonstrate a level of proficiency in his field which gives promise of successful completion of the requirements for the degree. The following regulations are in effect for matriculation in all departments:

1. To apply for matriculation, a student should have completed a minimum of fifteen credits of graduate work at the College and have attained a grade-point average of 2.8 or better. Grade-point average is based on a scale of A = 4, B = 3, C = 2, F = 0.
2. At least half of the course credits submitted must be in the field of major concentration and all graduate course work taken at the Institute must be included in computing the grade-point average.

To complete the matriculation procedure, the student should file a matriculation application with his adviser. Matriculation application forms are available at the Graduate Division office. Students completing twenty-four credits and failing to matriculate will not be permitted to continue studies in the Graduate Division.

GRADE REQUIREMENT

In order to obtain the Master's degree as conferred by the Institute a candidate must attain an average grade of B or better in his graduate course work. This requirement has been in effect for students admitted to the Graduate Division in September 1966 and thereafter. Students in a degree program have the option of designating up to two graduate courses as "not included in degree program." Courses so designated will not be included in calculating the grade point average for purposes of matriculation and graduation nor will they count toward the completion of degree requirements.

TIME LIMITATION

The Master's degree will be granted only to those students who complete the required curriculum and fulfill the conditions required for the stipulated degree within seven consecutive years prior to the date of graduation indicated on the candidacy application. A candidate for a degree who desires a special ruling by reason of hardship may submit a written appeal detailing the reasons for the appeal to the Dean of the Graduate Division.

THESIS INSTRUCTIONS

Theses submitted for the master's degree must follow a prescribed format. A booklet outlining the Institute's requirements for thesis submission is available at the Institute Bookstore.

APPLICATION FOR DEGREE

Degrees are awarded at the end of the spring semester or on October 1. Each prospective candidate for a degree to be awarded in the spring must file an application for the degree prior to the opening of the spring semester of the year in which the candidate expects to graduate. Applications for the October 1 degree must be received by September 15. Forms may be obtained from the office of the Graduate Division or from the Registrar's office.

DEGREE OF ENGINEER PROGRAMS

The continuing growth of technology and the increasing necessity for the application of new scientific knowledge in engineering practice have placed growing demands on the role of the truly professional engineer. To help meet these demands and to help in the development of a high level of competence in the practicing engineer, the Institute offers programs leading to the Engineer degrees: Chemical Engineer (Ch.E.), Civil Engineer (C.E.), Electrical Engineer (E.E.), and Mechanical Engineer (M.E.).

These programs are intended for men and women with a suitable background of engineering practice. The scope of scientific and technical competence sought will be broader than that for the master's degree. The emphasis will be on application of new knowledge, keeping in mind the engineer's vital function in the design process.

ADMISSION REQUIREMENTS

The minimum admission requirements are a master's degree in the appropriate engineering field and three years of professional experience of an acceptable level with evidence of responsibility for work in the field in which the degree is sought.

ADMISSIONS APPLICATION

Application should be made on the appropriate form (obtainable from the Graduate Division). A \$10.00 application fee (check or money order) must accompany the completed application. The applicant must arrange for submission, by each of the institutions concerned, of two transcripts of all academic work beyond secondary school. In addition, letters of recommendation (on form furnished by the Graduate Division) are required from the following:

1. The chairman or adviser of the department of major study in the applicant's undergraduate school;
2. The chairman or adviser of the department of major study that conferred the applicant's master's degree; and
3. The employer (or employers) who can describe in detail the nature of the applicant's industrial experience.

DEGREE REQUIREMENTS

The academic requirements for the degree include a minimum of twenty-four credits of course work beyond the master's degree. In addition, a professional project requiring a minimum of twelve credits of registration will be required.

COURSE WORK

The program of course work will be planned by the candidate and his candidacy committee. This committee will be appointed when the candidate has passed a written departmental candidacy examination. Permission to take the candidacy examination must be requested by filing a candidacy application form with the Graduate Division. This should be done shortly after the completion of twelve credits of course work, but in any event prior to the completion of eighteen credits. The program will be planned on the basis of the candidate's academic and professional background with particular weight given to the subject matter of the proposed professional project. At least twelve credits of the course work must be at the 700 level. Course work at the 500 level is not acceptable in fulfillment of the minimum requirements. An average grade of B or better will be required in meeting the degree requirements.

Since the program is geared to the needs of the working engineer, it is anticipated that course work will be taken on a part-time basis in the late afternoon or in the evening.

PROFESSIONAL PROJECT

The twelve-credit minimum of professional project will be in a significant phase of advanced technology. The work should culminate in an original design-oriented project report which will be defended in an oral examination. The examining committee will include faculty from various related disciplines, as well as practicing engineers of established competence in the field of the project.

APPLICATION FOR THE DEGREE OF ENGINEER

An application for the degree should be filed with the department of major study not later than the close of the first semester of the academic year in which it is expected that the degree will be conferred. Applications may be obtained from the Graduate Division office.

TIME LIMITATION

The Engineer degree will be granted only to those students who complete the required curriculum and fulfill the conditions required for the stipulated degree within five consecutive years prior to the date of graduation indicated on the application for the degree. A candidate who desires a special ruling by reason of hardship may submit a written appeal detailing the reasons for the appeal to the Dean of the Graduate Division.

DOCTOR OF ENGINEERING SCIENCE PROGRAMS

The impact of recent advances in science and engineering and the acceleration of research demands, not only for industry and defense but to an equal degree for education, have made doctoral programs mandatory. There is a growing and insistent need for qualified scholars to move into the frontiers of scientific and engineering knowledge and to transmit the consequent advances to the classrooms and laboratories of our institutions of higher learning. Responsive to such requirements, New Jersey Institute of Technology has formulated programs leading to the degree of *Doctor of Engineering Science*. At the present time these programs are restricted to the Departments of Chemical Engineering, Civil and Environmental Engineering, Electrical Engineering, and Mechanical Engineering, but their extension to other fields is contemplated for the future.

ADMISSION

Applications for admission to the doctoral program may be obtained from the Graduate Division. The applicant must arrange for two transcripts of all previous academic work beyond the secondary school to be sent directly to the Graduate Division by the institutions concerned.



The application fee of \$10.00 must accompany the completed application, in the form of a check or money-order, payable to New Jersey Institute of Technology.

Three letters of recommendation are required, one from each of the following:

- A. The chairman or adviser of the department of major study in the applicant's undergraduate school.
- B. The chairman or adviser of the department of major study in the graduate school that conferred the applicant's master's degree.
- C. An employer, or other person, familiar with the applicant's professional work or activity.

Admission will be predicated on satisfactory evidence of probable success as demonstrated from the information obtained from the applicant's academic background, recommendations, and possible interviews.

Admission to the doctoral program is limited to holders of an academically appropriate master's degree. If an applicant wishes to work for a degree in a field other than his previous major field of study and is otherwise qualified, his prospective department of major study can recommend a program, the satisfactory completion of which would make him eligible for the field of his choice.



DEGREE REQUIREMENTS

The requirements for the degree of *Doctor of Engineering Science* are:

1. Completion of the candidacy requirements cited below.
2. A minimum of twenty-four credits in course work beyond the master's degree.
3. A minimum of one academic year in full-time residence.
4. A minimum of thirty-six credits of original research or design, culminating in a dissertation which meets the publication requirements of the Institute. These requirements are outlined in a booklet available at the Institute Bookstore.
5. An oral defense of the research or design before a committee of the Graduate Faculty selected by the Department of major study with the concurrence of the Dean of the Graduate Division.

CANDIDACY REQUIREMENTS

Admission to the doctoral program does not imply candidacy for a degree. To be considered for admission to candidacy, the student must meet the following conditions:

1. Pass the qualifying examination(s) administered by his department of major study. The examination(s) must be taken within three years after admission to the doctoral program. Application for the examination(s) may be made through the office of the Graduate Division.
2. Demonstrate that facilities as required are available for his proposed research and that a faculty member is available and willing to supervise the student in his proposed work.
3. Submit a final acceptable course of study.

Candidacy application forms are available at the office of the Graduate Division and are to be filed with the requisite candidacy fee of \$20.00 at this same office. Candidacy must be established no later than one year prior to the Commencement at which the degree is to be conferred. Registration for dissertation and research will be permitted only for candidates for the degree. Upon recommendation of the department, a renewed application for candidacy will be considered from a student whose original application was denied. In such cases, the department will specify the conditions for re-application.

APPLICATION FOR THE DOCTORAL DEGREE

An application for the doctoral degree should be filed with the department of major study not later than the close of the first semester of the academic year in which it is expected that

the degree will be conferred. Applications may be obtained from the Graduate Division office.

TIME LIMITATION

The Doctoral degree will be granted only to those students who complete the required curriculum and fulfill the conditions required for the stipulated degree within seven consecutive years prior to the date of graduation indicated on the application for the degree. A candidate for a degree who desires a special ruling by reason of hardship may submit a written appeal detailing the reasons for the appeal to the Dean of the Graduate Division.





Procedures



CLASSIFICATION OF GRADUATE STUDENTS

REGULARLY ENROLLED STUDENTS

1. Students admitted to degree programs.
2. Students who have completed the requirements for, or have been awarded, advanced degrees in engineering or the sciences and wish to register for additional courses.

SPECIAL STUDENTS

1. Graduate degree students at other colleges or universities may enroll, for credit, in courses at New Jersey Institute of Technology. In addition to satisfying the prerequisites for the course or courses involved, each student must furnish a letter of approval from an appropriate administrative officer at his or her own institution.
2. Qualified undergraduates at New Jersey Institute of Technology may satisfy undergraduate elective requirements by satisfactory completion of certain graduate courses. Such students must receive the approval of the chairman of their undergraduate departments to register for these courses.
3. Academically qualified students who do not desire to enter degree programs may enroll for credit in individual graduate courses. Such students must present transcripts of previous academic work and other appropriate evidence at each registration to indicate preparation to undertake the course work involved. If approved by the Graduate Division, registration will be permitted, but only to the extent of available facilities. The cumulative number of courses to be taken by any special student may be limited by the Graduate Division, but in no case may exceed three. While parallel criteria are employed in approving special students and degree students, permission to enroll as a special student in no way implies eventual admission to a degree program.

AUDITORS

Students who wish to attend courses for which they are qualified, but who do not wish to participate in the work of the courses may be permitted to enroll as auditors. Registration will be approved only after a review of credentials by the Graduate Division and only to the extent that class places are available after registration of degree students. An appropriate designation signifying the auditing of a course will be made on student's record but no credit will be granted for the course.

FULL-TIME STUDENTS

All of the degree programs described in this catalog may be pursued on either a full-time or part-time basis. Full-time students are those whose focus of activity is on-campus. While full-time students will normally register for a minimum of nine credits per semester, that number of credits alone does not

define full-time status. Students on graduate assistantships are regarded as full-time students.

PART-TIME STUDENTS

Sufficient evening and Saturday sections of courses are offered so that course work requirements for the various degrees may be completed on a part-time basis by students who are employed in full-time work. (See the description of the doctoral programs for a statement of full-time residency requirements for the doctorate.)

Normally, part-time students are limited to a maximum of six credits per semester.

REGISTRATION

Prospective students will be informed of registration details by the Office of the Registrar, after an Acceptance for Admission form has been received from the Graduate Division.

Currently enrolled students will be informed of registration details for the Fall and Spring semesters by the Office of the Registrar during April and November, respectively, and may then register by mail. Students who fail to comply with these instructions must appear in person during registration to complete payment of tuition and fees. Students who have discontinued their studies and fail to follow the procedures described in the section "Interruption of Studies" will be required to appear in person during registration upon being granted permission to resume studies.

Failure to complete registration before the close of the registration period will make the student subject to payment of a late fee.

SCHEDULING OF CLASSES

Classes in all courses may be scheduled for day time, late afternoon or evening hours. *The right is reserved to cancel classes for which the registration is insufficient.*

Room and laboratory assignments will be announced on the bulletin boards of the Graduate Division at the close of registration.

Courses in heavy demand may be scheduled for additional sections in semesters other than those indicated in this catalog if adequate enrollment can be assured. Day and evening classes during the summer months are possible under the same condition.

Evening classes normally begin at 6:30 p.m. and end at 9:20 p.m. Some laboratory sessions begin at 6:00 p.m. and end at 9:50 p.m.

CHANGE OF PROGRAM

A student who adds a course, or courses, to his program will be charged the full tuition and fee for the course, or courses, added, regardless of the date on which the addition takes place. If, within the first two weeks of the semester, a student changes his schedule, he must fill out a set of schedule change forms available at the Graduate Division and at the Registrar's Office and see to it that they are properly authorized. His charges will then be recalculated and, if he is entitled to a refund or financial credit, such a refund or credit will be made.

INTERRUPTION OF STUDIES

A student enrolled in a degree program who finds it necessary to discontinue his studies temporarily may maintain registration with the approval of the Graduate Division. Payment of a registration fee of \$7.00 will be required for each semester during which this status is maintained. The time limitation for completion of degree programs stipulated on pages 18, 20 and 24, will include semesters during which registration is maintained. A student who anticipates a protracted absence for reasons beyond his control (e.g., a call to active military duty) should contact the Graduate Division regarding the possibility of a leave of absence.

A student who discontinues his studies without taking steps to maintain his status is subject to dismissal by the Graduate Division. Upon recommendation of the department of major study, reinstatement of a student so dismissed may be permitted by the Graduate Division. The degree requirements to be fulfilled by a reinstated student will be those in effect at the time of reinstatement.



WITHDRAWALS AND REFUNDS

WITHDRAWAL PROCEDURE

Registration for a course places a definite responsibility upon the student to carry the course through to completion and to receive the grade he has earned. It is recognized that in exceptional cases withdrawal by a student may be necessary. A pattern of course withdrawals by a degree student, however, will raise the serious question of the value to the student of continued registration in the graduate program. If a student wishes to withdraw from a course, or courses, or from college, he must notify the Dean of the Graduate Division. (Forms for this purpose may be obtained from the office of the Graduate Division or the Registrar's office). The date of receipt of the notice by the Graduate Division will be considered to be the date of withdrawal. Failure to notify the Division of withdrawal from a course may result in a failing grade in the course.

REFUNDS

Students who withdraw from the Institute of their own accord will receive a refund based upon the following schedule, provided that a signed withdrawal application has been received by the Graduate Division. The date of withdrawal will be the date upon which the application has been received by the Graduate Division. Refunds will not be granted for withdrawal applications received after the fifth week, except in cases of military induction as is explained elsewhere in this catalog. Applications for withdrawal may be obtained from the Registrar or from the Office of the Graduate Division.

All fees, once paid, are under no condition returnable.

The percentage of tuition refunded will be based on the following table:

<i>Date of Receipt of Application</i>	<i>Percentage Refund</i>
During the first week of the term	80%
During the second week of the term	80%
During the third week of the term	60%
During the fourth week of the term	40%
During the fifth week of the term	20%
During the remainder of the term	0%

The above schedule applies only to the regular fall and spring semesters but will also be used as a guide to compute comparable percentage refunds for short terms, such as a summer session.

REGULATIONS

The Institute endeavors to foster an environment in which learning and professional growth will flourish. To support the dedication which the vast majority of students bring to this effort, various rules and regulations must be imposed. Most of these are described in the various undergraduate bulletins of the Institute. Several of these which will be of interest to graduate students are listed below.

PROGRESS TOWARD DEGREE

Students are responsible for checking their progress toward fulfillment of requirements for degrees by occasional inquiry at the office of the Graduate Division or the office of the department of major study.

COMMENCEMENT

Candidates for a degree granted by the Institute shall appear in person upon the appointed Commencement Day to receive the degree, unless excused by the President of the Institute.

IDENTIFICATION CARD

As part of the registration procedure each student will be photographed and issued an I.D. card. Use of the various facilities of the Institute requires that this card be exhibited on request by authorized persons.

DRESS

It is expected that persons using facilities of the Institute will be reasonably and neatly attired.

GRADES

The following grades and their respective significance will be used by the Graduate Division of the Institute:

A — Work of high merit.

B — Work of commendable quality.

C — Work of acceptable quality.

F — Failure.

I — Grade deferred. Given in rare instances for students who would normally complete work but because of special circumstances could not. In these cases the grade of I must be removed not later than the semester succeeding the one in which the grade was received.

S — Satisfactory.

or

U — Unsatisfactory.

These will be used as final grades for doctoral seminars, or as progress grades for thesis work. A final grade (A, B, etc.) will be submitted when the master's thesis is accepted. Acceptance of the doctoral dissertation will be noted on the student's record.

W — Withdrawal.

AUD — Course work audited. No academic credit.

EXPENSES

TUITION AND REGULAR FEES (as of January 1, 1976)

Tuition (Residents of New Jersey)	\$35.00 per credit
Tuition (Non-residents of New Jersey)	\$45.00 per credit
Registration Fee	\$7.00 per semester
General Fee	\$8.00 per semester

APPLICATION, MATRICULATION AND SPECIAL FEES

APPLICATION FEE

Each candidate for admission to the Graduate Division must pay an *application fee* of \$10.00 at the time the application for admission is submitted. The fee is not returnable, regardless of whether or not the applicant is admitted to the Graduate Division. This fee covers service which is necessary to evaluate applications for admission.

MATRICULATION FEE

A *Matriculation fee* of \$5.00 is required upon acceptance as a candidate for a Master's degree. (See page 15.)

THESIS FEE

Each student who submits a master's thesis is required to pay a *Master's Thesis fee* of \$30.00 for binding the required three copies of his thesis.

PROFESSIONAL PROJECT FEE

Each student who submits a professional project in fulfillment of the requirements for the Degree of Engineer is required to pay a *Professional Project Fee* of \$40.00 for binding the required four copies of the project.

DISSERTATION FEE

A *Doctoral Dissertation fee* of \$75.00 will be required of each candidate for the Doctoral degree upon the acceptance of the dissertation. This fee covers the cost of binding, a microfilm negative, a microfilm print, and one xerographic copy of the dissertation for the New Jersey Institute of Technology Library.

LABORATORY FEE

For each course, other than thesis, requiring laboratory work, a *Laboratory Fee* and/or deposit is charged, at the time of registration, for expendable supplies and the maintenance of apparatus and equipment used in the laboratories. Payment of a laboratory deposit for thesis course is due only upon notice to the student by the Finance Office rather than at the time of registration. Laboratory fees do not cover breakage or loss of Institute property. The charge to the student for laboratory expenses may in certain courses exceed the amount of the deposit or the laboratory fee.

LATE REGISTRATION FEE

Registration is required for each semester. A *Late Registration Fee* of \$10.00 is required of those who register late.

SCHEDULE CHANGE FEE

A *Schedule Change Fee* of \$3.00 is charged when a student requests a schedule change for reasons other than those beyond his or her control.

CHANGE OF GRADE FEE

For any graduate course, except thesis, a fee of \$1.00 will be charged for the removal of an "I" (grade deferred).

GRADUATION FEE

A *Graduation Fee* of \$35.00 is required of all candidates for degrees. This fee includes rental of academic dress.

CANDIDACY FEE

A *Candidacy Fee* of \$20.00 is required upon applying for candidacy for the Doctor of Engineering Science degree. (See page 23.)

FINANCIAL SUPPORT

Through those graduate departments in which full-time study may be pursued, financial assistance is available for full-time students. Stipends for the academic year vary between \$2000 and \$3800, depending upon qualifications and the extent of service connected with the assistance grant. Additional support for summer research is available and, under certain of

the grants, additional aid for dependents is included. Among the support programs for full-time students which are currently available are the following:

- NJIT Alumni Association Doctoral Fellowship
- Allied Chemical Corp. Fellowships
- Celanese Corp. Fellowships
- Eastman Kodak Corp. Fellowships
- Exxon Education Foundation Fellowships
- E. I. du Pont de Nemours and Company, Inc. Fellowships
- Englehard Memorial Fellowships
- Diamond Shamrock Corp. Summer Fellowships
- Union Carbide Fellowships
- Graduate and Teaching Assistantships
- Research Assistantships

The College graduate assistantships are supported in part by NJIT's Foundation, which derives its funds from the generous public-spirited contributions of a wide variety of corporate and business sponsors.

Inquiries concerning fellowships and assistantships should be directed to the Graduate Division.

PART-TIME STUDY

Howard B. Begg Part-Time Study Scholarship

This fund provides tuition assistance for students pursuing the Master's degree in the Industrial and Management Engineering Department.

Westinghouse Continued Education Program

New Jersey Institute of Technology is one of twenty-five colleges and universities cooperating with the Westinghouse Electric Corporation in offering courses on the graduate level to Westinghouse employees. Details of the program will be found in the most recent edition of the Westinghouse publication "Continued Education—Announcement of Courses," which includes both a list of the institutions and their offerings and an explanation of the terms of financial support offered to the student-employee by the company.

PUBLIC LAW 358

In order to be eligible for educational benefits under Public Law 358, it is necessary for a veteran to have served on active duty for more than 180 days, any part of which must have been after January 31, 1955. This 181-day period, however, may not include training time spent in a Reserve or National Guard program. The deadline date for completing training is ten years after separation from active duty; this time cannot be extended. Veterans who qualify under the above conditions should file the necessary application with the Office of Veterans Affairs of NJIT.

Three large, solid black arrows are arranged in a triangular pattern pointing towards the center. One arrow points downwards from the top, one points to the right from the left, and one points upwards from the bottom. The title 'Courses of Instruction' is positioned to the right of the intersection of these arrows.

Courses of Instruction

Courses of instruction

The course and degree programs offered to graduate students by the several departments are described in the following pages.

Courses are identified by a combination of letters and numerals. The letters indicate the department administering the course; numbers distinguish the individual courses.

Numbers from 500 to 599 indicate courses normally offered for students who require such background for admission to 600, or 700 level courses. Graduate credit for such courses may be granted at the option of the department of major study. Some of these courses are open to qualified seniors.

Numbers from 600 to 699 indicate intermediate graduate courses.

Numbers from 700 to 799 indicate advanced graduate courses which have as prerequisites other graduate courses in the same field.

The courses here listed are those which have been approved in accordance with the policies of the Institute. The frequency of course offerings as listed is intended as a guide for planning programs of study. Some deviation from this listing may occur as a result of departmental or Institute needs, and courses may be cancelled because of insufficient registration. A list of scheduled courses will be issued by the Registrar prior to each semester.

The degree requirements as stated in the separate departmental and program summaries are designed also to serve as a guide to program planning and are subject to specific determination in consultation with departmental or program advisers.



Department of Chemical Engineering and Chemistry

MASTER OF SCIENCE PROGRAMS IN CHEMICAL ENGINEERING

It is expected that all candidates for the degree of *Master of Science in Chemical Engineering* will be graduates in Chemical Engineering from recognized and accredited curriculums or, by the completion of further prerequisites or preparatory work, will have reached the equivalent of this grade of preparedness.

The *Master of Science* program may be elected by graduates of accredited Chemical Engineering curriculums who wish to pursue a broader program of graduate study than that leading to the *Master of Science in Chemical Engineering*. The department also recommends a program leading to the degree of *Master of Science* for those who are graduates from accredited colleges in fields of engineering other than that of Chemical Engineering or who have earned the Bachelor's degree with a major in chemistry or related sciences.

MASTER OF SCIENCE IN CHEMICAL ENGINEERING

A. For the *Master of Science in Chemical Engineering*, candidates must include the following courses to satisfy requirements:

1. ChE 701—Thesis (6) or ChE 700—Project (3).
2. ChE 626—Mathematical Methods in Chemical Engineering (3).
3. For students who elect ChE 701, three courses (totaling 9 credits) from among the following; for students who elect ChE 700, four courses (totaling 12 credits) from among the following:
 - ChE 611—Thermodynamics
 - ChE 612—Kinetics of Reactions
 - ChE 623—Heat Transfer
 - ChE 624—Transport Phenomena I
 - ChE 634—Chemical Process Dynamics and Control
4. Six credits of electives related to the area of specialization.
5. Six credits of electives forming a related group and normally, outside the area of specialization.

MASTER OF SCIENCE

B. For the *Master of Science*, candidates must include the following courses to satisfy requirements:

1. ChE 701—Thesis (6) or ChE 700—Project (30.)
2. For students who elect ChE 701, nine credits from among courses in Chemical Engineering and forming a related group; for students who elect ChE 700, twelve credits from among courses in Chemical Engineering and forming a related group.
3. Fifteen credits of electives, of which six must be in a related area normally outside the area of specialization.

It is expected that candidates for the degree of *Master of Science* who are graduates in science or in some field other than Chemical Engineering, will have adequate training in mathematics, at least through the calculus and differential equations; in lecture and laboratory courses in chemistry; and in physics and related sciences sufficient to comprehend satisfactorily the graduate work offered.

MASTER OF SCIENCE PROGRAMS IN SYSTEMS ENGINEERING

The general areas of interest to the chemical engineer that fall within the domain of systems engineering or, more correctly, involve a systems approach, are process design and process control. The area of process design covers the total development of a process, the economic design of the appropriate equipment, the procurement and erection of the process equipment, and finally the operational aspects of the whole process unit, all under a set of steady state conditions. The area of process control is concerned specifically with the dynamic response of a process unit to variations in feed stocks, operating conditions, and utilities.

Within the above framework, one can obtain an MS degree in systems-chemical engineering via two programs: (1) Designated MS in Chemical Engineering, and (2) Undesignated MS. Listed below are two suggested typical programs.

For the student working toward the degree, Master of Science in Chemical Engineering:

- ChE 626—Mathematical Methods in Chemical Engrg.
- ChE 634—Chemical Process Dynamics and Control
- ChE 701—Thesis or ChE 700—Project
- ChE 741—Modern Methods in Process and Plant Design

For students who elect ChE 701, at least two of the following; for students who elect ChE 700, at least three of the following:

- ChE 611—Thermodynamics
- ChE 612—Kinetics of Reactions
- ChE 623—Heat Transfer
- ChE 624—Transport Phenomena I

Three electives from the following list related to the area of specialization:

- ChE 631—Equilibrium Stage Processes
- ChE 712—Optimization of Chemical Reactor Systems
- ChE 731—Advanced Techniques in Equilibrium Separations
- ChE 735—Optimization in Process Design and Control
- CS 500—Introduction to Systems Analysis
- CS 661—Systems Simulation
- CS 662—Model Analysis and Simulation
- EM 650—Introductory Operations Research
- IE 623—Linear Programming
- SS 601—Econometrics.

MASTER OF SCIENCE PROGRAMS IN ENGINEERING SCIENCE

For the student working toward the degree, Master of Science:

ChE 701—Thesis, or ChE 700—Project.

For students who elect ChE 701, three courses from the following forming a related group; for students who elect ChE 700, four courses, forming a related group, from the following:

ChE 611—Thermodynamics
ChE 612—Kinetics of Reactions
ChE 634—Chemical Process Dynamics and Control
ChE 712—Optimization of Chemical Reactor Systems
ChE 735—Optimization in Process Design and Control
ChE 741—Modern Methods in Process and Plant Design.

Five courses from the following forming a related group:

CS 500—Introduction to Systems Analysis
CS 661—Systems Simulation
CS 662—Model Analysis and Simulation
EM 616—Planning and Control of Products and Processes
EM 635—Management of Design and Development
EM 640—Distribution Logistics
EM 650—Introductory Operations Research
IE 623—Linear Programming
ME 646—Analysis and Synthesis for Design
SS 601—Econometrics.

As part of the Institute's Engineering Science program, advanced work in chemistry is available to qualified students with the bachelor's degree in chemistry or chemical engineering. For students wishing to concentrate their studies in chemistry the following courses must be included as part of the program of study leading to the master's degree:

1. Chem 502—Advanced Organic Chemistry I
2. Chem 610—Advanced Inorganic Chemistry
3. Chem 658—Advanced Physical Chemistry
4. ESc 701—Thesis (6) or ESc 700—Project (3) and an additional 3 credit course.
5. Fifteen credits of elective, which must form a meaningful and coherent program integrated with the major in chemistry, and normally including at least two related courses offered by other departments.

With prior approval students may integrate into their programs graduate courses in chemistry offered by the Chemistry Department of the Newark College of Arts and Sciences of Rutgers—The State University. Further information may be obtained from the departmental adviser and from the Graduate Division.

MASTER OF SCIENCE PROGRAMS IN APPLIED POLYMER SCIENCE AND ENGINEERING

A program of study in applied polymer science and engineering may be designed within the context of either the chemical engineering or the engineering science programs. Illustrative programs are indicated below.

For the student working toward the degree, Master of Science in Chemical Engineering (with option in applied polymer science and engineering):

1. ChE 701—Thesis (6)
2. ChE 626—Mathematical Methods in Chemical Engineering (3)
3. Chem 640—Polymer Chemistry (3)
4. ChE 645—Fundamentals of Rheology (3)
5. ME 580—Polymer Processing Techniques (3)
6. Two courses from the following (totaling 6 credits)

- ChE 611—Thermodynamics
- ChE 612—Kinetics of Reactions
- ChE 623—Heat Transfer
- ChE 624—Transport Phenomena I
- ChE 634—Chemical Process Dynamics and Control

7. Six credits of 600-level courses in polymer science or engineering.

For the student working toward the degree, Master of Science (with options in applied polymer science and engineering):

1. Chem 502—Advanced Organic Chemistry I
2. Chem 610—Advanced Inorganic Chemistry
3. Chem 658—Advanced Physical Chemistry
4. Chem 640—Polymer Chemistry
5. ChE 645—Fundamentals of Rheology
6. ME 580—Polymer Processing Techniques
7. ESc 701—Thesis (6 credits)
8. Six credits of 600-level courses in polymer science or engineering.

DOCTORAL PROGRAM

The program for the degree of *Doctor of Engineering Science* offered by the Department of Chemical Engineering and Chemistry is intended for the superior graduate student with a Master's degree in Chemical Engineering or in Chemistry or in a closely allied field. The student should have a broad background in the basic sciences of chemistry and physics, and in mathematics, and in the engineering sciences such as thermodynamics, reaction kinetics, and transport phenomena. Students with too narrow a specialization on the bachelor's or master's level will be required to broaden this background before becoming eligible as candidates for the doctoral degree.

Course requirements are specified by the department on an individual basis after consultation with the student. Research for the degree requires an original research project completion of which will represent a contribution to available knowledge.

QUALIFYING EXAMINATION

The examination will be taken in two parts. The first part is designed to test the general competence of students whose major interest is in chemical engineering or in chemistry. It will be taken at its first administration following admission to the doctoral program.

Students who have passed the first part of the qualifying examination may be permitted to register for up to 12 credits of ChE 790—Doctoral Dissertation and Research. Registration beyond 12 credits will be permitted only if the candidate has passed the second part of the qualifying examination which covers more advanced areas of study.

Registration for dissertation and research will require as pre-requisites:

1. Such courses as may be specified by the Department.
2. Satisfactory completion of the qualifying examination.
3. Approval by a departmental committee of the student's chosen dissertation topic, and availability of a faculty adviser to supervise the dissertation work.

Should the 36 dissertation credits be completed before the submission of the final copy of the dissertation and its acceptance by the department, it will be necessary for the student to register for a minimum of three additional dissertation credits per semester until the dissertation has been submitted and accepted. The oral dissertation examination will be given only after the submission of the final draft of the dissertation.

COURSES OF INSTRUCTION IN CHEMICAL ENGINEERING

- ChE 551. PRINCIPLES OF MASS TRANSFER. 3 credits, 1st sem. Dauerman.**
Prerequisites: Undergraduate thermodynamics and integral calculus. An introductory course in basic concepts of mass transfer. Special emphasis is placed on mass transfer concepts applicable to stage and continuous operations. Topics covered include evaporation, gas absorption, and distillation. Not available for credit to chemical engineering students.
- 575. STATISTICAL THERMODYNAMICS. 3 credits, 2nd sem.**
Prerequisite: Undergraduate course in thermodynamics. Equilibrium statistical mechanics with applications to the evaluation of thermodynamic properties. Among the topics considered are the ideal gas, monatomic solids, chemical equilibrium, the transition-state theory of reaction rates, intermolecular potential functions, and the evaluation of virial coefficients.

- ChE 611. THERMODYNAMICS. 3 credits, 1st sem. Tassios.**
Prerequisites: Undergraduate courses in physical chemistry and thermodynamics or equivalent. The fundamental principles of thermodynamics are developed quantitatively to include thermodynamic functions and their relations. Applications are discussed with particular attention to generalized methods. Methods are developed for the treatment of gaseous mixtures, liquid solutions, and vapor-liquid equilibria. The thermodynamics of chemical equilibria is considered. Statistical thermodynamics is discussed briefly.
- 612. KINETICS OF REACTIONS AND REACTOR DESIGN. 3 credits, 2nd sem. Hanesian.**
Prerequisites: Undergraduate chemical reaction kinetics and chemical reactor design. The basis for chemical reactor design is reviewed. Consideration is given to chemical reaction mechanisms, Arrhenius' equation, collision theory, transitions-state theory, analysis of laboratory, batch reactor data, and ideal chemical reactor design. Methods for non-isothermal, non-adiabatic chemical reactor design, non-ideal chemical reactor design, and various types of heterogeneous chemical reactor design are developed.
- 620. PETROLEUM REFINING. 3 credits, 1st sem. Spooner.**
Prerequisite: Previous training satisfactory to the department. A study of petroleum fractionation, cracking, reforming, treating, equipment design, operation, and economics of the various processes.
Offered 1976-77 and alternate years.
- 623. HEAT TRANSFER. 3 credits, 1st sem. Bart**
Prerequisite: B.S. in ChE. or M.E. or E.E. A study of heat transmission as applied to practical problems in design. Unsteady state conduction and batch heating and cooling problems are considered. Empirical correlations and their use in the design and optimization of equipment are covered. ME 610 may be substituted for ChE 623 with departmental approval.
- 624. TRANSPORT PHENOMENA I. 3 credits, 1st sem. Chen and Huang.**
Prerequisite: B.S. in ChE or M.E.; ChE 626 or equivalent advanced mathematics. ChE 626 may be taken concurrently, but only with permission of the instructor. An advanced treatment of molecular and turbulent momentum, energy, and mass transport. Emphasis is on the mathematical description of physical mechanisms in momentum and energy transport.
- 626. MATHEMATICAL METHODS IN CHEMICAL ENGINEERING. 3 credits, 1st sem. McCormick.**
Prerequisite: Differential equations, including solutions in power series. This course will emphasize the use of linear and partial differential equations, generalized Fourier expansions, orthogonal functions and operational calculus for the solution of chemical engineering problems. Typical topics will include unsteady state heat transfer and unsteady state diffusion, fluid momentum problems, plate efficiencies in fractionating columns, porous plate cooling, multipass heat exchanges, and the general development of mathematical expressions in engineering applications.
- 628. BIOCHEMICAL ENGINEERING. 3 credits, 2nd sem. Greenstein.**
Prerequisite: B.S. in ChE. The course covers the application of chemical engineering to biological process. Special attention is given to problems encountered in momentum, energy and mass transport, as well as chemical reaction kinetics in biological systems. The fundamentals of the transport processes and chemical reactions are applied to the design of systems.
Offered 1977-78 and alternate years.

- ChE 631. EQUILIBRIUM STAGE PROCESSES. 3 credits, 1st sem. Roche.**
Prerequisite: Undergraduate transport operations. This course draws together the important basic correlations and computational methods used in applying the equilibrium stage concept to the design of separation processes. Absorption, extraction and distillation are covered and treated as variations of one basic process. Equipment design and tower controls are also discussed.
Offered 1976-77 and alternate years.
- 634. CHEMICAL PROCESS DYNAMICS AND CONTROL. 3 credits, 2nd sem. Perna and Chen.**
Prerequisite: Undergraduate process dynamics or process control; ChE 626 or equivalent. An introductory course in the mathematical principles of process dynamics and control. Derivation and solution of differential equations describing the behavior of typical chemical engineering processing units. Mathematical analysis and design of control systems. Topics include frequency response analysis, stability analysis, root-loci, control system specifications, and application to process instrumentation design.
- 640. CHEMICAL PROCESS DEVELOPMENT. 3 credits, 1st or 2nd sem.**
Prerequisite: Unit operations or equivalent. Development of data is obtained in both small and large scale laboratory experiments. The design course includes pilot scale operations. Integration of unit processes, operational variables, and cost are stressed. Comprehensive reports will be written and judged by a departmental committee. Work in the course is on an individual basis at hours arranged by the students and professor. Enrollment is limited to three students each semester.
Hours by arrangement: 1 hour conference, 4 hours design per week.
Laboratory fee: \$5.00. Laboratory deposit: \$25.00.
- 641. CHEMICAL EQUIPMENT AND PLANT DESIGN. 3 credits, 1st or 2nd sem. Roche.**
Prerequisite: Unit operations or equivalent. A course dealing with the design of a chemical manufacturing plant or chemical engineering apparatus, involving selection of equipment auxiliaries, supplies, power, instrumentation layout with general specifications for buildings, plant site preparation, and location. Work in this course is on an individual basis at hours arranged by student and professor. Reports will be judged by a departmental committee. Enrollment is limited to three students each semester.
Hours by arrangement: 1 hour conference, 4 hours design per week.
- 645. FUNDAMENTALS OF RHEOLOGY. 3 credits, 1st sem.**
Prerequisites: ChE 626 or permission of the instructor. This course emphasizes the engineering approach to the fundamentals of the rheology of polymer melts and polymer solutions. The various types of time dependent and time-independent non-Newtonian fluids are classified. The principles of the experimental techniques used to characterize these materials are discussed. The flow of non-Newtonian fluids in simple geometry is illustrated in examples of the development of quantitative design considerations based on the measured rheological properties of real fluids.
- 646. POLYMERIZATION REACTOR DESIGN. 3 credits, 2nd sem.**
Prerequisites: ChE 612 or equivalent. Fundamentals of polymerization rate analysis. Scale up and design of homogeneous and heterogeneous systems. Single and multistage calculations for various mixing situations. Introduction to problems of control, stability, and optimization of various types of polymerization reactors.
- 656. CATALYSIS. 3 credits, 1st sem. Huang.**
Prerequisite: A course in reaction kinetics. Catalysis of chemical reactions, the mechanisms of catalysis and the nature of catalytic substances are considered. Homogeneous and enzyme catalysis, heterogeneous catalysis on solid surfaces, and the catalysis of chain reactions are treated quantitatively. Offered 1977-78 and alternate years.

ChE 685. UNIT OPERATIONS FOR INDUSTRIAL WASTE TREATMENT. 3 credits, 2nd sem. Perna.

Prerequisites: ChE551 or undergraduate transport operations. A course which introduces the student to basic concepts of unit operations which are applicable to the treatment of industrial effluent streams and for municipal waste water advanced treatment. Topics include the theory and applications of filtration methods, water-air processes for cooling and drying, absorption and ion exchange.

686. INDUSTRIAL WASTE AND CONTROL. 3 credits, 2nd sem. Liskowitz.

Prerequisites: EnE 502 and ChE 685 (may be taken concurrently). The industrial processes and the resulting waste problems associated with key industries (paper, food processing, chemical, petroleum, etc.) are examined. Case studies of specific waste control measures being used for these wastes are analyzed.

700. MASTER'S PROJECT. 3 credits, 1st or 2nd sem. Department Faculty.

An extensive paper involving design, construction and analysis, or theoretical investigation. The Master's project will be required of all candidates for the Master's degree who do not take ChE 701—Master's Thesis. Approval to register for the Master's project must be obtained from the project adviser.

If the use of laboratory facilities or equipment is necessary, a \$50.00 deposit must be maintained.

701. MASTER'S THESIS. 6 credits, 1st or 2nd sem. Department Faculty.

The completion, under the guidance of a departmental adviser, of an original project in research, design, or process development. The completed work in the form of a written thesis should be of calibre sufficient to warrant publication in a technical journal. Approval to register for the thesis must be obtained from the thesis adviser. *With the permission of the department, preparation for thesis may be scheduled over one to four consecutive terms. A student must register for a minimum of 3 credits per semester. Credit will be limited, however, to the 6 credits indicated for the thesis.*

If the use of laboratory facilities or equipment is necessary, a \$50.00 deposit must be maintained.

702. SELECTED TOPICS IN CHEMICAL ENGINEERING. 3 credits, 1st or 2nd sem.

Prerequisite: Department approval. This special area course will be given when interest develops. Such topics might include advanced thermodynamics, food technology, synthetic fuels and mass transfer in polymer engineering.

711. PHASE EQUILIBRIUM. 3 credits, 2nd sem. Tassios.

Prerequisite: ChE 611. This course deals with low-pressure and high-pressure vapor-liquid equilibrium and with liquid-liquid equilibrium. Among the topics covered are experimental methods, thermodynamic consistency tests of the data, expressions for the dependence of the activity coefficient on composition and temperature and prediction of multicomponent vapor-liquid and liquid-liquid equilibrium from binary data. Prediction methods of vapor and liquid phase nonidealities, based on equations of state and solution theories, are discussed.

Offered 1977-78 and alternate years.

712. OPTIMIZATION OF CHEMICAL REACTOR SYSTEMS. 3 credits, 1st sem. Hanesian.

Prerequisite: ChE 612, 626. Application of optimization theory to the design and operation of chemical reactor systems. The course is designed to show how to achieve optimum yields, conversions and minimum costs in chemical reactor design.

Offered 1976-77 and alternate years.

- ChE 725. TRANSPORT PHENOMENA II. 3 credits, 2nd sem. Huang.**
Prerequisite: ChE 624. A continuation of ChE 624 with emphasis on mass transport and on the evaluation of transport properties from kinetic theory considerations.
Offered 1977-78 and alternate years.
- 726. APPLIED FLUID MECHANICS. 3 credits, 2nd sem. Huang.**
Prerequisite: ChE 624. A brief survey of fluid mechanics theory followed by study of applications of interest to chemical engineers, such as flow through porous media, particle dynamics, non-Newtonian flow, and mixing.
Offered 1976-77 and alternate years.
- 731. ADVANCED TECHNIQUES IN EQUILIBRIUM SEPARATIONS. 3 credits, 2nd sem. Roche.**
Prerequisite: ChE 631. This course includes derivation of rigorous methods for stage process calculations as well as data correlations and consideration of design degrees of freedom. Emphasis is placed on computer techniques and on use of the computer by students to solve problems. Special topics, such as sidestream stripping, azeotropic and extractive distillation and separation accompanied by chemical reaction are also covered.
Offered 1976-77 and alternate years.
- 735. OPTIMIZATION IN PROCESS DESIGN AND CONTROL. 3 credits, 1st sem.**
Prerequisites: ChE 626 and ChE 634 or equivalent. Mathematical development of optimization techniques with applications to problems in chemical design and control. Methods of calculus of variations and dynamic programming are compared; the discrete maximum principle is developed and applied to problems in the design of multi-stage chemical processes such as cross-current extraction and a stirred tank reactor sequence.
Offered 1977-78 and alternate years.
- 741. MODERN METHODS IN PROCESS AND PLANT DESIGN. 3 credits, 1st sem. Roche.**
Prerequisite: Previous course in process or plant design; ChE 611, 612, and 626. This course deals with some of the newer concepts of process and plant design synthesis, analysis, and optimum design methods. Among the specific topics covered are process development, evaluation and licensing; structure of process design problems; economic design criteria; computer aided design methods; effects of uncertainty on designs; and the various non-process factors that affect a plant design such as contractor's responsibilities, project management, and cost control.
Offered 1977-78 and alternate years.
- 757. CATALYTIC REACTOR DESIGN. 3 credits, 2nd sem.**
Prerequisites: ChE 612, 656, and either ChE 623 or 624. A course dealing with the design and evaluation of chemical reactor systems. Mass, energy, and momentum transfer through beds and tubes packed with stationary and fluidized porous particles, together with simultaneous chemical reaction, are treated.
Offered 1977-78 and alternate years.
- 790. DOCTORAL DISSERTATION AND RESEARCH. Credits as designated, 1st or 2nd sem. Department Faculty.**
Required of all candidates for the degree of Doctor of Engineering Science in the Department of Chemical Engineering and Chemistry. A minimum of 36 credits is required. The student must register for at least 6 credits of dissertation per semester; registration for additional credits may be permitted beyond the six, with the approval of the adviser, to a maximum of 15 credits per semester. Registration for 3 credits is permitted during the summer session.
Hours to be arranged.
If use of laboratory facilities or equipment is necessary, a laboratory deposit of \$50.00 must be maintained, or such additional amount as may be necessary to provide laboratory facilities and equipment.

- ChE 791. DOCTORAL SEMINAR. No credits, 1st or 2nd sem. Department Faculty.**
A seminar in which faculty or others present summaries of advanced topics suitable for research. In the course students and faculty discuss research procedures, thesis organization, and content. Research students present their own problems and research progress for discussion and criticism. *Required for all doctoral candidates registered for ChE 790 unless requirement is waived, in writing, by dissertation adviser. Open to all students registered for ChE 701.*
Seminar fee: \$35.00 per semester.
- 793. PROFESSIONAL PROJECT. Credits as designated, 1st or 2nd sem. Department Faculty.**
Required of all candidates for the degree of Chemical Engineer. A minimum total of 12 credits is required. The student must register for at least 6 credits of professional project per semester until completion of 12 credits. If the student is still actively engaged in the preparation of the project after completion of 12 credits, continued registration of three credits per semester will be required. Registration for 3 credits is permitted during the summer session.
Hours to be arranged.
If use of laboratory facilities or equipment is necessary, a laboratory deposit of \$50.00 must be maintained, or such additional amount as may be deemed necessary to provide laboratory facilities and equipment.

COURSES OF INSTRUCTION IN CHEMISTRY

- Chem 502. ADVANCED ORGANIC CHEMISTRY I. 3 credits, 1st sem. Perlmutter and Trattner.**
Prerequisites: Undergraduate organic chemistry and physical chemistry. Organic molecules are treated from a structural, rather than a mechanistic, viewpoint. Topics covered include atomic and molecular structure, stereochemistry, reactive intermediated (cations, anions, radicals and carbenes), and spectroscopy.
- 540. INTRODUCTION TO POLYMERS. 3 credits, 1st sem. Snyder and Lei.**
Prerequisites: Undergraduate physical chemistry or thermodynamics. Synthesis of typical polymers of commercial importance is presented from a descriptive viewpoint. Determination of the size and shape of polymer molecules and the morphology of crystalline polymers is considered. Mechanical properties of polymers in the crystalline, glassy and elastomeric states are related to structure. Properties of available polymers are examined in relation to specific applications.
- 571. BIOCHEMISTRY. 3 credits, 2nd sem. Kristol and Shilman.**
Prerequisites: Undergraduates organic and physical chemistry or suitable background in these subjects. This is an introductory course in biochemistry. It includes fundamentals from the viewpoint of physical and organic chemistry and the industrial applications in the field. It is directed particularly to those students who have an interest in biophysics and bioengineering.
- 602. ADVANCED ORGANIC CHEMISTRY II. 3 credits, 2nd sem. Perlmutter and Trattner.**
Prerequisite: Undergraduate organic chemistry. Organic chemistry is treated from the point of view of reaction mechanisms. Reactions covered include nucleophilic and electrophilic aliphatic and aromatic substitution, addition, elimination, thermal and photochemical rearrangements, and oxidation and reduction reactions.
Offered 1977-78 and alternate years.
- 603. ADVANCED ORGANIC CHEMISTRY LABORATORY. 3 credits, 1st sem. Perlmutter and Snyder.**
Prerequisite: Undergraduate organic chemistry. More advanced syntheses than those normally carried out in the undergraduate laboratory are

emphasized. In addition, use is made of current analytical techniques and methods of separation to facilitate the syntheses. Both small and large scale preparations are assigned.

Laboratory fee: \$50.00.

- Chem 606. PHYSICAL ORGANIC CHEMISTRY. 3 credits, 2nd sem. Snyder.**
Prerequisite: Chem 502 or equivalent. Emphasis is placed on the physical aspects of the subject. The course covers bonding and spectra, equilibria, and kinetics, considered from the viewpoint of simple molecular orbital theory, statistical thermodynamics, and absolute reaction rate theory. Offered 1976-77 and alternate years.
- 610. ADVANCED INORGANIC CHEMISTRY. 3 credits, 2nd sem. Lambert and Suchow.**
Prerequisites: Undergraduate general and physical chemistry or permission of the instructor. A course in the theory and applications of inorganic chemistry. Chemical theory is applied to the prediction and elucidation of the properties and behavior of inorganic compounds.
- 611. SOLID STATE INORGANIC CHEMISTRY. 3 credits, 1st sem. Suchow.**
Prerequisite: Undergraduate physical chemistry or physics. A course dealing with relationships among structure, and physical and chemical properties of solid-state materials and with the formation of such materials. Offered 1976-77 and alternate years.
- 640. POLYMER CHEMISTRY. 3 credits, 1st sem. Lei and Snyder.**
Prerequisites: Organic and physical chemistry. This course deals principally with preparation of the several types of polymers, with the kinetics of polymerization, and with those properties of polymer solutions useful in characterizing molecular size and shape. *Note: Students who have completed Chem 540 will not be granted degree credit for Chem 640.* Offered 1976-77 and alternate years.
- 641. POLYMER PROPERTIES. 3 credits, 2nd sem. Lei.**
Prerequisite: Chem 540 or 640 or instructor's approval. Forces between polymer molecules and their relation to crystal structure are considered, and the fundamentals of rheology and viscoelastic properties of polymers are presented. Polymer crosslinking, reinforcement, and aging are considered from a chemical viewpoint. Offered 1976-77 and alternate years.
- 643. POLYMER LABORATORY I. 3 credits, 1st sem. Lei and Snyder.**
Prerequisites: Chem 540 or 640. Experiments will be selected to illustrate the various methods that are used to prepare polymers and copolymers. Preparations will include standard condensation, free radical and ionic types. Some elementary methods of polymer characterization will also be included e.g. density, melting temperature, molecular weight, solubility, and polymer purification. Measurements of polymerization kinetics will also be included.
Laboratory fee: \$50.00.
- 644. FUNDAMENTALS OF ADHESION. 3 credits, 1st sem. Snyder.**
Prerequisite: Chem 540 or 640 or equivalent. The fundamental aspects necessary to achieve an understanding of adhesion phenomena are presented. Among the topics considered are: intermolecular and interatomic forces, surface chemistry, absorption of polymers on surfaces, mechanisms of adhesion, bulk properties of the adhesives, and rheology of polymers used as adhesives.
Offered 1977-78 and alternate years.
- 645. POLYMER LABORATORY II. 3 credits, 1st sem. Snyder and Lei.**
Prerequisites: Chem 540 or 641. Experiments illustrating contemporary methods of polymer characterization will be performed. These will include the following methods: Osmometry, viscometry, light scattering, vapor pressure osmometry, differential thermal analysis, dilatometry, x-ray diffraction, birefringence, polymer fractionation, swelling, and infrared, ultraviolet and NMR spectroscopy.
Laboratory fee: \$50.00.

- Chem 651. RADIOISOTOPES THEORY AND APPLICATION. 3 credits, 2nd sem. Parker.**
Prerequisite: Modern physics. A study of the theory and principles involved in the application of radioisotopes. It includes the nuclear physics, instrumentation, legal, and safety aspects of radioisotopes utilization, calculations involved in designing a tracer experiment, as well as a study of specific application of radioisotopes to industrial problems.
Offered 1976-77 and alternate years.
- 658. ADVANCED PHYSICAL CHEMISTRY. 3 credits, 1st sem. Kimmel and Parker.**
Prerequisite: One year of undergraduate physical chemistry. This course deals with quantum chemistry and statistical mechanics and their applications to physical chemistry problems such as chemical bonding and spectra.
- 659. ATOMIC AND MOLECULAR STRUCTURE. 3 credits, 2nd sem. Kimmel.**
Prerequisite: Chem 658 or equivalent. A course concerned with atomic and molecular structure and properties, and the relationships between structure and physical properties.
Offered 1977-78 and alternate years.
- 661. INSTRUMENTAL ANALYSIS. 3 credits, 2nd sem. Dauerman.**
Prerequisite: Undergraduate physical chemistry or modern physics. The principles of instrumental techniques of current significance are presented. The interpretation and application of the information obtained are discussed. Emphasis is placed upon those methods which are of significance in air pollution, catalysis, combustion, and separation procedures.
- 664. ADVANCED ANALYTICAL CHEMISTRY. 3 credits, 1st sem. Dauerman and Kebbekus.**
Prerequisites: Undergraduate analytical chemistry and undergraduate physical chemistry (one semester), or permission of the instructor. Principles underlying modern methods of separation and determination of elements and compounds. Among the topics covered are acid-base theory, radioisotopes, non-aqueous solutions, organic reagents, chromatography, ion exchange, use of complexometric and instrumental methods.
Offered 1977-78 and alternate years.
- ESc 700. MASTER'S PROJECT. 3 credits, 1st or 2nd sem. Department Faculty.**
Prerequisite: Matriculation for the M.S. degree. An extensive report involving an experimental, theoretical, or literature investigation is required. The literature investigation should be an in-depth study of a given area resulting in a critical review of that area. The Master's project is required of all candidates for the Master of Science degree in areas of basic Engineering Science who do not take ESc 701—Master's Thesis. Approval to register for the Master's project must be obtained from the project adviser. With the approval of his adviser, a student may register for 1½ credits in each of two successive semesters. If the use of laboratory facilities or equipment is necessary, a \$50.00 deposit must be maintained.
- 701. MASTER'S THESIS. 6 credits, 1st or 2nd sem. Department Faculty.**
Prerequisite: Matriculation for the M.S. degree. An approved project involving design, construction, and experimental or theoretical investigation may be the basis for this thesis. The work will be carried out under the supervision of a designated member of the faculty. Approval to register for the thesis must be obtained from the thesis adviser. The thesis should be of such calibre as to warrant publication in a technical or scientific journal. *With the permission of the adviser, preparation for the thesis may be scheduled over one to four consecutive semesters. A student must register for a minimum of 3 credits per semester. Credit will be limited, however, to the 6 credits indicated for the thesis.*
If the use of laboratory facilities or equipment is necessary, a \$50.00 deposit must be maintained.

Department of Civil and Environmental Engineering

MASTER OF SCIENCE PROGRAMS

It is expected that all candidates for the degree of Master of Science in Civil Engineering will be graduates in civil or environmental engineering or, by the completion of further prerequisites or preparatory work, will have reached the equivalent of this grade of preparedness.

The Master of Science program may be elected by graduates of civil or environmental engineering curriculums who wish to pursue a broader program of graduate study than that leading to the Master of Science in Civil Engineering. The department also offers a program leading to the degree of Master of Science for those who are graduates in science or in fields of engineering other than civil or environmental engineering.

A program of more than the minimum number of credits may be necessary for the candidates who do not have adequate preparation in those areas which are fundamental to the graduate courses they propose to take.

MASTER OF SCIENCE IN CIVIL ENGINEERING

For the Master of Science in Civil Engineering, candidates must include:

1. CE 700—Civil Engineering Projects (3 credits); or CE 701—Master's Thesis (6 credits).
2. At least 12 credits of specialization, which include CE 700 or CE 701.
3. At least 6 credits of electives related to the area of specialization.
4. At least 6 credits of electives, outside the department.

MASTER OF SCIENCE

For the Master of Science, candidates must include:

1. CE 700—Civil Engineering Projects (3 credits); or CE 701—Master's Thesis (6 credits).
2. At least 12 credits of specialization, which include CE 700 or CE 701.
3. At least 6 credits of electives related to the area of specialization.
4. At least 6 credits of electives, outside the department.
5. The remaining 6 credits may be taken within or without the department.

FIELDS OF SPECIALIZATION

Suggested areas of specialization are construction, environment, soils and foundations, structures, urban or transportation engineering. Students interested in master's programs in environmental engineering, however, are referred to the description of inter-departmental programs in this field on page 112.

In designing a program within any of the fields of specialization, the student should consult with his departmental adviser in order to insure that all departmental and college-wide requirements are satisfied. Upon the completion of 6 credits each student must have the written approval of his adviser for his program.

INTER-DISCIPLINARY PROGRAMS

Students with interest in Urban Systems may wish to consider the following inter-disciplinary programs which are administered by the Department of Civil and Environmental Engineering.

URBAN SYSTEMS

An inter-disciplinary program leading to the Master of Science degree, offering analytical approaches to urban problems and policy-making. The objective of this program is to prepare individuals to assume roles as program analysts in urban government. Emphasis is placed on developing a background knowledge of urban processes linked with engineering approaches into specialization areas. A core set of courses is required, together with selected courses listed.

CORE COURSES

CE 650 Urban Systems Engineering	SS 521—Urban Social Structure
CE 655—Land Use Planning	SS 604—Economic Analysis of Urban Areas
CE 700—Civil Engineering Project	

URBAN SYSTEMS MANAGEMENT

EM602—Management Science	OS 694—Industrial Relations and Public Planning
EM 650—Introductory Operations Research	SS 601—Econometrics
OSOS 662—Organization Design and Development	SS 602—Cost-Benefit Analysis and Economic Decisions
OS 693—Labor-Management Relations in the Public Sector	SS 603—Public Financing
	SS 605—Urban Housing Economics

URBAN ENGINEERING

EnE 660—Introduction to Solid Waste Problems	CE 654—Mass Transportation Systems
EnE 667—Solid Waste Disposal Systems	CE 750—Urban Transportation Planning
EnE 668—Air Pollution Control	Math 661—Mathematical Statistics
EnE 671—Environmental Impact Analysis	SS 602—Cost-Benefit Analysis and Economic Decisions

DOCTORAL PROGRAM

The degree of *Doctor of Engineering Science in Civil Engineering* is conferred in recognition of marked ability and scholarship in the field of civil and environmental engineering and of high scholastic attainment and satisfactory completion of an original independent investigation in one of the specific areas of civil environmental engineering.

Although the requirements for the degree are not specifically quantitative in character, the candidate must fulfill the minimum degree requirements stated on pages 19-24. The candidate must satisfactorily complete all courses that the Department may specify.

QUALIFYING EXAMINATION

The candidate must satisfactorily complete a two-part qualifying examination. The first part of this examination is designed to test general knowledge of civil engineering and mathematics. It will be taken at its first administration following admission to the doctoral program. The second part of the examination, which will be both written and oral, is designed to test knowledge in the specific area of specialization and must be taken within three years of the first part.

REGISTRATION FOR DISSERTATION

The candidate must successfully complete and defend an original dissertation. Registration for dissertation credits will require prior approval of the candidate's chosen dissertation topic by the Department. Should the 36 credits assigned to the dissertation be completed before the submission of the final copy of the dissertation and its acceptance by the Department, it will be necessary for the students to register for additional dissertation and research credit at a minimum of three credits per semester. The oral dissertation examination will be given only after the acceptance of the completed dissertation.

COURSES OF INSTRUCTION IN CIVIL ENGINEERING

- Mech 540. ADVANCED STRENGTH OF MATERIALS. 3 credits, 1st sem. Ciesla**
Prerequisite: Mechanics of deformable bodies. Topics beyond the scope of elementary mechanics of deformable bodies are studies with particular emphasis on the assumptions, limitations and applications to actual problems.
Offered 1976-77 and alternate years.
- 630. THEORY OF ELASTICITY. 3 credits, 2nd sem. Golub.**
Prerequisite: Differential equations. The theory of elasticity is studied as a basis for both advanced stress analysis and for a critical examination of elementary stress analysis.
Offered 1976-77 and alternate years.
- CE 510. CIVIL ENGINEERING MATERIALS. 3 credits, 1st sem. Peck.**
Prerequisite: Undergraduate course in strength of materials. A study of the characteristics and properties of materials as they relate to design and construction procedures. Emphasis is placed on new applications of conventional materials and on recently introduced materials.
Offered 1976-77 and alternate years.
- 541. STRUCTURAL MODEL ANALYSIS. 3 credits, 1st sem. Craig.**
Prerequisite: Undergraduate course in structural analysis. Basic theory of the analysis of structures by means of models, model design, and the interpretation of model tests.
Laboratory fee: \$20.00.
Offered 1976-77 and alternate years.

- CE 610. CONSTRUCTION MANAGEMENT. 3 credits, 1st sem. Department Faculty.**
Prerequisites: B.S. degree in C.E., architecture, or related field. A study of the managerial aspects of contracting, with emphasis on the relative position of an individual firm within the entire construction industry. Topics include contractor organization and management, legal aspects of construction, and financial planning.
- 611. PROJECT PLANNING AND CONTROL. 3 credits, 2nd sem. Department Faculty.**
Prerequisite or corequisite: CE 610. Theories of management as related to construction projects are analyzed and applied to individual projects. Human relations as they affect the construction process are considered. Offered 1977-78 and alternate years.
- 620. OPEN CHANNEL FLOW. 3 credits, 1st sem. Disko and Golub.**
Prerequisite: Undergraduate fluid mechanics. The principles developed in fluid mechanics are applied to flow in the open channel. Steady and unsteady flow, channel controls and transitions are considered. Application is made to natural rivers and estuaries. Offered 1976-77 and alternate years.
- 621. HYDROLOGY. 3 credits, 2nd sem. Disko and Dresnack.**
Prerequisite: CE 620 or equivalent. The statistical nature of precipitation and runoff data is considered with emphasis on floods and droughts. The flow of groundwater is analyzed for various aquifers and conditions. Flood routing, watershed yield, and drainage problems are considered. Offered 1976-77 and alternate years.
- 631. REINFORCED CONCRETE I. 3 credits, 1st sem. Department Faculty.**
Prerequisite: An undergraduate course in the theory and design of reinforced concrete. A review of basic concepts of elastic and ultimate strength theories and a study of the present design codes. Design of concrete building frames, two way slabs, flat slabs, waffle slabs, curved beams, and other structural elements using the above two theories.
- 632. REINFORCED CONCRETE DESIGN II. 3 credits, 2nd sem. Department Faculty.**
Prerequisite: CE 631. This course covers the analysis and design of alternate structural building systems consisting of reinforced and prestressed concrete elements. Included is a study of the design of prestressed concrete members, reinforced concrete members, shear walls, and composite members both precast and cast in place. Offered 1976-77 and alternate years.
- 633. THEORY OF STRUCTURAL ANALYSIS. 3 credits, 1st sem. Stack-Staikidis.**
Prerequisite: Undergraduate course in structural analysis. A study of the elastic behavior of indeterminate structural systems. Deflection theories and the classical methods of analysis for structures with prismatic and non-prismatic members are developed. These methods are applied to continuous beams, frames, arches, rings and trusses. Computer methods are introduced.
- 634. STRUCTURAL DYNAMICS. 3 credits, 2nd sem. Department Faculty.**
Prerequisites: Undergraduate vibration analysis and CE 633. The basic concepts for the dynamic analysis of beams, frames and other types of structures are presented. The practical methods developed are applicable to problems such as the analysis of the effects of earthquake on buildings and moving loads on bridges. Offered 1976-77 and alternate years.
- 640. THEORETICAL SOIL MECHANICS. 3 credits, 1st sem. Chan.**
Prerequisite: Undergraduate course in soil mechanics. Deals with the theoretical aspects, including seepage analysis, single- and multi-directional consolidation, and stress distribution. Included are consideration of strength and deformation of soils, theories of bearing capacity, stability, and earth pressure analysis. Analytical aspects of soil dynamics

are also discussed.
Offered 1977-78 and alternate years.

- CE 641. ENGINEERING PROPERTIES OF SOILS. 3 credits, 2nd sem. Khera.**
Prerequisite: Undergraduate course in soil mechanics. An in-depth study of physical and mechanical properties of soils including mineralogy, compressibility, shear strength, and permeability. Laboratory testing and interpretation of results are studied.
Laboratory Fee: \$20.00.
Offered 1977-78 and alternate years.
- 642. SHALLOW FOUNDATIONS. 3 credits, 1st sem. Monahan.**
Prerequisite: Undergraduate course in soil mechanics. Emphasis is on selection of foundation type and allowable bearing capacity. Site investigation is considered in the light of geological and empirical evidence and the subsequent planning of physical involvement such as borings and test pits. The rationale of laboratory and field testing is examined. The effects of construction techniques such as excavation, dewatering, and surcharging are studied. Some design examples and case studies are included.
Offered 1976-77 and alternate years.
- 643. DEEP FOUNDATIONS. 3 credits, 2nd sem. Department Faculty.**
Prerequisite: Undergraduate course in soil mechanics. Covers planning, design, and installation of deep foundations, such as piles and caissons, for all types of structures. Special emphasis is placed on the economics of foundation selection and on studies of case histories.
Offered 1976-77 and alternate years.
- 644. GEOLOGY IN ENGINEERING. 3 credits, 1st sem. Monahan.**
Prerequisites: undergraduate courses in soil mechanics or geology. This is a case-history oriented course dealing with large engineering projects where extensive geologic investigations are necessary, such as dams, tunnels, and highways.
Offered 1977-78 and alternate years.
- 650. URBAN SYSTEMS ENGINEERING. 3 credits, 1st sem. Deutschman and Kuperstein.**
Prerequisite: B.S. degree in engineering or in the physical sciences or in the social sciences with a strong quantitative background. The course identifies the various urban problems subject to engineering analysis and then presents modern techniques for their solution, including inductive and deductive mathematical methods, mathematical modeling and simulation, and decision making under uncertainty.
Offered 1977-78 and alternate years.
- 651. TRAFFIC FLOW THEORY. 3 credits, 1st sem. Kuperstein.**
Prerequisites or corerequisites: Probability and statistics, and computer programming. An analytical approach to the study of transportation with emphasis on the interaction of the various elements. Methods are studied for analyzing the flow of vehicular traffic and obtaining the characteristics of air and ground transportation. Principles are applied to traffic and transit problems.
- 652. TRAFFIC ENGINEERING. 3 credits, 2nd sem. Kraft and Kuperstein.**
Prerequisite: CE 651. A course which studies the characteristic and behavior of the driver, vehicle, and road system, with applications to design, operation, and control of highway traffic. Applications of statistical methods are made.
Offered 1976-77 and alternate years.
- 653. TRAFFIC SAFETY. 3 credits, 2nd sem. Lehman.**
Prerequisite: CE 651. System behavioral principles are applied to a number of practical problems dealing with safety aspects of highway operation and design, and improvements of existing facilities. Solutions are evaluated on the basis of cost effectiveness.
Offered 1977-78 and alternate years.

- CE 654. MASS TRANSPORTATION SYSTEMS. 3 credits, 2nd sem. Deutschman.**
Prerequisite: CE 651. An investigation of bus, rapid transit, commuter railroads, and airplane modes as related to integrated transportation systems. Existing equipment, economics, capacity, and terminal characteristics are discussed, as well as new systems and concepts. Long and short range modes are compared.
Offered 1976-77 and alternate years.
- 655. LAND USE PLANNING. 3 credits, 1st sem. Deutschman.**
Prerequisites: B.S. degree in architecture, engineering, or science; course in probability and statistics and in computer programming (may be taken concurrently). Study is made of spatial relations of human behavior patterns to land use; methods of employment and population studies are evaluated; location and spatial requirements are related to land use plans; and concepts of urban renewal and recreational planning are investigated by case studies.
Offered 1976-77 and alternate years.
- 700. CIVIL ENGINEERING PROJECTS I. 3 credits, 1st or 2nd sem. Department Faculty.**
Prerequisites: Sufficient experience and/or graduate course work to support the project, and permission of the department faculty. Extensive investigation, analysis, or design of civil engineering problems not covered by regular graduate course work are required. A student who has done an exceptional quality of work in CE 700 may, upon his own initiative and with the approval of his adviser, substitute the work of this course as the equivalent of the first three credits for a Master's Thesis, CE 701.
- 701. MASTER'S THESIS. 6 credits, 1st or 2nd sem. Department Faculty.**
The thesis is to be prepared on a subject in the student's major field. The subject is to be approved by the department. Approval to register for the thesis must be obtained from the thesis adviser. *With the permission of the department, preparation for thesis may be scheduled over one to four consecutive terms. A student must register for a minimum of 3 credits per semester. Credit will be limited, however, to the 6 credits indicated for the thesis.*
If the use of laboratory facilities or equipment is necessary, a \$50.00 deposit must be maintained.
- 710. SYSTEMS IN BUILDING CONSTRUCTION. 3 credits, 1st sem. Peck.**
Prerequisite: CE 610. The study of the interrelation between the design and construction of building structures. The concepts of modular construction and industrialized building and their compatibility with conventional methods of construction are considered.
Offered 1977-78 and alternate years.
- 711. METHODS IMPROVEMENT IN CONSTRUCTION. 3 credits, 2nd sem. Peck.**
Prerequisite: CE 610. A thorough study of techniques for determining productivity. Modern innovations in the construction industry and their use in increasing the efficiency of the construction process are analyzed.
Offered 1976-77 and alternate years.
- 720. WATER RESOURCE SYSTEMS. 3 credits, 2nd sem. Cheng and Dresnack.**
Prerequisites: CE 620, 621. A system methodology is applied to the analysis of water resource development and operation. Topics included are operational hydrology, water quality criteria, streamflow requirements, resource allocation, and economics. These topics are developed in a series of lectures and supplemented by readings in current periodicals. Mathematical models are developed and employed in the evaluation of a case study.
Offered 1977-78 and alternate years.

- CE 721. ESTUARY AND COASTLINE HYDRAULICS. 3 credits, 1st sem. Cheng.**
Prerequisite: CE 620. Physical phenomena near the coastline, such as currents, tides, and tides in estuaries are discussed. Related hydrodynamic problems are formulated and solutions presented. Engineering problems such as pollution, sedimentation, salinity intrusion, hurricane surge, interaction of structures, and waves are analyzed.
Offered 1977-78 and alternate years.
- 730. PLASTIC ANALYSIS AND DESIGN. 3 credits, 1st sem. Department Faculty.**
Prerequisite: CE 633. Theory of plasticity as applied to structural design. Study of methods of predicting strength and deformation of single and multi-story steel frames in the plastic range. Comparison of plastic and elastic design techniques.
Offered 1976-77 and alternate years.
- 731. ANALYSIS AND DESIGN OF SHELL STRUCTURES. 3 credits, 2nd sem. Golub.**
Prerequisites: CE 631, 633. The course deals with the methods of analysis and design of shell structures for buildings. Topics include domes, hyperbolic paraboloids, folded plates, and cylindrical shells. Materials considered include reinforced and prestressed concrete, steel and aluminum. Computer techniques are introduced.
Offered 1977-78 and alternate years.
- 732. MATRIX METHODS IN STRUCTURES. 3 credits, 2nd sem. Stack-Staikidis.**
Prerequisite: CE 633. The course deals with the analysis of structural systems using matrix methods. It includes determination of stiffness and flexibility coefficients by various methods, element to system transformations, the flexibility and stiffness method as applied to determinate and indeterminate structures, and analysis by substructures, incursion, and iteration.
Offered 1976-77 and alternate years.
- 733. DESIGN OF METAL STRUCTURES. 3 credits, 2nd sem. Monasa.**
Prerequisite: CE 633. This course develops the methods of design of metal structural systems. Topics include combined action of unsymmetrical sections, torsion of open and closed sections, buckling of columns and plates with various end conditions and design of curved and boxed girders.
Offered 1976-77 and alternate years.
- 734. DESIGN OF TALL BUILDINGS AND SPACE STRUCTURES. 3 credits, 2nd sem. Craig.**
Prerequisite: CE 633. Design of tall buildings and space structures is considered with an emphasis on the framing systems. Recent developments and current research related to the design of such structures are discussed.
Offered 1977-78 and alternate years.
- 735. OPTIMIZATION OF STRUCTURES. 3 credits, 2nd sem. Stack-Staikidis.**
Prerequisites: CE 633, 732. This course deals with the generalized approach to optimization of structures employing mathematical criteria and constraints. Topics include optimization of structural elements and systems, weight and cost merit functions, selection of material and shapes for various classes of load transmission, and design of various structural elements based on a cost-weight trade-off and minimum weight.
Offered 1977-78 and alternate years.
- 736. FINITE ELEMENT METHODS IN STRUCTURAL AND CONTINUUM MECHANICS. 3 credits, 1st sem. Craig.**
Prerequisites: CS 621 or 622, CE 633 or 634. Some finite element approaches for the analysis of plane stress problems, plates in flexure, shells, and three-dimensional solids are presented. Choice of interpolation functions, convergence, and the capabilities of the methods are investigated. Comparisons are made with finite difference techniques. Applications to design are considered.
Offered 1977-78 and alternate years.

- CE 740. EARTH STRUCTURES. 3 credits, 1st sem. Khera.**
Prerequisite: CE 641. Earth pressure calculations for the design of retaining walls, bulkheads, open cuts, tunnels, and culverts are studied. Design and installation of bracing and anchoring systems and principles of earth and rockfill dam design are included.
Offered 1977-78 and alternate years.
- 741. SEEPAGE AND WELL ANALYSIS. 3 credits, 2nd sem. Monahan.**
Prerequisite: CE 640. This course deals with seepage through dams and foundations soils, flow net construction and analysis, piping and boiling, ground water lowering, and well analysis.
Offered 1977-78 and alternate years.
- 742. SOILS DYNAMICS. 3 credits, 1st sem. Chan.**
Prerequisites: CE 640, 641. Mathematical models describing the strength of soils and their dynamic behavior are studied. These are applied to the behavior of cohesive and cohesionless soils and to the analysis of pile foundations, machine foundations, dams, and earthquake action.
Offered 1976-77 and alternate years.
- 743. SOIL RHEOLOGY. 3 credits, 2nd sem. Chan.**
Prerequisites: CE 640, 641. Course topics include recent advances in theoretical and experimental rheology of soils and foundations, basic shear strength phenomena, failure criteria for isotropic and anisotropic soils, derivation of stress-strain time response of viscoelastic bodies, and rheological models. Engineering problems in phenomenological rheology are emphasized.
Offered 1976-77 and alternate years.
- 750. URBAN TRANSPORTATION PLANNING. 3 credits, 1st sem. Deutschman.** Prerequisites: CE 653, 654. This course deals with urban travel patterns and trends; community and land activity related to transportation planning; and transportation study techniques including survey methods, network analysis, assignment and distribution techniques. Case studies of statewide and urban areas are examined.
Offered 1977-78 and alternate years.
- 751. TRANSPORTATION DESIGN. 3 credits, 2nd sem. Kraft.**
Prerequisite: CE 750. Design problems which include airports, terminals, and highway intersections and interchanges are undertaken.
Offered 1977-78 and alternate years.
- 790. DOCTORAL DISSERTATION AND RESEARCH. Credits as designated, 1st or 2nd sem. Department Faculty.**
Required of all candidates for the degree of Doctor of Engineering Science in the Department of Civil and Environmental Engineering. A minimum of 36 credits is required. The student must register for at least 6 credits of dissertation per semester; registration for additional credits may be permitted beyond the six, with the approval of the adviser, to a maximum of 15 credits per semester. Registration for 3 credits is permitted during the summer session.
Hours to be arranged.
If use of laboratory facilities or equipment is necessary, a laboratory deposit of \$50.00 must be maintained, or such additional amount as may be necessary to provide laboratory facilities and equipment.
- 791. DOCTORAL SEMINAR. No Credit, 1st or 2nd sem. Department Faculty.**
A seminar in which faculty or others present summaries of advanced topics suitable for research. In the course students and faculty discuss research procedures, thesis organization, and content. Research students present their own problems and research progress for discussion and criticism. *Required of all doctoral candidates registered for CE 790 unless requirement is waived, in writing, by dissertation adviser.*
Seminar Fee \$35.00 per semester.

- CE 793. PROFESSIONAL PROJECT. Credits as designated, 1st or 2nd sem. Department Faculty.**
Required of all candidates for the degree of Civil Engineer. A minimum total of 12 credits is required. The student must register for at least 6 credits of professional project per semester until completion of 12 credits. If the student is still actively engaged in the preparation of the project after completion of 12 credits, continued registration of three credits per semester will be required. Registration for 3 credits is permitted during the summer session. Hours to be arranged.
If use of laboratory facilities or equipment is necessary a laboratory deposit of \$50.00 must be maintained, or such additional amount as may be necessary to provide laboratory facilities and equipment.

COURSES OF INSTRUCTION IN ENVIRONMENTAL ENGINEERING

- EnE 560. ENVIRONMENTAL CHEMISTRY. 3 credits, 1st or 2nd sem. Olenick and Trattner.**
Prerequisite: Undergraduate general chemistry. Basic physical and chemical principles applicable to environmental and sanitary engineering are presented and amplified in the laboratory.
Laboratory Fee: \$20.00.
- 660. INTRODUCTION TO SOLID WASTE PROBLEMS. 3 credits, 1st sem. Perna.**
Prerequisite: B.S. degree in engineering or science. An introductory course in solid waste disposal which covers industrial and urban sources of solid waste and the conventional methods of disposal of these wastes. Application of engineering principles as related to this is stressed.
Offered 1976-77 and alternate years.
- 661. ENVIRONMENTAL MICROBIOLOGY. 3 credits, 1st or 2nd sem. Liskowitz.**
Prerequisite: EnE 560 (May be taken concurrently). Biological and microbiological principles applicable to environmental and sanitary engineering are presented. Bacteriological examinations of water and waste-water are made in the laboratory.
Laboratory fee: \$20.00
- 663. POLLUTION: CHEMISTRY AND ECOLOGY. 3 credits, 1st or 2nd sem. Trattner.**
Prerequisite: One year of undergraduate general chemistry. This course considers the nature and effects of pollution as it relates to air, water, and soil, and the inhabitants of these areas. The current status of the science and technology of environmental improvement is discussed. Pollution prevention and current pollution research is studied. Antipollution legislation is considered.
- 664. PHYSICAL AND CHEMICAL TREATMENT. 3 credits, 2nd sem. Dresnack.**
Prerequisite: EnE 560. The physical and chemical operations and processes employed in the treatment of water and waste-water are presented. Topics include gas transfer, coagulation, flocculation, solid-liquid separation, filtration, and disinfection.
Offered 1976-77 and alternate years.
- 665. BIOLOGICAL TREATMENT. 3 credits, 2nd sem. Cheng.**
Prerequisites: EnE 560, 661. The principles of evaluation and control of water pollution are extended to describe aerobic treatment processes which include oxidation ponds, trickling filters, and activated sludge. Anaerobic digestion and sludge handling and disposal are included as well as biodegradability study techniques for various wastes.
- 666. ANALYSIS OF RECEIVING WATERS. 3 credit, 1st sem. Dresnack.**
Prerequisites or corequisites: EnE 560, 661. The ecological responses of various types of receiving waters to municipal and industrial waste loadings are considered in detail. Mathematical models for water quality predictions and planning are examined and developed.

- EnE 667. SOLID WASTE DISPOSAL SYSTEMS. 3 credits, 2nd sem. Cheremisinoff.**
Prerequisite: EnE 660. Review and evaluation of design criteria for methods and equipment employed in the disposal of industrial and municipal solid wastes. Application of systems techniques to transportation of solid wastes and selection of disposal sites are included.
Offered 1976-77 and alternate years.
- 668. AIR POLLUTION CONTROL. 3 credits, 2nd sem. Cheremisinoff.**
Prerequisite: EnE 560 or physical chemistry. The nature of the air pollution problem, its effect on the public at large, and the present legal and engineering controls used to combat the problem are considered.
- 669. WATER AND WASTEWATER ANALYSIS. 3 credits, 1st sem. Cheng and Trattner.**
Prerequisites or corequisites: EnE 560, 661. Measurement of parameters of interest in water and wastewater quality studies are performed in the laboratory. Specific projects requiring analysis, interpretation and recommendations will comprise a major part of the work.
Laboratory Fee: \$20.00.
- 670. ADVANCED PROCESSES IN WATER POLLUTION CONTROL. 3 credits, 2nd sem. Olenik.**
Prerequisite: EnE 669. Through the use of detailed laboratory experiments, various unit operations are studied. The unit operations considered are sedimentation, coagulation, and flocculation, chlorination, filtration, aeration, and sludge treatment and digestion. Aspects of pilot plant design and layout are considered. Design parameters discussed in prerequisite courses are developed by advance bench-scale laboratory procedures. Advanced design and synthesis are considered.
Laboratory fee: \$20.00.
- 671. ENVIRONMENTAL IMPACT ANALAYSIS. 3 credits, 2nd sem. Deutschman, Dresnack, Lehman.**
Prerequisite: A graduate course dealing with physical aspects of the environment. Overview of environmental problems, federal and state standards, methodology for developing impact statements, case studies based on recent experience, basis for assessment and decision-making.

Department of Computer and Information Science

MASTER OF SCIENCE IN COMPUTER SCIENCE

The graduate program is designed to serve the academic needs of students who wish to study advanced topics in computer science. A student admitted to the program will be assigned an adviser who will assist him in formulating a program of study based on the student's background and special interests. A minimum of 30 graduate credits must be included in the program according to the guidelines given below. The degree Master of Science in Computer Science will be awarded to the student upon successful completion of his program of study.

In addition to the admission and academic requirements of the Graduate Division of the College, entering students are expected to have the following preparation: (1) Working knowledge of at least one procedure-oriented language, such as FORTRAN; (2) at least a semester of assembly language programming; (3) some undergraduate mathematics beyond calculus.

Students whose education is in other disciplines may apply for admission. In these cases, the criteria for admission will be based on the detailed academic background of the student and his ability to undertake the study of advanced topics in computer science at the graduate level.

Students who are deficient in preparation will be considered for admission but will be required to complete additional courses as necessary to remove the deficiency.

GRADUATE PROGRAM IN MORRIS COUNTY

For the convenience of potential part-time students who live or work in the greater Morris County area, an evening program in computer science is offered at Drew University in Madison, N.J. Courses are conducted by NJIT faculty. Sufficient courses are offered so that degree requirements may be completed at the off-campus location. Details are available from the Graduate Division or from the NJIT Department of Computer and Information Science.

Although students are allowed considerable latitude in formulating their programs of study, certain guidelines must be adhered to. Each program must include:

- (1) CIS 635—Computer Programming Languages.
- (2) CIS 700—Master's Project or CIS 701—Master's Thesis.
- (3) CIS 710—Computer Science Seminar (this course carries no credit and is taken concurrently with the Master's Thesis or Project).
- (4) Twelve credits (aside from the above) in computer science. These credits are limited to no more than two of the areas of specialization listed below.
- (5) Twelve or nine credits of elective courses depending upon whether the Master's Project or Thesis is selected. Although these credits may include further courses in computer science, they must include 6

credits in other departments.

AREAS OF SPECIALIZATION

System Design: CIS 630, CIS 631, CIS 636, CIS 651, CIS 732

Formal Theory: CIS 540, CIS 640, CIS 641

Systems Analysis: CIS 500, CIS 661, CIS 662, CIS 665, CIS 762

While the foregoing areas of specialization are a succinct characterization of the academic branches of the field, the following course listings illustrate in more detail some individual programs of study. In order to delineate more clearly career

objectives, these programs are grouped into three categories: software engineering, information systems analysis, and computer application analysis. *Software engineering* is concerned with the functional design of the complete system and the development of specific schemes involving information processing technology to fulfill the stated requirements of the system. It is intended for the student whose undergraduate training is in computer science or who has considerable industrial computer science experience. *Information systems analysis*, related to software engineering, determines the needs for and the specifications of a particular system. Students choosing this option would be expected to have a solid foundation in business, management science or economics. *Computer application analysis* deals with such areas as simulation, graphics, artificial intelligence, heuristics, computer aided design, computer control, and data communications. Students majoring in this option should have a background in mathematics, engineering or the physical sciences.

SOFTWARE ENGINEERING

Emphasis on design of programming facilities

CIS 630—Operating System Design	CIS 661—Systems Simulation
CIS 631—Data Mgt. System Design	CIS 662—Model Anal. & Simulation
CIS 635—Computer Programming Languages	CIS 700—Master's Project
CIS 636—Compiling System Design	CIS 710—Computer Science Seminar
CIS 651—Data Communications	EE 677—Optimization Techniques
	Math 661—Mathematical Statistics

Emphasis on special-purpose computing

CIS 500—Introduction to System Analysis	CIS 661—Systems Simulation
CIS 621—Numerical Analysis I	CIS 700—Master's Project
CIS 622—Numerical Analysis II	CIS 710—Computer Science Seminar
CIS 631—Data Mgt. System Design	Math 511—Numerical Methods
CIS 635—Computer Prog. Lang.	Math 630—Matrix Theory
	Math 661—Mathematical Statistics

Emphasis on computer systems theory

CIS 540—Fundamentals of Logic and Automata	CIS 710—Computer Science Seminar
CIS 635—Computer Prog. Lang.	EE 575—Introduction to Digital Circuits
CIS 636—Compiling System Design	EE 675—Synthesis of Digital Control Circuits
CIS 640—Recursive Function Theory	Math 630—Matrix Theory
CIS 641—Formal Languages	Math 634—Abstract Algebra
CIS 700—Master's Project	

INFORMATION SYSTEM ANALYSIS

Emphasis on management information systems

CIS 630—Operating System Design	CIS 710—Computer Science Seminar
CIS 631—Data Mgt. System Design	CIS 732—Design of Interactive Systems
CIS 635—Computer Prog. Lang.	CIS 762—Design of Information Systems for Planning and forecasting
CIS 661—Systems Simulation	
CIS 662—Model Analysis and Simulation	
CIS 700—Master's Project	

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|---------------------------------------------------|--------------------------------------------|
| IE 601—Measurement Methods for Management Systems | IE 669—Human Design Factors in Engineering |
| IE 603—Behavioral Science | SS 601—Econometrics |
| IE 661—Man-Machine Systems | |

Emphasis on management and economics

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|----------------------------------------|--------------------------------------------------------------------|
| CIS 631—Data Management System Design | CIS 762—Design of Information Systems for Planning and forecasting |
| CIS 635—Computer Programming Languages | CIS 700—Master's Project |
| CIS 651—Data Communications | CIS 710—Computer Science Seminar |
| CIS 661—Systems Simulation | EM 693—Managerial Economics |
| CIS 662—Model Analysis and Simulation | IE 601—Measurement Methods for Management Systems |
| CIS 732—Design of Interactive Systems | SS 601—Econometrics |
| | SS 602—Cost-Benefit Analysis and Economic Decisions |

Emphasis on organizational systems

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|----------------------------------------|-----------------------------------------------|
| CIS 631—Data Management System Design | CIS 700—Master's Project |
| CIS 635—Computer Programming Languages | CIS 710—Computer Science Seminar |
| CIS 651—Data Communications | IE 603—Behavioral Science |
| CIS 661—Systems Simulation | IE 661—Man-Machine Systems |
| CIS 662—Model Analysis and Simulation | OS 683—Manpower Planning and Mgt. Development |
| | OS 671—Techniques of Executive Control |

Emphasis on quantitative managerial decision-making

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|----------------------------------------|-------------------------------------------------------|
| CIS 631—Data Management System Design | CIS 710—Computer Science Seminar |
| CIS 635—Computer Programming Languages | EM 602—Introduction to Management Science |
| CIS 651—Data Communications | EM 605—Introductory Operations Research |
| CIS 661—Systems Simulation | IE 605—Mathematical Programming in Management Science |
| CIS 662—Model Analysis and Simulation | IE 623—Linear Programming |
| CIS 700—Master's Project | |

COMPUTER APPLICATION ANALYSIS

Emphasis on computer communication systems

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|----------------------------------------|----------------------------------|
| CIS 630—Operating System Design | CIS 700—Master's Project |
| CIS 631—Data Management System Design | CIS 710—Computer Science Seminar |
| CIS 635—Computer Programming Languages | EE 601—Linear Systems |
| CIS 651—Data Communications | EE 661—Control System Components |
| CIS 665—Graph Theory | EE 664—Discrete Systems |
| | Math 668—Probability |

Emphasis on electromechanical component design

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|-------------------------------------------|---------------------------------------------|
| CIS 621—Numerical Analysis I | CIS 710—Computer Science Seminar |
| CIS 622—Numerical Analysis II | EE 601—Linear Systems |
| CIS 630—Operating System Design Languages | EE 661—Control System Components |
| CIS 635—Computer Programming | ME 630—Analytical Methods in Machine Design |
| CIS 651—Data Communications | ME 632—Instrumentation |
| CIS 700—Master's Project | |

Emphasis on traffic analysis

CIS 621—Numerical Analysis I	CIS 700—Master's Project
CIS 622—Numerical Analysis II	CIS 710—Computer Science Seminar
CIS 635—Computer Programming Languages	CE 652—Traffic Engineering
CIS 661—Systems Simulation	CE 654—Mass Transportation Systems
CIS 662—Model Analysis and Simulation	CE 655—Traffic Safety
	Math 661—Mathematical Statistics

Emphasis on design of chemical processes

CIS 621—Numerical Analysis I	ChE 640—Chemical Process Development
CIS 622—Numerical Analysis II	Math 661—Mathematical Statistics
CIS 630—Operating System Design	CIS 635—Computer Prog. Lang.
CIS 631—Data Management System Design	CIS 651—Data Communications
ChE 634—Chemical Process Dynamics and Control	CIS 700—Master's Project
	CIS 710—Computer Science Seminar

COURSES OF INSTRUCTION

CIS 500. INTRODUCTION TO SYSTEMS ANALYSIS. 3 credits, 1st or 2nd sem. College Faculty.

Prerequisite: Differential equations. Provides the background information and techniques for the study of systems concepts at the graduate level. Covers the solution of a wide variety of system engineering problems chosen from different disciplines and introduces mathematical tools only as needed to find practical solutions to these problems. Includes topics from network analysis, morphological analysis, dynamic analysis of systems, transport processes, control theory, and dimensional analysis. Also an overview of specialized languages for implementing various system approaches will be presented.

510. COMPUTER PROGRAMMING. 3 credits, 2nd sem. Department Faculty.

Prerequisite: Knowledge of at least one procedure-oriented language such as FORTRAN. Machine organization and structure, machine language programming, multiprogramming executive, batch processing monitor, program linkage and segmentation are studied as a means for program preparation. Various organizations used in computers are described.

515. ADVANCED COMPUTER PROGRAMMING FOR ENGINEERS. 3 credits, 1st sem. Department Faculty.

Prerequisite: Knowledge of at least one procedure-oriented language such as FORTRAN. This course is designed for engineering students who require an extensive knowledge of programming for their project or thesis work. Topics covered include a review of basic programming techniques, thorough treatment of algorithm design, error analysis and debugging using advanced features of FORTRAN IV, and programming facilities available on the operating system, and as time permits, problem oriented languages such as CSMP are examined. Students specializing in computer science may not take this course for credit.

540. FUNDAMENTALS OF LOGIC AND AUTOMATA. 3 credits, 1st sem. Department Faculty.

Prerequisite: Undergraduate calculus. This course develops the method and theory of logic and automata and its influence on the design of computer systems. Neutral networks and associated time and state diagrams are demonstrated. Included are elementary concepts in propositional calculus, semantical tableaux, qualification theory, finite-state machines, regular expressions, Kleene's theorem, and infinite state machines.

- CIS 621. NUMERICAL ANALYSIS I. 3 credits, 1st sem. Department Faculty.**
Prerequisite: Math 511 or an introductory course in numerical methods. The emphasis is on appropriate methods for digital computers. Topics include error analysis; methods of interpolation and quadrature; aspects of approximation theory; solution of ordinary differential equations.
- 622. NUMERICAL ANALYSIS II. 3 credits, 2nd sem. Department Faculty.**
Prerequisite: Math 511 or an introductory course in numerical methods. The course includes iterative methods for solving nonlinear equations; solution of systems of linear equations; the numerical eigenvector-eigenvalue problem; difference methods for partial differential equations; and problems in optimization.
- 630. OPERATING SYSTEM DESIGN. 3 credits, 1st sem. Moshos.**
Prerequisite: CIS 510 or familiarity with organization of at least one computer system. An intensive study of computer operating system design for job-by-job serial, batch, spooling, multiprogramming, time-sharing and realtime processing. The course presents the facilities and concepts of operating systems for creating an efficient computer environment for preparing and executing programs. Includes job and task control, synchronization of concurrent processes and processors, resources scheduling and protection, and management of hierarchel storage.
- 631. DATA MANAGEMENT SYSTEM DESIGN. 3 credits, 2nd sem. Moshos.**
Prerequisite: CIS 510 or familiarity with organization of at least one computer system. This is a companion course to CIS 630. The design of structured information files is presented; their generation, updating, revision and inquiry, from a user's perspective. Specialized self-contained and host language data management systems are examined. Course covers related topics of data management systems such as table and directory construction; search techniques; sorting; data integrity, descrption, representation, and validation; definition of data sets; I/O supervisors; organization of serial, sequential and DASD file systems, and file accessing methods.
- 635. COMPUTER PROGRAMMING LANGUAGES. 3 credits, 1st sem. Anderson.**
Prerequisite: CIS 510 or familiarity with the organization of at least one computer system and higher-level programming language such as FORTRAN. The theory and design of computer language system; the formal theory of syntax and language classification; a survey of procedure and problem oriented computer programming languages, their syntax rules, data structures and operations, control structures, and the appropriate environments and methods of their use; a survey of translator types.
- 636. COMPILING SYSTEM DESIGN. 3 credits, 2nd sem. Anderson.**
Prerequisite: CIS 635. A study of compilers and their relationships with their host computer systems, including the design of compilers themselves, the format of object programs, and the nature of run-time or object support systems; the design considerations for compilers in relation to their host environments and intended purposes such as in mini-computers, conversational systems, development and debugging systems, interpretive compilations, and production environments; the specific phases and techniques for implementation of compilers including scanning, lexical analysis, parsing, storage assignment, code generation, and error handling. Other special topics may be included in depth such as top-down parsing techniques, object code optimization techniques, pre-processors, and compiler-compilers.
- 640. RECURSIVE FUNCTION THEORY. 3 credits, 2nd sem. Department Faculty.**
Prerequisite: CIS 540 or equivalent. Topics include formal characterization of notion of algorithm, Godel numbering, S-M-N theorem unsolvability results; sets-recursive and recursively enumerable; one-one, many-one, truth-table and Turing reducibility; Post's problem and recursion theorem. Offered 1976-77 and alternate years.

- CIS 641. FORMAL LANGUAGES. 3 credits, 2nd sem. Department Faculty.**
Prerequisite: CIS 540 or equivalent. Formal grammar, finite automata and regular grammars, pushdown automata, the halting problem, linear bounded automata, time space bound for language recognition, and natural language recognition are covered.
Offered 1976-77 and alternate years.
- 651. DATA COMMUNICATIONS. 3 credits, 2nd sem. Moshos.**
Prerequisite: CIS 510 or familiarity with organization of at least one computer system. The theory and practice of data communications is presented for system engineers and computer system analysts. Quantitative methods related to the design of data communication networks are examined. Included are characteristics of common carrier facilities; encoding and line conditioning techniques for transmission and error control; synchronous transmission; line and computer interfaces with as modems, concentrators, multiplexers, and communication computers; survey of computer terminals and design of computer software interface.
- 661. SYSTEMS SIMULATION. 3 credits, 1st sem. Scher.**
Prerequisite: Statistics and knowledge of FORTRAN programming. An introductory study of computer simulation techniques used in the solution of systems problems. Discussion of techniques for generating pseudorandom numbers, and applicable statistical testing procedures. Formulation of a model for computer simulation solution, data gathering, parameter estimation and selected topics in methodology, such as the generation of pseudorandom numbers from non-uniform probability distributions. Applications are selected from engineering and industrial systems, using GPSS language.
- 662. MODEL ANALYSIS AND SIMULATION. 3 credits, 2nd sem. Scher.**
Prerequisite: Introductory course in simulation. Advanced topics in simulation methodology, including design of simulation experiments, variance reduction techniques, estimation procedures, validation and analysis of simulation results. Queueing systems. Implementing a simulation with the SIMSCRIPT II.5 language. Models of continuous systems, with applications to elementary socio-economic and industrial systems. Utilization of the CSMP and DYNAMO II languages.
- 665. GRAPH THEORY. 3 credits, 2nd sem. Anderson**
Prerequisite: Linear algebra. The elements of the theory of graphs, ordinary graphs and directed graphs are presented together with the motivating examples from the fields to which the theory applies. Such fields include communication networks, logistics, computer programs, programming languages, data structures, enumeration techniques, PERT techniques and many others. Emphasis is on the applications of graphtheoretic models to engineering problems and the use of computers to represent and analyze these models.
- 700. MASTER'S PROJECT. 3 credits, 1st or 2nd sem. Department Faculty.**
Prerequisite: Matriculation for the M.S. degree. An approved project involving design, construction, and analysis, or theoretical investigation is required of all candidates for the Master of Science degree who do not take CIS 701, Master's Thesis. The work will normally be initiated in a course in the Computer Science area with the knowledge and approval of the course instructor who will become the student's project adviser. Candidates working on projects are required to attend CIS 710, Computer Science Seminar, concurrently, and to present their papers orally. A student whose work in CIS 700 is of exceptional quality may be permitted to extend the Master's Project into a Master's Thesis, CIS 701. With the approval of his adviser, a student may register for 1½ credits in each of two successive semesters. If the use of laboratory facilities or equipment is necessary, a \$25.00 deposit must be maintained.

- CIS 701. MASTER'S THESIS. 6 credits, 1st or 2nd sem. Department Faculty.**
 Prerequisite: Matriculation for the M.S. degree. An approved project involving design, construction, and analysis or theoretical investigation may be the basis for the thesis. The work will be carried out under the supervision of a designated member of the faculty. The thesis should be of such caliber as to warrant publication in a technical or scientific journal. Candidates working on theses are required to attend a semester of CIS 710, Computer Science Seminar; they will report on their research at the seminar. Approval to register for the thesis must be obtained from the thesis adviser. *With the permission of the adviser, preparation for the thesis may be scheduled over one to four consecutive semesters. A student must register for a minimum of 3 credits per semester. Credit will be limited, however, to the 6 credits indicated for the thesis.*
 If the use of laboratory facilities or equipment is necessary, a \$25.00 deposit must be maintained.
- 710. COMPUTER SCIENCE SEMINAR. No credit, 1st and 2nd sem. Department Faculty.**
 Presentations covering active areas of research in computer and information science are given by faculty members, outside speakers, and primarily by students working on Master's theses or projects. The aim of the seminar is twofold: (1) To give the student training in making an effective oral presentation of his own investigations, and (2) To increase his familiarity with research areas other than his own. Meetings are open to all NJIT students and staff.
 Seminar fee: \$35.00 per semester.
- 732. DESIGN OF INTERACTIVE SYSTEMS. 3 credits, 1st sem. Turoff.**
 Prerequisite: CIS 635. This course deals with the design of various terminal oriented systems for use by individuals who are not computer professionals. The material will cover the man-machine interface design as well as the impact of this on hardware and software. The various systems examined will include alternative designs for text editing, CAI (Computer Assisted Instruction), retrieval and query systems, conferencing systems, MIS (Management Information Systems) and other user-oriented systems for immediate access.
 A case study approach will be used reviewing current papers and operational systems.
- 762. COMPUTERIZED INFORMATION SYSTEMS FOR PLANNING AND FORECASTING 3 credits, 2nd sem. Turoff.**
 Prerequisite: CIS 661. This course covers the processing of subjective and empirical data for use in planning and forecasting information systems and the incorporation of these facilities into information system designs. Subjects included will be the use in information systems design in such concepts as risk analysis, subjective probabilities, Bayesian decision structures, clustering and scaling analysis, cross-impact, relevance tree analysis and regression analysis. Particular emphasis will be made in incorporating these techniques into specialized systems such as Project Management Systems, Medical Diagnostic Systems, Shortage Monitoring and Allocation Systems, Corporate Planning Systems and Forecasting and Policy Analysis Systems.
- 785. SELECTED TOPICS IN COMPUTER AND INFORMATION SCIENCE I. 3 credits, 1st sem. Department Faculty.**
 Prerequisites: Determined by nature of topic area. This course examines in depth a special interest area of Computer and Information Science. It emphasizes recent work in area selected for the offering of the course. Advance notice of the topics to be covered will be given.
- 786. SELECTED TOPICS IN COMPUTER AND INFORMATION SCIENCE II. 3 credits, 2nd sem. Department Faculty.**
 A continuation of CIS 785.

Department of Electrical Engineering

MASTER OF SCIENCE PROGRAMS

The *Master of Science in Electrical Engineering* is intended for the electrical engineering graduate, or the holder of an equivalent degree, who wishes to further his formal electrical engineering education by specializing in some advanced phase of electrical engineering or in preparation for a further advanced degree.

The *Master of Science* is intended for the science or non-electrical engineering graduate who wishes to specialize in some advanced electrical engineering work, or for the electrical engineering graduate who wishes to further his education by broadening his field and taking a relatively large number of courses in some other field of study.

Programs for both degrees are designed for students with an excellent undergraduate background in mathematics through differential equation and vector analysis and in electric networks, transients, electronics, and electromagnetic fields, including laboratory work in some of these areas. Candidates for the *M.S. in E.E.* will be required to demonstrate proficiency in all of these fields.

Candidates for the *M.S.* will be required to demonstrate proficiency in those areas which are fundamental to the graduate courses they propose to take. A candidate demonstrating such proficiency to the satisfaction of his adviser may proceed immediately to the advanced courses in Areas I through VIII, shown below. Others will be required to take such undergraduate prerequisites as may be needed and some or all of the following basic graduate courses:

- CIS 510—Computer Programming
- EE 530—Electromagnetic Field Theory
- EE 540—Electronic Circuits
- EE 550—Circuit Analysis
- EE 563—Introduction to Control Systems
- EE 575—Introduction to Digital Circuits
- EE 580—Introduction to Analog Computation
- Math 573—Differential Equations I

A program of more than the minimum number of credits will be necessary for a candidate requiring courses listed above.

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

- A. For the *Master of Science in Electrical Engineering*, candidates must complete at least 30 credits, including:
1. EE 700—Master's Project or EE 701—Master's Thesis.
 2. EE 601—Linear Systems.
 3. Math 658—Operational Analysis
 4. The 18 credits of specialization, which include EE 700 or EE 701 and EE 601, must be limited to no more than two related areas.

- At least 6 credits in a correlated (non-electrical) field as a minor.

MASTER OF SCIENCE

B. For the *Master of Science*, candidates must complete at least 30 credits, including:

- EE 700—Master's Project or EE 701—Master's Thesis.
- EE 601—Linear Systems.
- Math 658—Operational Analysis
- The 15 credits of specialization, which include EE 700 or EE 701 and EE 601, must be limited to no more than two related areas.
- At least 6 credits in a correlated (non-electrical) field as a minor.

AREAS OF SPECIALIZATION

For the convenience of the candidate and his adviser in the selection of an integral program for the Master's Degree, the offerings of the department have been divided into the following fields of specialization:

Area I. ELECTRIC CIRCUIT DESIGN AND SYNTHESIS

EE 645—Feedback Amplifiers I	EE 745—Feedback Amplifiers II
EE 648—Wave Shape Control	EE 752—Network Theory II
EE 652—Network Theory I	EE 753—Electric Filter Design
EE 658—Integrated Circuits I	EE 758—Integrated Circuits II

AREA II. CONTROL SYSTEMS

ChE 634—Chemical Process Dynamics and Control	EE 766—Stability Theory of Non-linear Systems
EE 661—Control Syst. Components	EE 768—Optimal Control Theory
EE 662—Large Power Control Systems	EE 769—Stochastic Estimation and Control
EE 663—Control System Laboratory	EE 680—Analog and Analog/Hybrid Computer Techniques
EE 664—Discrete Systems	ME 632—Instrumentation
EE 667—System Studies in Bio-Engineering	ME 753—Adv. Control of Electro-Mechanical Networks
EE 673—Random Signal Analysis I	
EE 677—Optimization Techniques	
EE 765—Intro. to Nonlinear Syst.	

AREA III. ELECTRONIC COMPUTER SYSTEMS

EE 648—Wave Shape Control	EE 677—Optimization Techniques
EE 650—Transistor Circuits	EE 680—Analog and Analog/Hybrid Computer Techniques
EE 664—Discrete Systems	EE 681—Digital Computer Methods in Electrical Engrg.
EE 667—Systems Studies in Bioengineering	EE 682—Computer-Aided Network Design
EE 675—Synthesis of Digital Control Circuits	

AREA IV. COMMUNICATION SYSTEMS

EE 622—Wave Propagation	EE 673—Random Signal Analysis I
EE 630—Microwave Electronic Systems	EE 742—Communication Systems II
EE 642—Communication Systems I	EE 744—Communication Systems Design

- | | |
|--------------------------------------------------------|------------------------------------------------------|
| EE 749—Seminar in Communication Systems | EE 776—Information Theory |
| EE 755—Digital Communication | EE 777—Statistical Decision Theory in Communications |
| EE 759—Principles of Phase Lock and Frequency Feedback | EE 778—Algebraic Coding for Information Transmission |
| EE 773—Random Signal Analysis II | |

Area V. COMMUNICATION DEVICES

- | | |
|-------------------------------------|-------------------------------|
| EE 622—Wave Propagation | EE 658—Integrated Circuits I |
| EE 630—Microwave Electronic Systems | EE 730—Theory of Guided Waves |
| EE 650—Transistor Circuits | EE 739—Lasers and Masers |
| EE 657—Semiconductor Devices | EE 758—Integrated Circuits II |

AREA VI. FIELDS AND WAVES

- | | |
|---------------------------------------------|-------------------------------------|
| EE 622—Wave Propagation | EE 630—Microwave Electronic Systems |
| EE 730—Theory of Guided Waves | |
| EE 735—Quantum Electronics | |
| EE 736—Introduction to Quantum Field Theory | |

Area VII. ELECTRONIC SYSTEMS RELIABILITY

- | | |
|-----------------------------------|----------------------------------------|
| EE 641—Reliability in Electronics | EE 674—Noise in Electrical Circuits |
| EE 645—Feedback Amplifiers I | EE 748—Seminar on Reliability Problems |
| EE 650—Transistor Circuits | |
| EE 657—Semiconductor Devices | |

Area VIII. ELECTRIC POWER SYSTEMS

- | | |
|-------------------------------------------------------|--------------------------------------------------------|
| EE 610—Power System Steady-State Analysis | EE 635—Conduction in Plasma |
| EE 611—Transients in Power Systems | EE 710—Economic Control of Interconnected Systems |
| EE 612—Computer Methods in Power System Analysis | EE 711—Stability Theory of Electric Power Systems |
| EE 613—Protection of Power Systems | EE 712—Magnetohydrodynamic Power Generation |
| EE 614—Dynamics of Electromech. Energy Conversion | EE 719—Advanced Electromechanical Energy Conversion II |
| EE 615—Advanced Electromechanical Energy Conversion I | |

The department may require a program of more than the minimum number of 30 credits for a candidate wishing to satisfy the departmental degree requirements in more than two of the above areas.

SYSTEMS ENGINEERING

A student wishing to design an inter-disciplinary program with emphasis on systems engineering is encouraged to consider combining courses in Area II above with some of the following:

- | | |
|-----------------------------------------|----------------------------------------|
| CIS 500—Introduction to System Analysis | CIS 635—Computer Programming Languages |
| CIS 630—Operating System Design | CE 650—Urban Systems Engineering |
| CIS 631—Data Management System Design | |

CE 654—Mass Transportation Systems
EE 616—Planning and Control of Products & Processes
EM 640—Distribution Logistics
EM 650—Operations Research
IE 603—Behavioral Science
IE 705—Math. Programming in Management Science
ME 632—Instrumentation
ME 634—Analysis and Synthesis for Design

ME 753—Advanced Control of Electro Mechanical Networks
CE 652—Traffic Engineering
CE 653—Traffic Safety
ME 660—Noise Control
ME 661—Thermal Pollution of Water and Air
ME 753—Advanced Control of Electro-Mechanical Networks

INTER-DISCIPLINARY SYSTEMS PROGRAM

The following two programs are given as examples of possible inter-disciplinary system programs:

Program 1

ChE 685—Unit Operations for Industrial Waste Treatment
EE 601—Linear Systems
EE 673—Random Signal Analysis I
EE 677—Optimization Techniques
EE 700—Master's Project

EE 765—Introduction to Non-Linear Systems
Math 658—Operational Analysis
ME 632—Instrumentation
ME 660—Noise Control
ME 661—Thermal Pollution of Water and Air

Program 2

EE 601—Linear Systems
EE 664—Discrete Systems
EE 673—Random Signal Analysis I
EE 677—Optimization Techniques
EE 700—Master's Project

CE 651—Traffic Flow Theory
CE 652—Traffic Engineering
CE 654—Mass Transportation Syst.
Math 661—Mathematical Statistics
Math 662—Statistical Interference

DOCTORAL PROGRAM

Other programs may be set up in consultation with the student's adviser—the above are examples which are by no means exclusive.

The program for the degree of *Doctor of Engineering Science* in Electrical Engineering is intended for the superior electrical engineering student with a Master's degree in Electrical Engineering who has a broad background in engineering, mathematics and physics and who wishes to do advanced work in an area of electrical engineering research. Students with too narrow a specialization in the bachelor's or master's programs will be required to broaden this background before becoming eligible as candidates for the Doctoral degree. At least 50 per cent of the undergraduate course work should have been in physical science or allied fields and the work on the M.S. level should indicate a major in electrical engineering and a minor in either mathematics or physics or both.

Course requirements for the doctoral program will be specified in consultation with the student, and the dissertation for the degree will require original research, completion of which will contribute to the available knowledge in the field. The

program will include at least 12 credits of courses on the 700 level as approved by the adviser.

QUALIFYING EXAMINATION

The qualifying examination will require competence in the following fields:

1. Mathematics: Differential equations and vector analysis; transformation or operational calculus; advanced calculus; complex variables; elements of probability; and stochastic processes.
2. Engineering Physics: Undergraduate physics, including kinetics, kinematics and thermodynamics. Advanced topics in classical and modern physics. Also included are engineering applications to branches of engineering other than electrical.
3. General Electrical Engineering: Undergraduate electrical engineering and elementary graduate study in circuits, fields, electronics, linear systems, and digital computer programming.
4. A specialized area of Electrical Engineering: This field must be indicated to the department chairman within two months before the date of the qualifying examination. This section of the examination will entail a critical evaluation of the area specified in order to determine ability to conduct research requiring such knowledge and to apply this knowledge to broader and more general problems.

The first three parts must be taken together and should be taken as soon as possible. The fourth part (specialized area) is to be taken when the adviser and student feel that the student is ready. In any event, all parts must be taken within three years of admission to the doctoral program.

REGISTRATION FOR DISSERTATION

Registration for dissertation and research will require as prerequisites:

1. Such courses as may be specified by the department.
2. Satisfactory completion of the qualifying examination.
3. Demonstration of proficiency in both analog and digital computer programming.
4. Demonstration by the candidate that facilities for his proposed research will be available and that a faculty member is willing to supervise the dissertation. An approved written research proposal is required for this purpose.

Should the 36 credits of research be completed before the submission of the final copy of the dissertation and its acceptance by the department, it will be necessary for the student to register for a minimum of three additional dissertation credits per semester until the dissertation has been submitted and accepted. The oral examination will be given only after the submission of the final draft dissertation.

DOCTORAL WORK AT FORT MONMOUTH

In cooperation with the United States Army Electronics Command (Fort Monmouth), substantial portions of the doctoral course offerings in the communications field are available in classrooms at Fort Monmouth. In addition, departmental faculty with research interests in communications are regularly available at Fort Monmouth for dissertation supervision. Features of this program are open to employees of the Electronics Command as well as to other eligible students who live or work in the area.

COURSES OF INSTRUCTION

- EE 530. ELECTROMAGNETIC FIELD THEORY. 3 credits, 1st sem.**
Prerequisite: Undergraduate vector analysis or equivalent. The course covers electrostatic fields, magnetostatic fields, Maxwell's equations, the Poynting vector, relationship between circuit theory and Maxwell's equations, some low-frequency and high-frequency applications of the equations; retarded potential type of solutions; wave equations; and plane waves.
- 540. ELECTRONIC CIRCUITS. 3 credits, 2nd sem.**
Prerequisite: EE 550 or equivalent. Untuned electronic amplifiers, with linear and nonlinear circuits. Feedback amplifiers and oscillators. Amplitude modulation. Rectifiers and filters.
- 550. CIRCUIT ANALYSIS. 3 credits, 1st sem.**
This course is an introduction to the analysis of linear circuits and systems. Techniques used include mesh and nodal analysis, network theorems, steady-state and transient methods, analogs, Fourier series and transforms, and Laplace transforms. Pole-zero diagrams are developed as an aid in the study of low-order systems.
- 563. INTRODUCTION TO CONTROL SYSTEMS. 3 credits, 1st sem.**
Prerequisite: Bachelor's degree in engineering. Linear feedback control systems are treated in both state-variable and transfer-function representation. Nyquist criterion, root-locus and parameter-plane methods are introduced and applied to both analysis and design of linear time-invariant systems. Principles of controllability and observability are studied. A survey of various topics is given, such as a-c carrier control systems and some selected nonlinear and optimization problems.
- 575. INTRODUCTION TO DIGITAL CIRCUITS. 3 credits, 1st sem.**
Prerequisite: Undergraduate course in electronic circuits. This course develops the mathematics and minimization techniques together with the circuit implementation for the design of combinational and sequential digital solid state-logic circuits. Elementary computer and control circuits are used as examples.
- 580. INTRODUCTION TO ANALOG COMPUTATION. 3 credits, 2nd sem.**
Prerequisite: Undergraduate course in electronic circuits. The course considers the basic analog computer and the types of applicable problems. The topics of amplitude and time scaling, ordinary linear and nonlinear differential equations, simulation of transfer functions in the time domain, problem a "set up" and solution checks are studied.
- 601. LINEAR SYSTEMS. 3 credits, 1st or 2nd sem.**
Methods of linear-system analysis, in both time and frequency domains, are studied. Techniques used in the study of continuous and discrete systems include state-variable representation, matrices, Fourier transforms, Laplace transforms, inversion theorems, sampling theory, discrete and fast Fourier transforms, and Z-transforms. Computer simulation of linear systems is used, and, where feasible, computer solutions are obtained.

- EE 610. POWER SYSTEM STEADY-STATE ANALYSIS. 3 credits, 1st sem.**
Prerequisite: B.S. in E.E. or M.E. This course develops the technique to analyze power system networks and the methods to solve system fault problems, real power; and reactive power flow problems. Symmetrical components and matrix application are introduced. Digital solutions of load flow studies and fault studies are emphasized.
Offered 1976-77 and 1979-80.
- 611. TRANSIENTS IN POWER SYSTEMS. 3 credits, 1st sem.**
Prerequisite: B.S. in E.E. or M.E. Topics of the course include transient performance of power systems with lumped properties, interruption of arcs, restriking voltage, reignition, inertia effects, switching of rotational systems; magnetic saturation in stationary networks, harmonic oscillations, saturated systems; transient performance of synchronous machines, transient effects of damper networks.
Offered 1978-79 and 1981-82
- 612. COMPUTER METHODS IN POWER SYSTEM ANALYSIS. 3 credits, 1st sem.**
Prerequisite: Undergraduate computer programming. This course presents techniques that have been applied successfully in solving power system problems with a digital computer. It is designed to inform prospective power engineers of methods currently employed in the electric utility industry. Solution techniques are presented for the short circuit, load flow and power system stability problems. The mathematical techniques required for a computer solution are emphasized.
Offered 1977-78 and 1980-81.
- 613. PROTECTION OF POWER SYSTEMS. 3 credits, 1st sem.**
Prerequisite: EE 610. Topics of the course include coils, condensers and resistors as protective devices, fundamental principles of protective relaying, relay operating characteristics, power and current directional relays, differential relays, distance and wire pilot relays, heating and harmonic effects.
Offered 1977-78 and 1980-81.
- 614. DYNAMICS OF ELECTROMECHANICAL ENERGY CONVERSION. 3 credits, 2nd sem.**
Prerequisites: E.E. 530 and undergraduate electric machines. The course covers dynamic behavior of lumped parameter systems, study of a continuum electromechanics, such as magnetic diffusion and the stressensor; and dynamics of electromechanical continua in 2- and 3-dimensional systems.
Offered 1977-78 and 1980-81.
- 615. ADVANCED ELECTROMECHANICAL ENERGY CONVERSION I. 3 credits, 1st sem.**
Prerequisite: Undergraduate electric machines. The course topics include steady-state performance of synchronous machines; time constants, sudden reactive loading; sudden short-circuit conditions; dynamic behavior of synchronous machines; speed torque-current control of induction machines; magnetic noise and voltage ripples; and Kron generalized machine theory.
Offered 1978-79 and 1981-82
- 622. WAVE PROPAGATION. 3 credits, 2nd sem.**
Prerequisite: Undergraduate field theory. Basic concepts of wave propagation are studied, including discussion of sources, boundary and radiation conditions, and effects of different materials on field quantities. Reduction of Maxwell's equations to transmission-line equations is presented to give a general approach to guided-wave and resonator problems. Antenna concepts and practical antenna systems are discussed. Time permitting, field problems are analyzed using Ray optics.

- EE 630. MICROWAVE ELECTRONIC SYSTEMS. 3 credits, 2nd sem.**
 This course is concerned with the foundations of microwave engineering. The topics covered include electromagnetic theory, waveguides, microwave circuit analysis, passive microwave devices, electromagnetic resonators, periodic structures and filters, and microwave tubes.
 Offered 1976-77 and alternate years.
- 635. CONDUCTION IN PLASMA. 3 credits, 1st sem.**
 Prerequisite: EE 614. Topics discussed include Maxwellian velocity distribution function, concentration and diffusion gradients, mean free path, methods of ionization, field intensified ionization, drift velocity, plasma temperature methods of deionization, plasma oscillations and plasma sheath, spark breakdown and mechanism of arcs.
 Offered 1976-77 and 1979-80.
- 641. RELIABILITY IN ELECTRONICS. 3 credits, 1st sem.**
 This course deals with the study of factors causing instability and reliability failure in electronic equipment and components. Particularly, study is made of problems in dielectrics, including distribution of potentials and electric fields. Transistors are studied from the point of view of beta stability and leakage current problems, including conditions prevailing under different reverse bias conditions. Effects of problems caused by switching time and recombination velocities in solid state are considered. For electron tubes cathodic failure mechanisms are studied, together with the effect of emission current densities on life. Problems of current interest to the members of the class will be investigated. Throughout this course, emphasis is placed on engineering approach, but basic statistics required for sampling are also covered. Different types of accelerated life testing problems and physical principles underlying these are critically studied.
- 642. COMMUNICATION SYSTEMS I. 3 credits, 1st sem.**
 This course covers the fundamental principles of modulation theory and modulation systems which are used in the design of CW communication systems. Modulation systems are discussed from the point of view of bandwidth occupancy, threshold effects, signal-to-noise ratio, distortion, interchannel crosstalk, and other parameters.
- 645. FEEDBACK AMPLIFIERS I. 3 credits, 1st sem.**
 Prerequisite: EE 540 or equivalent. This course deals with the analysis and design of electronic feedback systems. Topics include flow graphs, Mason's gain formula, return ratio, return difference, fractionated gain formula, asymptotic gain formula, null return ratio, Blackman's impedance relation, and generalized Blackman's impedance relation. Series-series, series-shunt, shunt-series, shunt-shunt, and bridge feedback, balanced and unbalanced, are studied, typical BJT and FET configurations are analyzed. Effects of feedback on gain sensitivity, ripple transmission, and S/N ratio are studied. High-frequency BJT and FET models are studied; high-frequency response is obtained by unilateralization, stage separation, and computer methods. Analysis "directly from the circuit" is stressed.
 Offered 1976-77 and alternate years.
- 648. WAVE SHAPE CONTROL. 3 credits, 2 sem.**
 Prerequisite: Undergraduate semiconductor circuits. Analysis of non-sinusoidal voltage waves and pulses and methods of producing them; the effects on wave forms of linear, non-linear, unilateral, bilateral, single and multivariable circuit elements are examined, together with the selection and comparison of waves and pulses in respect to amplitude, frequency or phase, and time; and the procedure for performing the common mathematical operations on wave forms and results therefrom are included.
- 650. TRANSISTOR CIRCUITS. 3 credits, 1st sem.**
 Prerequisite: Undergraduate semiconductor circuits. Topics included are low frequency parameters and models, bias considerations, low frequency applications, high frequency parameters and models, high frequency applications, oscillators, and switching circuit applications.

- EE 652. NETWORK THEORY I. 3 credits, 1st sem.**
 Topics included from network analysis are linear graph theory, matrices of directed graphs and their properties, and network equations in matrix form. One-port, two-port, and multi-port network functions are found, including topological formulas and scattering parameters. State equations and the properties of network functions as functions of complex variables are studied. Topics from network synthesis include the properties of positive real functions and the synthesis of LC and RC networks.
- 657. SEMICONDUCTOR DEVICES. 3 credits, 1st sem.**
 Following study of the theory of PN junctions and metal semiconductor contacts, the static and dynamic characteristics of MOS transistors, power and switching bipolar transistors, and diodes, including Shottky-barrier, IMPATT, and tunnel, are examined in detail. Optoelectric devices, particularly electroluminescent diodes, photodetectors, and solar cells, are studied, as well as special microwave and switching PNP devices.
 Offered 1976-77 and alternate years.
- 658. INTEGRATED CIRCUITS I. 3 credits, 1st sem.**
 Prerequisite: Undergraduate semiconductor circuits. Following an introduction to integrated-circuit manufacture, layout design, and processing technologies, the following topics are covered: design and characteristics of basic linear I.C. circuits and operational amplifiers, thermal effects and electrothermal circuit models, linear applications of operational amplifiers, and the design and application of TTL, ECL, MTL, and MOS digital circuits.
 Offered 1977-78 and alternate years.
- 661. CONTROL SYSTEM COMPONENTS. 3 credits, 2nd sem.**
 Prerequisite: EE 563. The steady-state and transient characteristics of commonly used magnetic components such as servomotors, rate generators, synchros, eddy-current and inertia dampers, polarized torque motors, hysteresis clutches and particle clutches are covered. Emphasis is placed on problems affecting the performance of the complete system.
 Offered 1977-78 and alternate years.
- 662. LARGE POWER CONTROL SYSTEMS. 3 credits, 2nd sem.**
 Prerequisites: EE 563, 614 or equivalents. The emphasis in this course is on the design and test analysis of servomechanisms and regulation systems involving large power components such as d-c machines, induction motors, and alternators. Positioning and velocity servos using rotating amplifiers are covered. A velocity servo for controlling a large induction motor is designed, and a typical alternator voltage regulator studied with regard to its servo characteristics. Methods of determining motor size and gear ratio in large positioning servos are covered.
 Offered 1976-77 and alternate years.
- 663. CONTROL SYSTEM LABORATORY. 3 credits, 2nd sem.**
 Prerequisite: EE 563 or equivalent. A laboratory course in the practice and principles of control system design and evaluation. Use of components, techniques of testing and system synthesis. Nonlinearities and other realistic constraints are emphasized.
 Laboratory fee: \$15.00.
 Offered 1976-77 and alternate years.
- 664. DISCRETE SYSTEMS. 3 credits, 1st sem.**
 Prerequisite: EE 601. The fundamental aspects of discrete systems, including state-variable representation, Z-transform and advanced Z-transform representation, are introduced and applied to the analysis and synthesis of sampled-data control systems. Discussions of pulse modulation, sampling, predictors, and computer-control systems are included. Stability of discrete systems and design for both deterministic and stochastic signals are studied.
 Offered 1976-77 and alternate years.
- 667. SYSTEMS STUDIES IN BIOENGINEERING. 3 credits, 2nd sem.**
 Prerequisites: Knowledge of at least one problem-oriented digital computer language and EE 550 or an undergraduate or graduate course on linear

system theory. Basic techniques of simulation are first discussed including digital simulation languages such as CSMP. Two physiologic systems of current interest are next examined in depth using linear systems analysis, leading to the formulation of mathematical, digital computer or electric circuit models. Systems to be examined include the circulatory, respiratory or hormonal control systems.

Offered 1976-77 and alternate years.

EE673. RANDOM SIGNAL ANALYSIS I. 3 credits, 1st sem.

This course is an introduction to random processes. Principles which apply to statistical characterization of measured environmental parameters, electrical signal correlation and spectral analysis, detection of signals in noise and optimum filtering are covered.

Offered 1976-77 and alternate years.

674. NOISE IN ELECTRICAL CIRCUITS. 3 credits, 2nd sem.

The common types of noise classified as to origin and characteristics; methods of analytical evaluation and procedures for measurement; effects on amplifier sensitivity; design of minimal noise circuits are topics studied in detail.

675. SYNTHESIS OF DIGITAL CONTROL CIRCUITS. 3 credits, 2nd sem.

Prerequisite: Undergraduate course in digital circuits. Advanced design techniques for combinational circuits including multi-output circuits, symmetry, functional decomposition, linear separability, threshold logic, sequential circuit synthesis including the Mealy and Moore models, counters, registers, iterative circuits, and sequential coding.

677. OPTIMIZATION TECHNIQUES. 3 credits, 1st sem.

Prerequisite: Differential equations. Several analytical and numerical methods for finding an extremum are presented with emphasis on how and when to apply them. Classical differentiation, Lagrange multipliers, the calculus of variations, penalty functions, slack variables, search techniques, and stochastic approximation are covered.

Offered 1977-78 and alternate years.

680. ANALOG AND ANALOG/HYBRID COMPUTER TECHNIQUES. 3 credits, 1st sem.

Prerequisites: EE-575, EE-580 or undergraduate course in analog computation and digital logic circuits. This course provides the student with the concepts and programming techniques of analog and hybrid computation and simulation. Topics include: solution of linear, adjoint, and nonlinear differential equation, generation of explicit, implicit and bivariable functions; advanced transfer function simulation, and optimization techniques using logic controlled iterative analog/hybrid computers. Laboratory demonstrations are included.

681. DIGITAL COMPUTER METHODS IN E.E. 3 credits, 2nd sem.

Prerequisite: EE 550 or equivalent. This course is an introduction to numerical analysis methods in electrical engineering. Topics include polynomial root-finding, numerical integration, matrix manipulations, Monte Carlo methods, and solutions of differential equations. Applications are made to the calculation of network time response from frequency response, active filter design, voltage-divider design, and transient response of non-linear networks.

682. COMPUTER-AIDED NETWORK DESIGN. 3 credits, 2nd sem.

Prerequisites: EE 601 or equivalent. Computational algorithms which underlie some basic digital-computer network-analysis programs are studied. Topics include a review of network topology, matrices, Branin's link-at-a-time algorithm, and state-variable methods. Problems of integration, eigenvalue calculation, and sparse matrix techniques are also considered.

Offered 1976-77 and alternate years.

700. MASTER'S PROJECT. 3 credits, 1st or 2nd sem.

Prerequisite: Written approval of project adviser. An extensive paper involving design, construction and analysis, or theoretical investigation, will be required of all candidates for the Master's degree who do not take EE 701,

Master's Thesis. With the approval of his project adviser, a student may register for 1 1/2 credits in each of two successive semesters. Further information may be obtained from the department adviser. If the use of laboratory facilities or equipment is necessary, a \$25.00 deposit must be maintained.

- EE 701. MASTER'S THESIS. 6 credits, 1st or 2nd sem.**
Prerequisite: Written approval of thesis adviser. Projects involving design, construction, experimental or theoretical investigation may be approved by the graduate adviser as the basis for a thesis. Approved cooperative projects with industry or governmental agencies may be acceptable. The work is carried on under the supervision of a designated member of the department staff. The completed work in the form of a written thesis should be of sufficient merit to warrant publication in a technical journal. *With the permission of the department, preparation for thesis may be scheduled over one to four consecutive terms. A student must register for a minimum of 3 credits per semester. Credit will be limited, however, to the 6 credits indicated for the thesis.*
If the use of laboratory facilities or equipment is necessary, a \$25.00 deposit must be maintained.
- 710. ECONOMIC CONTROL OF INTERCONNECTED SYSTEMS. 3 credits, 2nd sem.**
Prerequisite: EE 610. Theoretical developments and computer methods in determining economic operation within the boundaries of a given steam-electric operating area. Energy accounting control, and economic theories for interconnected steam and hydro-electric power systems with emphasis on digital computers.
Offered 1977-78 and 1980-81
- 711. STABILITY THEORY OF ELECTRIC POWER SYSTEMS. 3 credits, 2nd sem.**
Prerequisites: EE 610, 615. This course covers the elements of the stability problem, the principal factors affecting stability, the ordinary simplified methods of making stability calculations, and illustrations of the application of these methods to studies of power systems. It also deals with synchronous machines, excitation systems, damping, and saturation.
Offered 1978-79 and 1981-82.
- 712. MAGNETOHYDRODYNAMIC POWER GENERATION. 3 credits, 2nd sem.**
Prerequisite: EE 635. Topics include magnetohydrodynamic equations, similarity parameters, MHD generator geometrics, seeding and ionization in MHD generators, conversion efficiencies of MHD generators, and power generation systems.
Offered 1976-77 and 1979-80.
- 719. ADVANCED ELECTROMECHANICAL ENERGY CONVERSION II. 3 credits, 2nd sem.**
Prerequisites: EE 615, 622. Derivation of circuit models of rotating systems based on the cross-sectional space wave method and the study of generalized Maxwell-Lorentz equations applied to coupled rotational bodies.
Offered 1978-79 and 1981-82.
- 730. THEORY OF GUIDED WAVES. 3 credits, 1st sem.**
Prerequisite: EE 622. This course deals with mathematical analysis of uniform waveguides, resonant cavities, coupling devices and waveguides filled with isotropic dielectric media. Transmission line formulation of field problems and of associated impedance scattering concepts using eigenfunctions, integral equations and variation techniques are covered.
Offered 1976-77 and alternate years.
- 735. QUANTUM ELECTRONICS. 3 credits, 1st sem.**
Prerequisites: Phys 633 or equivalent. After reviewing the modern physics background needed for the understanding of quantum electronics, the course investigates conduction phenomena, junction properties and selected devices. Included are: band theory of solids, semiconductors in

and out of equilibrium, PN junctions, transistors, FET, tunnel devices, lasers.

Offered 1977-78 and alternate years.

EE 736.

INTRODUCTION TO QUANTUM FIELD THEORY. 3 credits, 2nd sem.

Prerequisites: EE 622, Phys 633. This course is a review of theory of special relativity, four-dimensional formulation of electrodynamics, quantum theory of electromagnetic fields, second quantization and interaction of radiation and discrete energy level systems.

Offered 1977-78 and alternate years.

739.

LASERS AND MASERS. 3 credits, 2nd sem.

Prerequisite: EE 735. This course covers selected topics in maser design, modulation, and applications. Included are population inversions methods, maser states in ammonia and the ammonia maser, maser levels in parameters, 3-level solid and gas masers, noise, and degrees of coherence. Offered 1977-78 and alternate years.

742.

COMMUNICATION SYSTEMS II. 3 credits, 2nd sem.

Prerequisite: EE 642. This course is a continuation of EE 642, covering advanced topics which include threshold in F.M. and threshold extension techniques, sampling, pulse amplitude modulation.

Offered 1977-78 and 1980-81.

744.

COMMUNICATIONS SYSTEMS DESIGN. 3 credits, 2nd sem.

Prerequisite: EE 642. This course covers the design of point-to-point and multiloop microwave communication systems with multiplexed basebands. Topics include statistics of channel utilization, multi-channel peak factor, S/N and noise-power ratios above and below the F.M. threshold F.M. and baseband distortion, propagation losses and phenomena in a real environment, antennas and passive reflectors, noise sources and effective temperatures, fading, and diversity.

Offered 1976-77 and 1979-80.

745.

FEEDBACK AMPLIFIERS II. 3 credits, 2nd sem.

Prerequisite: EE 645. This course studies the stability problem in detail, including Routh's test, root-locus methods, and the Nyquist criterion. Topics include Hilbert transforms, phase area theorem, gain slope theorem, relation of phase to gain, use of Thomas Tables, excess phase, Bode's ideal loop gain characteristic, relation of frequency characteristic to phase margin for ideal characteristic, relation of step response to phase margin for ideal characteristic, approximation of ideal characteristic and compensation with computer-aided circuit analysis.

Offered 1976-77 and alternate years.

748.

SEMINAR ON RELIABILITY PROBLEMS. 3 credits, 2nd sem.

Prerequisite: EE 641 or equivalent. A detailed study of active elements is made in terms of stability of different parameters as a function of stress levels and time. Applications of reliability principles to the study of circuits and systems is undertaken, including the role of localized and overall feedback systems and dependence on components. Problems of current interest to members of the class will be investigated.

Offered 1977-78 and alternate years.

749.

SEMINAR IN COMMUNICATION SYSTEMS. 3 credits, 2nd sem.

Prerequisite: EE 642. The course deals with selected topics in advanced communication systems theory and design. Current literature is reviewed. Emphasis is given to current research areas and to specialized topics as determined by the interests of the students.

Offered 1976-77 and 1979-80.

752.

NETWORK THEORY II. 3 credits, 2nd sem.

Prerequisite: EE 652. Included are general methods of classical passive network synthesis and selected topics from active network synthesis. Also included are the use of controlled sources, negative immittance converters and operational amplifiers as network elements, selected synthesis procedures using these elements, sensitivity functions and stability, and active realizations of low-pass, high-pass, band-pass, band-stop and all-pass

- networks.
Offered 1977-78 and alternate years.
- EE 753. ELECTRIC FILTER DESIGN. 3 credits, 1st sem.**
Prerequisite: EE 652. The course deals with the theory and design of reactance filters composed of inductors, capacitors, crystals and/or coaxial lines. Filter theory based on lattice networks; ladder structures; impedance transformations; effect of dissipation; charts and tables as aids in computing response. Darlington's insertion loss theory is applied to filter design. Computer aided design considerations are included.
Offered 1976-77 and alternate years.
- 755. DIGITAL COMMUNICATION. 3 credits, 2nd sem.**
Prerequisite: EE 642 or equivalent. The course deals with the theory and practice of digital communication. Topics included are representation of information in digital forms; statistics of digital signals; frequency analysis of digital signals; effects of restricted bandwidth; Nyquist's criteria; baseband systems; multilevel signaling, methods of establishing a reference; methods of synchronization; and equalization.
Offered 1978-79 and 1981-82.
- 758. INTEGRATED CIRCUITS II. 3 credits, 2nd sem.**
Prerequisite: EE 658. Topics include design and application of semiconductor bipolar and MOS memories, digital applications of operational amplifiers, charge-coupled devices and magnetic-bubble circuits and systems, and subjects of current interest in integrated circuits.
Offered 1977-78 and alternate years.
- 759. PRINCIPLES OF PHASE LOCK AND FREQUENCY FEEDBACK. 3 credits, 1st sem.**
Prerequisite: EE 642. This course presents the principles of operation and design for the phase locked and frequency feedback loops. The linear equivalent circuit, nonlinear effects and optimization against noise are covered. The principles are used in a wide range of applications including low-level signal reception, tracking, phase extraction, filtering, and frequency synchronization. FM communication is emphasized.
Offered 1978-79 and 1981-82.
- 765. INTRODUCTION TO NONLINEAR SYSTEMS. 3 credits, 1st sem.**
Prerequisite: EE 563 or EE 601. This course includes a review of fundamental aspects of differential equations and their state-variable representation; introduction to concepts of stability; state-plane methods, and small-signal linearization. Concepts of equivalent gain, the describing function and dual-input describing function are introduced in a fundamental way that permits their application to a large class of nonlinear systems. Linear and nonlinear compensation and design, large-signal testing and stabilization of complex nonlinear systems; and relay control systems are covered.
Offered 1977-78 and alternate years.
- 766. STABILITY THEORY OF NONLINEAR SYSTEMS. 3 credits, 2nd sem.**
Prerequisite: EE 601 or EE 765. Introduction of concepts of stability in dynamic systems; theory and application of Lyapunov's direct method; practical consideration in engineering systems; introduction and applications of functional analysis; and the frequency response method of Popov and its extension to the investigation of stability, boundedness and damping in a class of unforced and forced nonlinear systems are included.
Offered 1977-78 and alternate years.
- 768. OPTIMAL CONTROL THEORY. 3 credits, 1st sem.**
Prerequisites: EE 601 and 677, or equivalents. Optimal control for classes of deterministic systems with various constraints is studied. Techniques used include calculus of variations, dynamic programming, and the maximum principle. State variable constraints are discussed. Applications of theory to design problems are covered.
Offered 1976-77 and alternate years.

- EE 769. STOCHASTIC ESTIMATION AND CONTROL. 3 credits, 2nd sem.**
Prerequisite: EE 673. Classical steady-state statistical design in the Wiener sense of continuous and discrete systems; Kalman-type filters used in estimation and identification as applied to communication and control, and introduction to adaptive and learning systems.
Offered 1976-77 and alternate years.
- 773. RANDOM SIGNAL ANALYSIS II. 3 credits, 2nd sem.**
Prerequisite: EE 673. This course is a continuation of EE 673 and deals with more advanced topics. Included are nonstationary stochastic processes, harmonic analysis, the zero crossing problem. Markoff processes, the Poisson process, orthogonal expansions, non-Gaussian processes, nonlinear operations.
Offered 1978-77 and 1981-82.
- 776. INFORMATION THEORY. 3 credits, 2nd sem.**
Prerequisite: EE 673 or EE 642 or Math 577. This course deals with the classical theory of information as developed from Shannon's theory. Topics include information measure, Markov sources and extensions, the adjoint source, uniquely decodeable and instantaneous codes and their construction, Shannon's first and second theorems, mutual information, and performance bounds on block and convolutional codes.
Offered 1977-78 and 1980-81.
- 777. STATISTICAL DECISION THEORY IN COMMUNICATIONS. 3 credits, 1st sem.**
Prerequisite: EE 673 or equivalent. Review of detection, estimation and modulation theory; hypothesis testing problem; Bayes decision criteria, minimax and $pr(\cdot)$ tests; Neyman-Pearson tests; receiver operating characteristics; M-hypothesis, model; Baynes estimation; non-random parameter estimation; bounds; Cramer-Rao inequality; the general Gaussian problem; covariance matrices; performance bounds and approximations are topics covered.
Offered 1976-77 and 1979-80.
- 778. ALGEBRAIC CODING FOR INFORMATION TRANSMISSION. 3 credits, 1st sem.**
Prerequisite: EE 673 or EE 642 or Math 577. This course deals with the application of coding to error detection and error correction in communication systems, including encoding and decoding of major block and convolutional codes. Topics include a review of linear algebra, linear block codes, cyclic codes, BCH and other random and burst correcting block codes, convolutional codes and their distance properties, and convolutional decoding including sequential and Viterbi decoders.
Offered 1977-78 and 1980-81.
- 788. SELECTED TOPICS IN ELECTRICAL ENGINEERING. 3 credits, 1st sem.**
Prerequisites: EE 601, Math 658, and departmental approval. This special area course will be given when suitable interest develops. Advance notice of forthcoming topics will be announced.
- 789. SELECTED TOPICS IN ELECTRICAL ENGINEERING. 3 credits, 2nd sem.**
See prerequisites and description for EE 788, above.
- 790. DOCTORAL DISSERTATION AND RESEARCH. Credits as designated, 1st or 2nd sem.**
Corequisite: EE 791. Required of all candidates for the degree of Doctor of Engineering Science in the Department of Electrical Engineering. A minimum of 36 credits is required. The student must register for at least 6 credits of dissertation per semester; registration for additional credits may be permitted beyond the six, with the approval of the adviser, up to a maximum of 12 credits per semester. Candidates registering for EE 790 must register concurrently for EE 791 unless requirement is waived, in writing, by dissertation adviser. If use of laboratory facilities or equipment is necessary, a laboratory deposit of \$25.00 per semester must be maintained, or such additional amounts as may be necessary to provide laboratory facilities and equipment.

EE 791. DOCTORAL SEMINAR. No credit, 1st or 2nd sem.

A seminar in which faculty, students, and others will present summaries of advanced topics suitable for research. In the course students and faculty will discuss research procedures, dissertation organization, and content. Research students will present their own problems and research progress for discussion and criticism. *Required of all doctoral candidates registered for EE 790 and EE 792 unless requirement is waived, in writing, by dissertation adviser. Open to all doctoral students and students registered for EE 701.*

Seminar Fee: \$35.00 per semester.

792. PRE-DOCTORAL RESEARCH. 3 credits per semester, 1st or 2nd sem.

Prerequisite: Permission of the department. Corequisite: EE 791. Permitted for students admitted to the program leading to the degree of Doctor of Engineering Science in Electrical Engineering. Research carried on under the supervision of a designated member of the department faculty. If the student's research activity culminates in a doctoral research in the same area, up to a maximum of 9 credits may be applied toward the 36 credits required under EE 790 after the student fulfills requirements of doctoral candidacy. Candidates registering for EE 792 must register concurrently for EE 791 unless requirement is waived, in writing, by thesis adviser.

793. PROFESSIONAL PROJECT. Credits as designated, 1st or 2nd sem.

Required of all candidates for the degree of Electrical Engineer. A minimum total of 12 credits is required. The student must register for at least 6 credits of professional project per semester until completion of 12 credits. If the student is still actively engaged in the preparation of the project after completion of 12 credits, continued registration of three credits per semester will be required. Registration for 3 credits is permitted during the summer session.

Hours to be arranged.

If use of laboratory facilities or equipment is necessary a laboratory deposit of \$50.00 must be maintained, or such additional amount as may be necessary to provide laboratory facilities and equipment.



Department of Industrial and Management Engineering

Graduate programs in the department of Industrial and Management Engineering are designed to prepare the student for a wide variety of career objectives. Each student's program is designed in cooperation with the student's adviser, and will lead to one of three degrees: Master of Science in Industrial Engineering, Master of Science in Management Engineering, or Master of Science.

In the case of the undesignated Master of Science Degree, a variety of cross-disciplinary programs can be designed in cooperation with other departments or schools.

GENERAL ADVISEMENT AND RECOMMENDATIONS

The degree *Master of Science in Industrial Engineering* is the recommended objective for the graduate of an industrial engineering curriculum or the holder of an equivalent engineering degree who wishes to further his formal education by specializing in an advanced phase of industrial engineering study or who wishes to prepare for a further advanced degree. Programs of specialization are available in decision theory, systems engineering, man-machine system, operational assurance, and human factors.

MASTER OF SCIENCE MANAGEMENT ENGINEERING

The degree *Master of Science in Management Engineering* is the recommended objective for the graduate of an engineering curriculum who desires to strengthen his formal education by following a second engineering program emphasizing quantitative management methodology.

MASTER OF SCIENCE

The degree *Master of Science* is the recommended objective for those whose careers are in, or moving toward, management in an engineering or scientifically oriented enterprise.

Application for entry into any of the above programs must be supported by evidence of high attainment in undergraduate studies, particularly in those area fundamental to the graduate courses making up the program of study.

As a minimum, each applicant must show satisfactory completion of approved courses in the areas of economics, industrial management, probability and statistics, accounting and cost accounting, and engineering economy. Deficiencies in these areas may require the student to take undergraduate courses or one or more of the following basic graduate course, which are to be completed before additional graduate courses may be taken:

- EM 501—Industrial Management
- EM 502—Engineering Cost Analysis
- EM 503—Methods and Applications of Industrial Statistics and Probability.

The three courses listed above may not be included in the thirty credits required for the master's degree for candidates majoring in the Industrial and Management Engineering Department.

The student's attention is called to the presence of certain required courses mandated by the different programs available. Thus a program of more than the minimum number of credits may be necessary, depending upon the student's thesis objectives and background preparation.

The elective courses may be chosen from the offerings of any department, and with prior approval of the graduate advisor from course offerings of the Graduate School of Business Administration or the Department of Economics of the Newark College of Arts and Science of Rutgers—the State University; or, in the case of health and safety engineering from course offerings of the New Jersey School of Medicine and Dentistry, as may be applicable to the student's specialization.

A student desiring to take courses at the above schools should acquaint himself with their registration procedures, as their scholastic calendar may not coincide with those of NJIT. Further information may be obtained from the Graduate Division.

Students preparing for registration for thesis must have obtained the consent of a prospective thesis advisor prior to registration for either IE 701 or EM 701.

A thesis is normally required of all candidates for the master's degree, with the exception that those students who select the undesignated master's program can substitute the satisfactory completion of the design project courses, EM 715 and EM 716, in lieu of the thesis.

Each student is required to prepare a program of studies for approval by the departmental graduate advisor at the time of entry into the program. Modifications of program may be made only with advisor approval.

MASTER OF SCIENCE IN INDUSTRIAL ENGINEERING

For the degree *Master of Science in Industrial Engineering*, four programs of specialization are available: Decision Theory, Systems Engineering, Man-Machine Systems, and Operational Assurance. Of the mandated eighteen credits of specialization, the following fifteen credits are required for the above areas:

- EM 609—Advanced Analytical Engineering Statistics (3)
- IE 621—Applications of Digital Computers in Industrial Engineering (3)
- IE 641—Operations Analysis of Systems (3)
- IE 701—Master's Thesis (6).

MASTER OF SCIENCE IN MANAGEMENT ENGINEERING

For the degree *Master of Science in Management Engineering*, seven programs of specialization are available: Engineering Management; Management Systems; Management of Research, Development and Design; Management of Manpower Policies and Employment Relations; Management of Public and Regulated Enterprises, Cost Engineering, Management of Health and Safety. Of the required eighteen credits of specialization for this degree, six must be for the Master's Thesis, EM 701. The remaining twelve credits of specialization may be selected from the following:

- EM 602—Management Science.
- EM 604—Analytical Engineering Statistics
- EM 613—Manufacturing Engineering
- EM 655—Management of Information Systems
- IE 603—Behavioral Science
- IE 607—Seminar in Contemporary Problems
- IE 669—Human Design Factors in Engineering

The twelve credit hours of elective studies completing the minimum program of study for this degree are then selected by the student in consultation with the graduate advisor.

For the degree *Master of Science*, candidates must include the following six course credits as part of the fifteen credits of specialization required for the degree:

- EM 701—Master's Thesis (6) or
- EM 715—Design of an Enterprise (3)
- EM 716—Seminar in the Design of an Enterprise (3)

The student may then set up a program over the broadest of options, working in conjunction with his department advisor and within the general academic requirements of the Graduate Division.

The following course groups are shown as option suggestions for students seeking guidance in setting up specialized programs within the undesignated Master of Science Degree.

For *Engineering Management*, choose at least nine credits from the following:

- | | |
|-----------------------------------------------------|--------------------------------------------------|
| EM 602— Management Science | OS 681— Personnel Problems |
| EM 660— Financing an Industrial Enterprise | OS 681— Personnel Management |
| EM 693— Managerial Economics | OS 692— Contemporary Collective Bargaining |
| EM 771— Industrial Costing and Management Control | OS 694— Industrial Relations and Public Planning |
| IE 603— Behavioral Science | |
| IE 607— Seminar in Contemporary Management Problems | |

For *Management Systems*, at least nine credits from the following:

CS 500— Introduction to Systems Analysis	EM 655— Management of Information Systems
CS 603— Operating System Design	IE 601— Measurement Methods for Management Systems
CS 631— Data Mgmt. Systems Design	IE 621— Applications of Digital Computers in I. E.
EM 602— Management Science	IE 641— Operations Analysis
EM 650— Introductory Operations Research	IE 661— Man and Machine Systems

For Management of Research, Design and Development, at least nine credits from the following:

EM 602— Management Science	IE 621— Applications of Digital Computers in I.E.
EM 604— Analytical Engineering Statistics	OS 661— Methods of Research in the Behavioral Sciences
EM 608— Product Liability Control	OS 683— Manpower Planning and Management Dev.
EM 635— Management of Engineering Research & Dev.	OS 683— Manpower Palnning and Management Dev.
IE 603— Behavioral Science	
IE 607— Seminar in Contemporary Management Problems	

For Management of Manpower Policies and Employment Relations, at least nine credits from the following:

EM 602— Management Science	OS 681— Personnel Management
IE 603— Behavioral Science	OS 683— Manpower Planning and Management Dev.
IE 607— Seminar in Contemporary Management Problems	OS 695— Industrial Relations and Public Planning
OS 661— Methods of Research in the Behavioral Sciences	

This program is presented in conjunction with the Department of Organizational and Social Sciences. Students choosing this option, who are working toward the undesignated M.S. degree, will design their programs under the supervision of an adviser from the Department of Organizational and Social Sciences. (See pp. 106-107 for further details.) If the thesis is chosen in an area served by that department, it will normally be done with a thesis advisor from that department.

For Management of Public and Regulated Enterprises, at least nine credits from the following:

EM 602— Management Science	OS 694— Industrial Relations and Public Planning
IE 603— Behavioral Science	SS 521— Urban Social Structure
IE 607— Seminar in Contemporary Management Problems	SS 603— Public Finance

This program is presented in conjunction with the Department of Organizational and Social Sciences. Students choosing this option, who are working toward the undesignated M.S. degree, will design their programs under the supervision of an adviser from the Department of Organizational and Social

Sciences (See pp. 106-107 for further details.) If the thesis is chosen in an area served by that department, it will normally be done with a thesis advisor from that department.

The program in *Cost Engineering* is presented for those engineers interested in specializing in that facet of engineering which is primarily concerned with the economic aspects and implementation of Engineering Design. Such activities include profitability analysis, planning, cost estimation, cost control, and project management.

Required Courses:

EM 701— Master's Thesis (6) plus 9 credits to be selected by the student in consultation with the Departmental advisor.

The remaining elective 15 credits may be taken from the suggested electives listed below from the graduate offerings of New Jersey Institute of Technology or the Newark College of Arts and Science of Rutgers, the State University.

Suggested Electives:

SS 602—	Cost-Benefit Analysis and Economic Decisions	CE 711—	Methods Improvement in Construction
SS 606—	Technology Forecasting	CS 631—	Data Mgmt. System Design
OS 611—	Psychology in Engineering	IE 621—	Applications of Digital Computers in I.E.
OS 692—	Contemporary Collective Bargaining	EM 660—	Financing an Industrial Enterprise
CE 610—	Construction Management	EM 693—	Managerial Economics
CE 611—	Project Planning and Control	EM 771—	Industrial Costing and Management Control
CE 710—	Systems in Building Constr.		

The program in *Health and Safety* is designed to educate the graduate for specialization in the field of health and safety management. His or her duties in this area are expected to include the monitoring of the design of proposed facilities to ensure their compliance with the law, evaluation of products and services for potential liabilities due to their use and correction of unhealthy or unsafe occupational conditions.

Required courses:

EM 633—	Legal Aspects of Health and Safety	IE 615—	Elements of Occupational Health
EM 701—	Master's Thesis		
IE 614—	Safety Engineering Methods		

plus 15 credits of elective courses from the suggested electives listed below, or from the graduate offerings of New Jersey Institute of Technology, the Newark College of Arts and Science of Rutgers—The State University, or the New Jersey School of Medicine and Dentistry that may be applicable to the student's specialization with the field of health and safety engineering.

Suggested electives:

Chem 651—Radio Isotopes Theory and Applications	EnE 667—	Solid Waste Disposal Systems
Chem 661—Instrumental Analysis	EnE 668—	Air Pollution Control
EM 602—Introduction to Management Science	CE 652—	Traffic Engineering
EM 604—Analytical Engineering Statistics	CE 655—	Traffic Safety
EM 605—Engineering Reliability	IE 603—	Behavioral Science
EM 606—Maintainability Engineering	IE 661—	Man-Machine Systems
EM 608—Product Liability Control	IE 669—	Human Design Factors in Engineering
EM 613—Manufacturing Engineering	ME 660—	Noise Control
EM 672—Industrial Quality Control	ME 661—	Thermal Pollution of Water and Air
EnE 660—Introduction to Solid Waste Problems	OS 611—	Psychology in Engineering
EnE 663—Pollution: Chemistry and Ecology	OS 661—	Methods of Research in the Behavioral Sciences
	OS681—	Personnel Management

COURSES OF INSTRUCTION IN INDUSTRIAL ENGINEERING

- IE 601. MEASUREMENT METHODS FOR MANAGEMENT SYSTEMS. 3 credits, 1st sem.**
Prerequisite: Undergraduate mathematics for management science or EM 602. A quantitative study of various analytical methods for designing and evaluating systems employed in the management of complex enterprises. Study covers decision-making, efficiency measurement and methods for obtaining optimal system performance.
Offered 1977-78 and alternate years.
- 603. BEHAVIORAL SCIENCE. 3 credits, 1st or 2nd sem.**
Prerequisite: Undergraduate probability and statistics or EM 503. A study of scientific research of human behavior in organizations. The course deals with the processes and problems of communication in organizations, line-staff and supervisor-surbordinate relationship and formal and informal organizations. The student investigates organization models and analyzes the technical and social structure of organizations.
- 607. SEMINAR IN CONTEMPORARY MANAGEMENT PROBLEMS. 3 credits, 1st sem.**
Prerequisites: Undergraduate courses in economics and management. Reading, discussions, field studies and reports in the areas of contemporary management, behavioral science, management science, ergonomics and systems planning and control. Course is designed to encourage and give direction to student research for the thesis.
- 614. SAFETY ENGINEERING METHODS. 3 credits, 1st sem.**
Prerequisites: Undergraduate statistics and industrial or construction management. The principles and practices of safety engineering. Principal topics considered are inspection and measurement procedures, various protective devices available and their utilization to meet statutory requirements.
Offered 1976-77 and alternate years.
- 615. ELEMENTS OF OCCUPATIONAL HEALTH. 3 credits, 2nd sem.**
Prerequisite: Undergraduate statistics. The course is intended to acquaint the student with the in-plant effect of noise, improper lighting, heat humidity on worker welfare and productivity. Acceptable standards and the methods

that can be employed to minimize worker hazards stemming from these causes are investigated.

Offered 1976-77 and alternate years.

IE621. APPLICATION OF DIGITAL COMPUTERS IN INDUSTRIAL ENGINEERING. 3 credits, 1st sem.

Prerequisites: Computer programming experience and EM 602. This course explores some of the applications of digital computers in the industrial engineering and managerial realm. Areas such as PERT, simulation, random number generation, linear programming, correlation and regression analysis, and decision theory are discussed and problems solved utilizing the digital computer. Other languages (COBOL, ALGOL, etc.) and their application to data processing are covered.

623. LINEAR PROGRAMMING. 3 credits, 1st sem.

Prerequisite: Introductory course in management science of EM 602. This course treats the principles, methodology, and practical applications of mathematical programming to complex problems in production and marketing, simplex technique, duality theory and parametric analysis. Emphasis is placed on problem formulation, the choice of criteria, and the evaluation of results within the framework of managerial restrictions. Included are representative problems in such areas as the allocation of plant facilities, personnel assignments, production scheduling, product mix, "make or buy," transportation, and distribution.

641. OPERATIONS ANALYSIS. 3 credits, 2nd sem.

Prerequisites: EM 602 and computer programming experience. A study of management systems. Analysis is made of business behavior through use of models representing the elements of an industrial enterprise. Special attention is given to the dynamics of interaction of the individual elements of the enterprise which make up the total system under study.

Offered 1977-78 and alternate years.

661. MAN-MACHINE SYSTEMS. 3 credits, 2nd sem.

Prerequisite: Statistics. An analysis of man-environment systems. Study is made of physical and psychological effects of system on deterministic and conditional responses of individuals and groups and the resulting interaction between individuals, groups and machine systems. The course surveys current research in the biological sciences as pertains to man-machine systems.

669. HUMAN DESIGN FACTORS IN ENGINEERING. 3 credits, 1st sem.

Prerequisite: Probability and statistics. A study of the methods and findings of human factors research related to product and equipment design and development, capabilities and limitations of the human sensory-motor system, and design of displays. The resulting interaction between individuals groups and machine systems is examined in terms of system acquisition management. The course surveys current research in the engineering fields as pertains to the man-machine interface.

Offered 1977-78 and alternate years.

701. MASTER'S THESIS. 6 credits. Department Faculty.

Prerequisite: Matriculation for the M.S. in Industrial Engineering, the thesis adviser's approval, and adequate graduate courses in the field of the proposed thesis. All candidates for the degree of Master of Science must submit an acceptable thesis on an approved subject. This thesis must be a desirable contribution to the literature of the field, and it should preferably be an aid to the candidate's efforts in his present position or toward a potential position. While original and novel research may not always result, the thesis should result in a new conclusion or application. Approval to register for the thesis must be obtained from the thesis adviser. *With the permission of the Department, preparation for the thesis may be scheduled over one to four consecutive terms. A student must register for a minimum of 3 credits per semester. Credit will be limited, however, to the 6 credits indicated for the thesis.*

If the use of laboratory facilities or equipment is necessary, a \$25.00 deposit must be maintained.

IE 705. MATHEMATICAL PROGRAMMING IN MANAGEMENT SCIENCE. 3 credits, 2nd sem.

Prerequisites: IE 623 and EM 650. An advanced study of various mathematical programming techniques—such as linear and non-linear, parametric, integer, stochastic and dynamic—in management systems. Readings and discussions emphasize the mathematical advances and applications in operations research.

Offered 1977-78 and alternate years.

COURSES OF INSTRUCTION IN MANAGEMENT ENGINEERING

EM 501. INDUSTRIAL MANAGEMENT. 3 credits, 1st or 2nd sem.

Credit granted only with major department approval. A course in the field of industrial management stressing the operational aspects of the management techniques. Included topics are organization, product design and development, distribution, logistics, marketing, plant location and layout, materials handling, production planning and control, inventory control, quality control, work analysis, and incentive plans.

502. ENGINEERING COST ANALYSIS. 3 credits, 1st or 2nd sem.

Credit granted only with major department approval. A course stressing the financial, engineering economy, and cost control aspects of industrial management. It treats the accounting cycle and introduces cost accounting procedures and cost model techniques of making cost comparisons through engineering economy studies as an approach to problems in industrial management.

503. METHODS AND APPLICATIONS OF INDUSTRIAL STATISTICS AND PROBABILITY. 3 credits, 1st or 2nd sem.

Credit granted only with major department approval. An analytical approach to basic engineering probability and statistics, with applications drawn from both manufacturing and process industries. Emphasis is placed upon the utility of statistical inference derived from engineering data.

602. MANAGEMENT SCIENCE. 3 credits, 1st or 2nd sem.

Prerequisites: Undergraduate calculus, and probability and statistics. A study of the mathematical theory and applications of analytical techniques in the operation of management systems. Specifically, the course discusses the mathematical basis of current analytical techniques in management science.

604. ANALYTICAL ENGINEERING STATISTICS. 3 credits, 1st sem.

Prerequisites: Undergraduate calculus and probability and statistics. A study of statistical methods of analysis of engineering and managerial data, aimed at augmenting a first course in statistics and probability. Coverage includes such areas as linear and non-linear regression and correlation, forecasting, analysis of variance and co-variance, Bayes theorem, non-parametric methods, and treatment of extreme and missing values. Applications in management decision making and industrial engineering are stressed.

605. ENGINEERING RELIABILITY. 3 credits, 1st sem.

Prerequisite: Statistics. A study of the fundamental concepts underlying modern reliability with application to practical industrial problems. This course will treat statistical concepts, reliability through design, reliability through testing, analysis of reliability data, and the organization and management of a reliability program.

Offered 1977-78 and alternate years.

- EM 606. MAINTAINABILITY ENGINEERING. 3 credits, 2nd sem.**
Prerequisite: Statistics. A study of the fundamental factors and parameters which affect maintainability design with applications to military and industrial problems. The subject matter considers applicable statistical concepts; maintainability prediction, allocation, and demonstration; availability, system and cost effectiveness; provisioning; optimal maintenance policies; and management of a maintainability program. Offered 1977-78 and alternate years.
- 608. PRODUCT LIABILITY CONTROL. 3 credits, 2nd sem.**
Prerequisite: Statistics. A presentation of the laws and engineering techniques applicable to minimizing product liability, quantitative cost analysis, the effect of legal doctrines on minimizing hazards of design and manufacture, and the use of actuarial techniques and legal precedents applicable to design, manufacturing, advertising and marketing problems. Some of the topics discussed are warranties, notices, disclaimers, definition of liability, use of expert witnesses, reliability prediction and analysis methods, safety engineering precepts and design review. When possible, an observance of an actual trial will be arranged. A review of government regulations for safety and protection will be continuous.
- 609. ADVANCED ANALYTICAL ENGINEERING STATISTICS. 3 credits, 2nd sem.**
Prerequisite: EM 604. An extension of the techniques of engineering statistical analysis to industrial applications. Emphasis is placed on the design and analysis of tests for multivariate level problems. Offered 1976-77 and alternate years.
- 613. MANUFACTURING ENGINEERING. 3 credits, 1st sem.**
Prerequisites: Undergraduate production process design and engineering cost analysis. This course deals with establishing and maintaining production processes, and with estimating product processing costs. Specific areas studied include stages of processing, equipment determination and justification, the relationship of plant layout, tooling, metrology, and product design to product cost, and the methods of total cost determination for new products.
- 616. PLANNING AND CONTROL OF PRODUCTS AND PROCESSES. 3 credits, 1st sem.**
Prerequisite: Undergraduate economics, accounting, engineering economy, and probability and statistics. A study of the principles and procedures used by job order, continuous and batch types of industries in forecasting, planning, and controlling production goods. Emphasis is placed on the organization of the control group and the development of control criteria. Among the topics discussed are: sales forecasting, product and process analysis including procurement, inventory management and control, tool control, routing, scheduling and dispatching. Also treated are control mechanisms and systems.
- 631. LEGAL ASPECTS IN ENVIRONMENTAL ENGINEERING. 3 credits, 1st sem.**
A study of the power of the federal, state, local governments and international law in pollution control of air, water and solid wastes. The preparation of environmental impact statements and the right of private citizens to bring suit under the Clean Air Act of 1970 and the Federal Water Pollution Act of 1972 are discussed as well as limitations on these rights. Offered 1977-78 and alternate years.
- 632. LEGAL ASPECTS IN CONSTRUCTION. 3 credits, 1st sem.**
An introduction to the legal factors affecting construction activities. Among the major topics covered are contract responsibilities of contractor, engineer and owner; subcontracts and third party liability; construction law and code compliance; and insurance and bonds.

- EM 633. LEGAL ASPECTS OF HEALTH AND SAFETY. 3 credits, 2nd sem.**
A discussion of the laws and regulations pertaining to occupational health, safety and product liability. The student is shown how to determine these codes and write operating procedures to be used for internal compliance. Offered 1977-78 and alternate years.
- 635. MANAGEMENT OF ENGINEERING RESEARCH AND DEVELOPMENT. 3 credits, 2nd sem.**
Prerequisites: Principles of management and statistics, or EM 501 and 503. A systems approach to the total management process for research development and engineering resources and tasks. Includes identification, analysis and evaluation of the operational characteristics and structure of the research laboratory and engineering office. The functions of planning, organizing, staffing, direction, control, innovation and representation form the framework for investigation. Emphasis is placed upon planning and control theories, techniques and current practices in scientific and engineering management.
- 640. DISTRIBUTION LOGISTICS. 3 credits, 2nd sem.**
Prerequisite: EM 602. A study of distribution logistics, with emphasis on systems engineering techniques and the application to the problem of optimizing corporate profit and customer service objectives. The areas covered include transportation modes, inventory policies, warehousing and order processing. These areas, when optimized, will result in the best logistics gross margin for the company. Offered 1977-78 and alternate years.
- 650. OPERATIONS RESEARCH. 3 credits, 2nd sem.**
Prerequisite: Introductory course in management science or EM 602. This course treats the foundations, methodology and applications of operations research. Topics included are: statistical techniques, stochastic processes, waiting line theory, linear and nonlinear programming, theory of games, cybernetics, information theory, and symbolic logic. The practical limitations and the criteria of effectiveness for the several techniques are stressed.
- 655. MANAGEMENT ASPECTS OF INFORMATION SYST. 3 credits, 2nd sem.**
Prerequisite: Computer programming experience. This course treats information flow in an organization as an integrated system and managerial resource. Various techniques of data analysis, design, and processing are reviewed from the point of view of management requirements and the related characteristics of computerized information handling equipment. Problems of data acquisition, storage, processing, retrieval, and transmission to decision-makers are discussed. Some of the application areas investigated include: information systems for finance, production, inventory, accounting, marketing and distribution.
- 660. FINANCING AN INDUSTRIAL ENTERPRISE. 3 credits, 1st or 2nd sem.**
Prerequisites: Undergraduate economics, accounting, and engineering economy. The principles underlying the financial practices and management of the modern business corporation are covered. This course emphasizes the alternative sources of funds available, including permanent and working capital needs, internal and external financing, and the role of budgets in financial planning and control. It concentrates on the function of finance as a major aspect of the management process.
- 672. INDUSTRIAL QUALITY CONTROL. 3 credits, 1st sem.**
Prerequisite: Statistics. The management of quality assurance, development and treatment of the operational and statistical principles of acceptance sampling and process control, and quality problems in automated production lines are covered. Offered 1977-78 and alternate years.
- 693. MANAGERIAL ECONOMICS. 3 credits, 1st sem. Wolf.**
Prerequisites: Undergraduate economics and accounting or EM 502. This course analyzes the internal and external influences on the economic practices of business. It introduces the student to classical and current theories

concerning the economic behavior of the firm and to contemporary analytical techniques. The course aims at providing an understanding, from an economic point of view, of the behavior of costs, prices, and profits. Among the topics treated are: demand analysis, competition and monopoly, capital expenditure planning, profit theories, and business cycles, as well as the econometric models pertaining to the analysis of market strategies, competitive action, and demand behavior.

EM 701. MASTER'S DESIGN THESIS. 6 credits. Department Faculty.

Prerequisite: Matriculation for the M.S., adequate graduate courses in the field of the proposed thesis, and the thesis adviser's approval. All candidates for the degree of Master of Science must submit an acceptable thesis on an approved subject. This thesis must be a desirable contribution to the field, and it should preferably be an aid to the candidate's efforts in his present position or toward a potential position. While an original and novel design may not always result, the thesis should result in a new conclusion or application. *With the permission of the Department, preparation for the thesis may be scheduled over one to four consecutive terms. A student must register for a minimum of 3 credits per semester. Credit will be limited, however, to the 6 credits indicated for the thesis.* If the use of laboratory facilities or equipment is necessary, a \$25.00 deposit must be maintained.

715. DESIGN OF AN ENTERPRISE. 3 credits, 1st or 2nd sem.

Prerequisites: Undergraduate economics, industrial management, accounting, engineering economy, and probability and statistics, nine credits of EM courses of level 600 or above plus matriculation and adviser's approval. This course deals with organization and management of enterprises from initial planning through production and distribution of manufactured products. Each student will prepare a study for an industry of his choice.

716. SEMINAR IN THE DESIGN OF AN ENTERPRISE. 3 credits, 1st or 2nd sem.

Prerequisite: EM 715. Each student will select an enterprise on the basis of the industry investigated in EM 715. The complete report of the design of the particular enterprise will be prepared and reported in seminar emphasizing, according to the student's interest, the management of research and development, the management of production, the management of distribution, or the management of manpower.

771. OPERATIONS COST AND MANAGEMENT CONTROL. 3 credits, 2nd sem.

Prerequisites: Six credits of EM courses of 600 level or above. The analysis and control of cost and other operational aspects of enterprises. Included are manufacturing, distribution and overhead budgets, cost accounting, management-information systems, relevant behavioral factors, financial and other management reports. Case studies will be utilized to apply and evaluate the control methods discussed.

Department of Mathematics

MASTER OF SCIENCE PROGRAM IN APPLIED MATHEMATICS

The program leading to a Master's degree in Applied Mathematics is intended for students whose interests lie in Applied Mathematics and its interdisciplinary aspects. It is expected that those applying for admission to this program will have undergraduate training in mathematics, engineering, computer science, or the physical sciences.

The emphasis of the program is on the applications of advanced mathematics appropriate to disciplines, research, and further graduate study. Each student will plan an approved

course of study based on a set of required courses and electives; the whole designed to develop a comprehensive foundation in Applied Mathematics.

Degree Requirements

Candidates for the Master of Science degree in Applied Mathematics are required to complete at least 30 credits of approved graduate work including a three-credit Master's Project or a six-credit Master's Thesis. All students are required to complete successfully the following program:

1. Math 545 and Math 546.
or
Math 551 and Math 652.
2. Math 656.
3. Fifteen credits of approved specialization courses, including no more than three credits in courses numbered 500 to 599.
4. Six credits of approved related electives, normally outside the students major area.
5. Math 700 or Math 701.

The Master's Project or Thesis credits are part of the fifteen credits of approved specialization courses.

COURSES OF INSTRUCTION

Math 511. NUMERICAL METHODS. 3 credits, 1st sem.

Prerequisites: Calculus, differential equations, and knowledge of at least one procedure oriented computer language such as Fortran. This course is designed to familiarize students with theory and techniques of numerical methods applicable to problems in the field of engineering and the physical sciences. Attention is given to algorithms suitable for digital computer application. Topics include errors in numerical calculation; numerical approximation in interpolation, differentiation and integration; discussion of iteration and convergence; least squares and other types of approximation; roots of algebraic and transcendental equations; and the solution of ordinary differential equations.

545. ADVANCED CALCULUS I. 3 credits, 1st sem.

Prerequisite: Undergraduate differential and integral calculus. This course deals with the topics of advanced calculus such as the number system, functions, continuity, differentiability, the Riemann Integral, sequences, series, and uniform convergence.

546. ADVANCED CALCULUS II. 3 credits, 2nd sem.

Prerequisite: Math 545 or equivalent. This course is a continuation of Math 545 and considers such topics as partial differentiation, transformations, implicit function theorem. Multiple integrals, and line and surface integrals.

551. APPLIED MATHEMATICS I. 3 credits, 1st sem.

Prerequisites: Undergraduate differential equations and physics. Mathematical methods useful in the analysis of engineering problems are considered. The course covers selected topics from the following: Integral theorems of Green, Stokes, and Gauss, infinite series, integral transforms, special functions.

573. DIFFERENTIAL EQUATIONS I. 3 credits, 1st or 2nd sem.

Prerequisite: Undergraduate differential equations. Advanced topics in ordinary differential equations with applications to engineering problems.

- Math 574. DIFFERENTIAL EQUATIONS II. 3 credits, 2nd sem.**
Prerequisite: A course in differential equations. The course studies boundary value problems arising from partial differential equations of engineering and science. The mathematical methods include separation of variables, Fourier series, Green's functions, and a study of special functions including Bessel functions and Legendre polynomials.
Offered 1975-76 and alternate years.
- 577. STOCHASTIC PROCESSES. 3 credits, 1st sem.**
Prerequisite: Undergraduate differential equations. The course begins with the development of basic probability concepts of discrete and continuous random variables. Gaussian processes, correlation functions and power spectra are introduced. Applications include the response of linear communication systems to random input signals.
Offered 1976-77 and alternate years.
- 630. MATRIX THEORY. 3 credits, 1st or 2nd sem.**
Prerequisites: Undergraduate calculus. The course involves the development of mathematical concepts requisite for study of the applications of matrix theory to engineering. Topics considered include matrix inversion, linear dependence, characteristic roots, and vector spaces.
- 634. ABSTRACT ALGEBRA. 3 credits 2nd sem.**
Prerequisite: Undergraduate course in linear algebra or permission of department. The course is an introduction to the theory of groups, rings, and fields. Topics which are usually emphasized include permutation groups, fundamental isomorphism theorems, Sylow theorems, cyclic groups, and the solvability of equations.
Offered 1976-77 and alternate years.
- 648. APPLIED MATHEMATICS FOR CIVIL ENGINEERS. 3 credits, 1st or 2nd sem.**
Prerequisite: Differential equations. The course develops the basic elements of probability, statistics, and decision making theory, emphasizing the application of these theories to civil engineering problems. Topics include matrix techniques with probability applications; data reduction; elements of probability theory; common probabilistic models including binomial, Poisson, and normal distributions and Markov chains; the relation of observed data to these models; and Bayesian decision theory.
- 652. APPLIED MATHEMATICS II. 3 credits, 2nd sem.**
Prerequisite: Math 551, or equivalent. Subject matter includes tensor analysis, calculus of variations, integral equations, Green's functions, and conformal mapping.
- 656. FUNCTIONS OF A COMPLEX VARIABLE I. 3 credits, 1st sem.**
Prerequisites: Differential and integral calculus. This course contains a substantial introduction to the theory of functions of a complex variable, with emphasis on those parts which are most useful in applications. The applications include the uses of the theory of residues and contour integrals in the evaluation of real integrals.
- 657. FUNCTIONS OF A COMPLEX VARIABLE II. 3 credits, 2nd sem. Katzen.**
Prerequisite: Math 656. This course in complex variables investigates more thoroughly the theory of conformal mapping, with applications to engineering problems. Topics considered are the Schwarz-Christoffel transformation, Neumann and Dirichlet problems in the plane, and integrals of the Poisson type.
Offered 1976-77 and alternate years.
- 658. OPERATIONAL ANALYSIS. 3 credits, 1st or 2nd sem.**
Prerequisites: Undergraduate differential equations. Operational methods related to problems in physics and engineering. Topics include Fourier series and integrals; Laplace transform; Z-transform; complex variables and operator inversion; Dirac delta-function and generalized functions; and application to boundary value problems, mechanical vibrations, electrical circuits, and control theory.
- 661. MATHEMATICAL STATISTICS. 3 credits, 1st or 2nd sem.**

Prerequisites: Differential and integral calculus. This course develops the fundamental notions of statistics necessary for the analysis of numerical data. Special attention is given to the problem of determining when statistical methods are appropriate. Case histories of the proper and improper use of statistics are considered.

- Math 662. STATISTICAL INFERENCE. 3 credits, 2nd sem. Flatow.**
Prerequisite: Math 661 or equivalent. This course considers inferences about populations based on samples, design of experiments, elementary decision theory, and minimax principle.
- 668. PROBABILITY. 3 credits, 2nd sem.**
Prerequisite: Math 577 or 661, or an introductory course in probability. This course contains a mathematical treatment of random phenomena. Topics include axioms of probability conditional probability; independence; random variables, discrete and continuous; modes of convergence; classical limit theorems, including weak and strong versions of the law of large numbers, the central limit theorem, and others; and Markov chains. Numerous applications to engineering and reliability theory are considered.
- 671. APPROXIMATE METHODS IN ENGINEERING ANALYSIS. 3 credits, 2nd sem.**
Prerequisite: Undergraduate partial differential equations or Math 551 or equivalent. Topics include approximate methods of solution of partial differential boundary value problems that occur in heat, mass, and momentum transfer problems, perturbation methods; regular and singular perturbation problems; integral methods; variational methods; and point matching methods.
- 675. PARTIAL DIFFERENTIAL EQUATIONS OF APPLIED MATHEMATICS. 3 credits, 2nd sem. Peyser.**
Prerequisite: Math 574 or equivalent. Topics include first order equations; classification of second order equations, canonical forms, characteristics; initial and boundary value problems of hyperbolic, parabolic and elliptic equations; Dirichlet and Neumann problems; Green's function; Riemann's method; and numerical methods. Applications are chosen from the fields of vibrations, wave propagation, heat conduction, electrodynamics, and fluid dynamics. Offered 1976-77 and alternate years.
- 676. ADVANCED ORDINARY DIFFERENTIAL EQUATIONS. 3 credits. 1st sem. Rausen.**
Prerequisites: Undergraduate differential equations or Math 573, and Math 545 or equivalent. The first half of the course deals with the general theory of ordinary differential equations and systems of differential equations: existence and uniqueness of solutions, dependence on initial conditions and on parameters, linear systems. The theory is then applied to selected special topics, such as stability and asymptotic behavior of solutions, perturbations of periodic solutions, geometric theory of two-dimensional autonomous systems, second order equations and boundary value problems.
- 700. MASTER'S PROJECT. 3 credits, 1st or 2nd sem. Department Faculty.**
Prerequisite: Matriculation for the M.S. degree. An extensive paper involving a mathematical investigation is required of all candidates for the Master of Science degree in Applied Mathematics, who do not take Math 701, Master's Thesis. The work will normally be initiated with the approval of a Faculty member who will become the student's project adviser. A student whose work in Math 700 is of exceptional quality may be permitted to extend the Master's Project into a Master's Thesis, Math 700. With the approval of his adviser, a student may register for one and one-half credits in each of two successive semesters.
- 701. MASTER'S THESIS. 6 credits, 1st or 2nd sem. Department Faculty.**
Prerequisite: Matriculation for the M.S. degree. An approved program involving a mathematical investigation may be the basis for the thesis. The work will be carried out under the supervision of a designated member of the Faculty. Approval to register for the thesis must be obtained from the

thesis adviser. With the permission of the adviser, preparation for the thesis may be scheduled over one to four consecutive semesters. Credit will be limited to the 6 credits indicated for the thesis.

Math 720. TENSOR ANALYSIS. 3 credits, 2nd sem.

Prerequisites: Vector analysis and Math 630, or equivalents. After a review of vector analysis in general curvilinear coordinates, the course covers the algebra and differential calculus of tensors, applications to differential geometry, analytical mechanics, and mechanics of continuous media. The choice of applications will be determined by the students' professional fields.

Offered 1977-78 and alternate years.

746. REAL ANALYSIS. 3 credits, 1st sem.

Prerequisite: Math 545 or equivalent. Topics covered include the number systems; elementary topology; linear spaces up to the Stone-Weierstrass theorem; Lebesgue and Stieltjes integrals; and L_p -spaces, L_2 -spaces, and Fourier series.

Offered 1977-78 and alternate years.

761. MATHEMATICS OF RELIABILITY. 3 credits, 2nd sem. Barkan.

Prerequisite: Math 661 or equivalent. This course is intended to provide the foundation necessary for understanding and solving reliability problems. Means for improvement of reliability of devices and systems in design, manufacture, and inspection are examined mathematically. Chance, gamma, beta, extreme, value distributions, and other life distributions are studied.

Offered 1977-78 and alternate years.

Department of Mechanical Engineering

MASTER OF SCIENCE PROGRAMS

Programs leading to the degrees *Master of Science* and *Master of Science in Mechanical Engineering* are offered by the Department and are described below. Candidates for these degrees must include, with the prior approval of the adviser, either ME 700—Mechanical Engineering Design or ME 701—Thesis. Electives must include at least two graduate courses in mathematics or computer science.

MASTER OF SCIENCE IN MECHANICAL ENGINEERING

The *M.S. in M.E.* is intended for the mechanical engineering graduate who wishes to further his formal mechanical engineering education by specializing in some advanced phase of mechanical engineering or in preparation for a further advanced degree.

MASTER OF SCIENCE

The *M.S.* is intended for the student who wishes to pursue an interdisciplinary program with a major area of concentration centered on the mechanical engineering offering.

The Department offers applied and theoretical courses covering the general areas of fluid mechanics, heat transfer, stress analysis, design, control engineering, and polymer processing. Supporting this course offering, the department is presently engaged in research and development in automotive

pollution, biomechanics, and medical engineering, system optimization, heat transfer, polymer engineering, instrumentation, design engineering, and solid and fluid mechanics.

A. *M.S. in M.E.*

For the Master of Science in Mechanical Engineering, candidates must complete 30 credits which include:

1. 18 credits of specialization which form a coherent program. The program is to include ME 700—Master's Project (3 credits) or ME 701—Master's Thesis (6 credits). Full time students or those students contemplating further study are expected to do a thesis.
2. A minimum of 6 credits in mathematics or computer science.
3. 6 credits of electives from the mechanical or related non-mechanical course offering.

B. *M.S.*

For the Master of Science, candidates must complete 30 credits which include:

1. 15 credits of specialization, including ME 700—Master's Project (3 credits) or ME 701—Master's Thesis (6 credits). These courses should constitute a coherent program of study and may include courses from other departments.
2. 6 credits in mathematics or computer science.
3. 9 credits of electives from the mechanical or related non-mechanical course offering.

Depending upon the undergraduate background and major, students in the M.S. program may have to enroll in courses for a total of more than 30 credits.

SYSTEMS ENGINEERING

Students with a mechanical engineering background or with an interest in systems related to the discipline of mechanical engineering can design a systems engineering program from the offerings of this and other departments. Suitable programs can be devised which will lead to either the degree of Master of Science or Master of Science in Mechanical Engineering.

Listed below are some typical programs for a few of the possible systems engineering areas relating to mechanical engineering. These are intended as a guide to aid the student in conjunction with his adviser in formulating a program suited to his own needs and interests. Interdisciplinary programs are encouraged.

The following core courses are suggested as basic to all systems programs related to mechanical engineering and should be taken as early as possible:

CS 500—	Introduction to Systems Analysis	CS 661—	Systems Simulation
		EE 677—	Optimization techniques

The following courses could then be utilized to provide programs in:

BIOMEDICAL ENGINEERING SYSTEMS

ChE 628—	Biochemical Engineering	ME 571—	Biomechanics of Human Structure and Motion
ME 570—	Introduction to Biomechanical Engineering	ME 632—	Instrumentation

ELECTRO-MECHANICAL CONTROL SYSTEMS

EE 768—	Optimal Control Theory	ME 753—	Advanced Control of Electro-Mechanical Systems
ME 635—	Design of Automatic Machinery		
Me 653—	Control of Electro-Mechanical Systems		

MACHINE SYSTEMS

ME 615—	Advanced Mechanical Vibrations	ME 634—	Analysis and Synthesis for Design
ME 630—	Analytical Methods in Machine Design	ME 635—	Design of Automatic Machinery

POWER GENERATION SYSTEMS

ME 540—	Combustion Engine Emissions and Their Control	ME 642—	Power Plant Design
		ME 661—	Thermal Pollution of Water and Air
ME 641—	Combustion		

APPLIED POLYMER SCIENCE AND ENGINEERING

In conjunction with the Department of Chemical Engineering and Chemistry, the Department of Mechanical Engineering has formulated an inter-disciplinary sequence of courses in applied polymer science and engineering. Mechanical engineering students working toward the Master's Degree in this option will require the following core courses.

1. ME 580 Polymer Processing Techniques
2. ChE 645 Fundamentals of Rheology
3. Chem 540 Introduction to Polymers

ENGINEER DEGREE PROGRAM

The program leading to the degree of Engineer in Mechanical Engineering is intended for those engineers who are seeking technical competence which is broader than that for the Master's degree.

Course requirements for the engineer degree program are a minimum of 24 credits of course work beyond the master's degree, and a professional project of at least 12 credits. A minimum of 12 credits of course work must be at the 700 level.

Since the program is intended mainly for the practicing engineer, it is possible to complete the degree requirements on a part-time (evening) basis.

CANDIDACY EXAMINATION

The candidacy examination for the degree of Engineer will consist of written and oral portions. The written portion is designed to test the student's ability to analyze design problems. The areas covered by the written examinations will include thermodynamics, heat transfer, fluid mechanics, dynamics, stress analysis, and mathematics.

PROFESSIONAL PROJECT

The professional project for the degree of Engineer must have sufficient breadth to indicate an understanding of the wide range of decisions which go into a successful engineering design (choice of materials, method of manufacture, economic considerations). The emphasis in the project, however, should be on the analysis, showing an understanding of how basic engineering sciences are applied to the solution of design projects.

DOCTORAL PROGRAM

The program leading to the degree of *Doctor of Engineering Science in Mechanical Engineering* is intended for the superior student with a broad background in engineering, mathematics and physics and a Master's degree in Mechanical Engineering who wishes to do advanced study and research in an area of mechanical engineering.

Prospective candidates should be well grounded in applied mathematics as well as in the engineering sciences. A student whose general qualifications are acceptable but who lacks the required breadth of training will be required to make up deficiencies before being admitted to candidacy for the doctoral degree.

Course requirements for the doctoral program will be specified in consultation with the student and the research for the degree will require an original investigation, completion of which will contribute to current knowledge in the field.

QUALIFYING EXAMINATION

Doctoral students will be eligible to take the qualifying examinations after they have completed two academic years of graduate work beyond the B.S. degree. A series of four written and one comprehensive oral examination must be taken and passed. The written examinations are to include one in Mathematics and three others appropriate to the student's fields of study. The general areas for these examinations are:

1. Applied Mathematics which will include such topics as ordinary and partial differential equations, vector analysis, complex variables, numerical methods, and boundary value problems.
2. Engineering (three areas to be selected):
 - Automatic Control
 - Dynamics and Vibration
 - Elasticity
 - Fluid Mechanics

Heat Transfer
Stress Analysis
Thermodynamics
Special area (if applicable)

The doctoral student should discuss with his adviser which of the examinations are appropriate and then write to the chairman of the department requesting permission to take them. The examinations will normally be scheduled once each academic year. The student will be notified as to the scheduled dates after his application to take the examinations has been approved.

REGISTRATION FOR DISSERTATION

Registration for dissertation and research will require as prerequisites the following:

1. Completion of the courses specified by the Department.
2. Satisfactory completion of the doctoral examinations.
3. Demonstration by the candidate that facilities for his proposed research will be available and that a faculty member is willing to supervise the dissertation.

Should the investigation and final draft of the dissertation not be completed within the normal 36 credit hour period, additional dissertation registration for a minimum of three credits per semester will be required until the dissertation is completed and accepted. The oral defense will take place only after submission of the final draft of the dissertation.

COURSES OF INSTRUCTION

- ME 510. DYNAMICS OF COMPRESSIBLE FLUIDS. 3 credits, 1st sem.**
Prerequisites: Undergraduate differential equations, fluid mechanics, and thermodynamics. This course covers one dimensional reversible and irreversible compressible fluid flow including effects of variable area, friction, mass addition, heat addition, and normal shock; two dimensional reversible subsonic and supersonic flows with an introduction to the method of characteristics; and two dimensional oblique shock.
- 535. COMPUTER AIDED DESIGN. 3 credits, 2nd sem.**
Prerequisite: Differential equations, computer programming, machine design, heat transfer. A problem oriented course in which emphasis is placed on modeling and solving realistic mechanical engineering design problems with the aid of the computer. Class discussion is directed to guide the student in simulating a problem and devising an approximate computer program. The student will be required to solve some representative mechanical engineering problems by means of the computer.
- 540. COMBUSTION ENGINE EMISSIONS AND THEIR CONTROL. 3 credits, 1st sem.**
Prerequisite: Undergraduate thermodynamics. This course is a study of the role of gasoline and Diesel engines in air pollution, including photochemical smog. The relationship between fundamental engine design, combustion and emission formulation is traced for the homogeneous combustion process of the gasoline engine and the heterogeneous combustion process of the Diesel engine. A discussion of present and future emission control techniques is included. Experiments and demonstrations on fuel characteristics, engine performance and exhaust emissions are performed.

ME 570. INTRODUCTION TO BIOMECHANICAL ENGINEERING. 3 credits, 1st sem.

Prerequisites: Undergraduate thermodynamics, and statics and dynamics. This is an introductory course in biomechanical engineering designed to interpret the functioning of physiological systems in terms of mechanical engineering systems. Topics include fluid flow aspects, structural and motion aspects, transport and material aspects and energy balance of the body as well as the overall interaction of the body with the environment.

571. BIOMECHANICS OF HUMAN STRUCTURE AND MOTION. 3 credits, 2nd sem.

Prerequisites: Undergraduate statics, kinematics, and dynamics. Principles of engineering mechanics and materials science are applied to the study of the behavior of human structural and kinematic systems and to the design of prosthetic devices. Topics include anatomy; human force systems; human motion; bioengineering materials; and design of implants, supports, braces, and replacement limbs.

580. POLYMER PROCESSING TECHNIQUES. 3 credits, 1st sem.

Prerequisites: Undergraduate courses in fluid dynamics and heat transfer. A combination lecture-laboratory course dealing with engineering properties of plastics and manufacturing processes. Included are the fundamentals of the various processing techniques: extrusion; injection molding, compression molding, thermoforming, casting, foaming, et cetera. The mechanical properties of plastics and the effect of additives will be discussed.

Offered 1976-77 and alternate years.

607. ADVANCED THERMODYNAMICS. 3 credits, 1st sem.

Prerequisite: Undergraduate thermodynamics. A study of the basic laws of thermodynamics as applied to various thermodynamic systems. Topics include general thermodynamic relationships for single and multi-component systems, stability, phase and chemical equilibrium, thermal stress, surface tension phenomena, gas liquification, magnetic cooling, superconductivity, and negative Kelvin temperatures.

Offered 1977-78 and alternate years.

610. HEAT TRANSFER. 3 credits, 1st sem.

Prerequisites: Undergraduate fluid mechanics, heat transfer, and vector analysis or Math 551 or equivalent. A study of heat transfer by conduction, convection, radiation, and during phase change. Analytical and numerical solutions to steady and unsteady state conduction; boundary layer theory and applications to convective heat transfer; analogy between fluid flow and heat transfer; basic laws of radiation and applications; and combined heat transfer mechanisms. ChE 623 may be substituted for ME 610 with departmental approval.

611. DYNAMICS OF INCOMPRESSIBLE FLUIDS. 3 credits, 1st sem.

Prerequisites: Vector analysis or Math 551 or equivalent. An introduction to the hydrodynamics of ideal fluids; two dimensional potential and stream functions; conformal mapping. The differential equations of viscous flow are developed and applied to various configurations. Boundary layer theory and dimensional analysis are introduced.

612. GAS DYNAMICS. 3 credits, 1st sem.

Prerequisites: Vector analysis or Math 551 and ME 510 or equivalents. The physical phenomena of gas dynamics are examined rigorously and the mathematical methods and techniques needed for analysis and study are presented. The dynamical and thermodynamical relations for the more commonly encountered flow situations are prescribed, utilizing the vector calculus. The nonlinearity of the resulting equations is examined critically. Methods of solution such as numerical, linearization or small perturbation, transformation of variables and successive approximations are discussed. The method of characteristics is presented in detail for flows involving hyperbolic equations.

Offered 1977-78 and alternate years.

- ME 613. RADIATION HEAT TRANSFER. 3 credits, 2nd sem.**
Prerequisites: Undergraduate differential equations, thermodynamics, and heat transfer. The course covers heat radiation of solid bodies and of gases and flames; evaluation of angle factors; discussion of radiative properties of electrical conductors and non-conductors; application of radiative networks to many body problems; diffuse specular reflectors; and artificial satellites and space vehicles. The analogy between heat transfer by radiation and electrical networks is stressed. Also discussed are problems where both conduction and radiation must be considered.
Offered 1977-78 and alternate years.
- 615. ADVANCED MECHANICAL VIBRATIONS. 3 credits, 1st sem.**
Prerequisite: Undergraduate vibrations. Included in the course are a consideration of the more advanced principles of vibration. Lagrange's equation of motion, field balancing, matrix notation and iteration procedure, influence coefficients, and Fourier series representation are applied to the solution of vibration problems.
Offered 1976-77 and alternate years.
- 616. MATRIX-TENSOR METHODS IN MECHANICAL ENGINEERING. 3 credits, 2nd sem.**
Prerequisites: Undergraduate differential equations, fluid mechanics and vector analysis or Math 551 or equivalent. Engineering analysis applications of matrix algebra, matrix calculus and introductory tensor methods. Study of matrix methods in the derivation of the fundamental equations in solid and fluid mechanics. Applications to elasticity, plates and shells, viscous fluids and curvilinear coordinates. Matrix-tensor theory is used to show the basic unity in the various applications in engineering analysis.
- 617. RANDOM VIBRATION. 3 credits, 2nd sem.**
Prerequisites: Mechanics of deformable bodies, mechanical vibrations and vector analysis or Math 551 or equivalent. An extension of classical vibration theory to problems of random excitation which includes analysis of vibration response utilizing the mobility and impedance of mechanical components, spectral density representations, and analog computer methods. Design for shock and random loading is considered.
Offered 1976-77 and alternate years.
- 630. ANALYTICAL METHODS IN MACHINE DESIGN. 3 credits, 1st sem.**
Prerequisites: Undergraduate differential equations, senior machine design, and Math 551 or equivalent. The course covers basic theory underlying the analytical methods used in machine design. Comparisons are made between solutions made by approximate engineering methods and more exact methods in order to evaluate the validity and range of applicability of the solutions. Topics include advanced analysis of threaded members; keyed, splined, and shrink fits when subject to torque; the fly-wheel as an indeterminate structure; preloaded bearings; surging, presetting and buckling of coiled springs; and accurate analysis of impact stresses, and stresses beyond the yield point.
- 631. BEARINGS AND BEARING LUBRICATION. 3 credits, 1st sem.**
Prerequisites: Undergraduate differential equations and senior machine design. A lecture course on the theoretical and physical aspects of lubrication. Both hydrostatic and hydrodynamic problems are considered. Reynold's differential equation for pressure distribution is applied to the solution of slider bearing and journal bearing problems with and without end leakage.
Offered 1975-76 and alternate years.
- 632. INSTRUMENTATION. 3 credits, 2nd sem.**
Prerequisites: Undergraduate differential equations, fluid mechanics, and thermodynamics. The course is directed to the theory and design of the primary elements of instrumentation such as pressure, temperature, force, and speed measuring elements. Emphasized are response time for dynamic measurement, application of instrumentation in the fields of fluid mechanics, heat transfer, and combustion. Laboratory includes fabrication

techniques and testing of various configurations—electrical, mechanical and hydropneumatic.

Laboratory fee: \$15.00

Offered 1976-77 and alternate years.

ME 633. DYNAMICS OF MACHINERY. 3 credits, 2nd sem.

Prerequisites: Undergraduate differential equations, machine design, and vector analysis of Math 551 or equivalent. An advanced treatment of mechanical elements, linkages, cams, gears, and miscellaneous mechanisms; dynamic consideration, including inertia and gyroscopic effects commonly encountered in the design of automatic machinery and control mechanisms; impulse loads and transient conditions of motion; mechanical computing devices, multi-cylinder balancing, and governor control are among the topics examined.

Offered 1977-78 and alternate years.

634. ANALYSIS AND SYNTHESIS FOR DESIGN. 3 credits, 1st sem.

Prerequisites: Bachelors degree in engineering. Application of the fundamental concepts and principles of advanced mathematics, physics, mechanics, electricity, thermodynamics, fluid dynamics, and heat transfer, combined with economic consideration and decision-making processes to the rigorous training in the design, analysis, and synthesis of complex engineering systems and their components.

635. DESIGN OF AUTOMATIC MACHINERY. 3 credits, 2nd sem.

Prerequisite: Undergraduate course in machine design. A lecture and design laboratory course involving the concepts, philosophy and methods involved in the design of automated machinery and equipment. Representative topics discussed and investigated are transfer systems, feeding devices, parts orientation, performance of assembly machines and their economics from the design standpoint.

Offered 1976-77 and alternate years.

640. GAS TURBINES. 3 credits, 2nd sem.

Prerequisites: Undergraduate courses in differential equations and fluid mechanics (including compressible flow) or equivalent. Included in the course are fundamental considerations in the design and development of the gas turbine power plant for stationary and mobile applications; detailed study of power plant cycles and components; and analysis of compressors, combustors, turbines, nozzles and interconnecting passages.

Offered 1977-78 and alternate years.

641. REFRIGERATION AND AIR CONDITIONING. 3 credits, 2nd sem.

Prerequisites: Undergraduate differential equations, fluid mechanics, and thermodynamics. The course consists of a study of the theory and design of modern refrigeration and air conditioning systems; analysis of absorption, of modern refrigeration and air conditioning systems; analysis of absorption, and refinements of vapor compression cycles. The study of cooling towers, spray apparatus, central air conditioning systems, heat pumps and controls and transient problems are implemented by means of design projects.

Offered 1976-77 and alternate years.

642. POWER PLANT DESIGN. 3 credits, 2nd sem.

Prerequisites: Undergraduate fluid mechanics and thermodynamics. An analysis of modern power plant cycles including heater arrangements and heat balances using an analytical approach. Current practice used to alleviate the adverse effect on the environment due to thermal and atmospheric discharges of modern generating facilities are considered. Methods of predicting performance of generating equipment by short cut methods are also introduced: Economic considerations in the selection and arrangement of auxiliaries are presented along with the theory and practical application of incremental loading and rates. A systems approach to the use of fuel energy for the future is considered.

Offered 1977-78 and alternate years.

- ME 643. COMBUSTION. 3 credits, 1st sem.**
Prerequisites: Chemistry, fluid mechanics and thermodynamics. A study of the chemical and physical process of combustion is presented. Topics include ideal combustion, actual combustion, mass balance, energy of reaction, maximum adiabatic combustion temperature, chemical equilibrium, heating values of fuels, limits of combustion, combustion in furnaces, internal combustion engines and other heat engines, with emphasis on the analysis and control of the products of combustion in light of environmental considerations.
Offered 1976-77 and alternate years.
- 650. EXPERIMENTAL STRESS ANALYSIS. 3 credits, 1st sem.**
Prerequisites: Undergraduate differential equations and mechanics of deformable bodies. A lecture and laboratory course dealing with experimental methods of analyzing stress and strain distributions. Static, dynamic, and residual stress distributions are examined utilizing brittle lacquers, strain gages, and related instrumentation. Current developments in theory and technique are applied to the solution of special problems.
Laboratory fee: \$15.00.
Offered 1976-77 and alternate years.
- 651. PHOTOELASTICITY. 3 credits, 2nd sem.**
Prerequisites: Undergraduate differential equations and mechanics of deformable bodies. A lecture and laboratory course dealing with the use of polarized light for the solution of problems of stress analysis. Related theory and recent experimental techniques utilizing the polariscope, photoelastic coatings, and Moire patterns will be applied to the solution of industrial problems. Frozen stress methods are considered in applications involving three-dimensional stress distributions.
Laboratory fee: \$15.00.
Offered 1977-78 and alternate years.
- 652. DESIGN OF PLATES AND SHELLS. 3 credits, 2nd sem.**
Prerequisites: Mechanics of deformable bodies and vector analysis or Math 551 or equivalent. A study of plates and shells oriented toward mechanical engineering design which covers solutions for typical loading and boundary conditions by analytical and numerical methods, including digital computer techniques. Sandwich construction, plate and shell interfaces, and thermal stresses are also considered.
Offered 1977-78 and alternate years.
- 653. CONTROL OF ELECTRO-MECHANICAL NETWORKS. 3 credits, 1st sem.**
Prerequisites: Undergraduate electrical circuits and mechanical vibrations or equivalent. This course presents methods by which electro-mechanical systems, having electro-mechanical control loops, may be modeled and analyzed. The presentation makes use of mechanical networks, a concept which is readily adapted to dynamic systems. Such systems are examined for stability and response to various inputs using techniques that are appropriate to electro-mechanical networks.
Offered 1977-78 and alternate years.
- 654. PRESSURE VESSEL DESIGN. 3 credits, 1st sem.**
Prerequisites: Undergraduate strength of materials and applied mathematics for engineers. This course is designed to provide the student with practical experience in designing pressure vessels. Topics included are analysis of shells, vessel flanges and ends, junctions, pipe bends and pipe attachments. Consideration is given to stability and creep effects. A significant portion of the course is devoted to computer analysis of pressure vessels. ASME pressure vessel codes will be consulted throughout the course.
Offered 1977-78 and alternate years.
- 660. NOISE CONTROL. 3 credits, 2nd sem.**
Prerequisites: Undergraduate differential equations and college physics. A study of engineering methods for reducing noise pollution including reduction of intensity at the source, limitation of transmission paths and absorp-

tion; applications to structures, machinery, ground transportation, and aircraft; and noise measurement.

Offered 1976-77 and alternate years.

ME 661

THERMAL POLLUTION OF WATER AND AIR. 3 credits, 1st sem.

Prerequisites: Undergraduate differential equations, fluid mechanics, and thermodynamics. Study of sources and processes causing thermal pollution and their effects on the environment; study of heat exchange mechanisms between water and air with emphasis on thermal pollution of rivers, streams, lakes and reservoirs; design of cooling ponds and towers; and use of instruments and techniques in thermal pollution control studies. Offered 1976-77 and alternate years.

662.

AIR POLLUTION CONTROL AND DESIGN. 3 credits, 1st sem.

Prerequisite: Undergraduate thermodynamics. An investigation of the techniques utilized for the solution of air pollution problems. Topics include the design and behavior of equipment to control gaseous and particulate pollutants such as filters, precipitators, scrubbers, and absorption systems. A term project involving mechanical design is required.

664.

ENGINEERING METEOROLOGY. 3 credits, 2nd sem.

Prerequisite: Undergraduate calculus, thermodynamics and fluid mechanics. A study of specific topics from the areas of physical meteorology and dynamical meteorology selected to enable the non-meteorologist to understand and utilize developments in these areas where applicable to his own work. Topics include atmospheric energy balance and equations of motion.

Offered 1976-77 and alternate years.

680.

POLYMER PROCESSING. 3 credits, 2nd sem.

Prerequisites: ChE 645 or equivalent and undergraduate heat transfer studies. Application of heat transfer, fluid mechanics and thermodynamics to the design and control of polymer processing equipment. Detailed consideration of extrusion, collandering, rotational molding, stamping and injection molding.

Offered 1976-77 and alternate years.

700.

MECHANICAL ENGINEERING DESIGN. 3 credits, 1st or 2nd sem.

Prerequisite: Departmental approval. An extensive paper involving design, construction and analysis, or theoretical investigation will be required of all candidates for the Master's degree who do not take ME 701, Thesis. Further information may be obtained from the departmental adviser.

If the use of laboratory facilities or equipment is necessary, a \$25.00 deposit must be maintained.

701.

MASTER'S THESIS. 6 credits, 1st or 2nd sem. Department Faculty.

Prerequisite: Departmental approval. Projects involving design, construction, experimental or theoretical investigation may be approved by the graduate adviser as the basis of the thesis. The work is carried out under the supervision of a designated member of the departmental staff. The completed work in the form of a written thesis should be of sufficient merit to warrant publication in a technical journal. *With the permission of the department, preparation for thesis may be scheduled over one to four consecutive terms. A student must register for a minimum of 3 credits per semester. Credit will be limited, however, to the 6 credits indicated for the thesis.* If the use of laboratory facilities or equipment is necessary, a \$25.00 deposit must be maintained.

710.

CONDUCTION HEAT TRANSFER. 3 credits, 2nd sem.

Prerequisite: ME 610. A study of heat transfer by conduction. Differential and integral forms of the energy equation are developed. Analytical methods for transient and steady one-, two- and three-dimensional heat transfer problems are considered. Variational calculus is introduced and applied to one-dimensional problems.

Offered 1975-76 and alternate years.

- ME 711. CONVECTION HEAT TRANSFER. 3 credits, 2nd sem.**
Prerequisite: ME 610. This course deals with the theory of convection heat transfer with emphasis on techniques involved in thermal design of complex systems. Heat transfer in condensation and boiling is treated. Analytical and digital computer methods for transient and steady state heat transfer problems including conduction, convection, radiation, phase change, and heat generation are considered.
Offered 1977-78 and alternate years.
- 712. MECHANICS OF VISCOUS FLUIDS. 3 credits, 2nd sem.**
Prerequisite: ME 611. A study of the properties and behavior of real fluids in laminar and turbulent motion. Mathematical and empirical laws and methods currently used are developed and discussed in the light of applications to flows in ducts, boundary layers over surfaces and bodies, in fluid machinery, etc. Convective heat transfer applications and compressibility effects are included.
Offered 1977-78 and alternate years.
- 717. SELECTED TOPICS IN MECHANICAL ENGINEERING I. 3 credits, 1st sem.**
Prerequisite: Departmental approval. This special area course will be given when interest develops. Such topics might include advanced mechanisms, aerodynamics, analysis of M.E. systems, design optimization, and case studies in design.
- 718. SELECTED TOPICS IN MECHANICAL ENGINEERING II. 3 credits, 2nd sem.**
See course description for ME 717, above.
- 720. VISCOELASTICITY. 3 credits, 1st sem.**
Prerequisite: Theory of elasticity. Published papers and classical texts are used to present analytical and experimental treatments of engineering problems involving rate effects in materials. This treatment is followed by a discussion of recent papers, intended to broaden still further the analysis and prediction of rheological properties of materials.
Offered 1976-77 and alternate years.
- 721. THERMAL STRESSES. 3 credits, 2nd sem.**
Prerequisites: Vector analysis of Math 551 and theory of elasticity. Foundations of thermoelasticity, reduction of thermoelastic problems to constant temperature equivalents, fundamentals of heat transfer; and elastic and inelastic stress analysis are topics discussed.
Offered 1977-78 and alternate years.
- 753. ADVANCED CONTROL OF ELECTRO-MECHANICAL NETWORKS. 3 credits, 2nd sem.**
Prerequisite: ME 653, or EE 656, or equivalent. This course presents methods which can be used to model and to analyze electro-mechanical systems having several inputs and several outputs all with several degrees of cross-coupling, such as an autopilot, an inertial navigation system, a gyro-stabilized platform, and a moderately complex computer. In each case considered, methods are developed for determining, in closed form, the characteristic equation, and transition matrix, response to various simultaneous inputs, and the performance of the perturbed model of the ideal system.
Offered 1977-78 and alternate years.
- 785. THEORY OF DEFORMABLE SOLIDS IN MECHANICAL ENGINEERING I. 3 credits, 1st sem.**
Prerequisite: Math 720. The course considers concepts of measure of strain, strain tensor, stress tensor, equilibrium equations, constitutive relations, compatibility conditions, conditions for and formulation of two-dimensional problems, and the relationship of engineering theories for beams, plates and shells to the equations of elasticity.
- 786. THEORY OF DEFORMABLE SOLIDS IN MECHANICAL ENGINEERING II. 3 credits, 2nd sem.**
Prerequisite: ME 785. This course considers methods of solution for various

problems formulated in ME 785. Included are eigenfunction solutions, operational methods, and methods utilizing complex variables theory; solutions of three-dimensional problems; solutions of contact problems; wave propagation; and non-linear problems.

- ME 787. INELASTIC BEHAVIOR OF CONTINUOUS MEDIA. 3 credits, 1st sem.**
Prerequisite: Math 720. The course embodies applications of the developments of Math 720. The tensor methods developed in Math 720 and the treatment of kinematics of continuous media put forward there are used in treating the dynamics and thermodynamics of continuous media. The field and constitutive equations for the plasticity theories are discussed, and recent treatments of inelastic media are considered. The final part of the course is devoted to common aspects of visco-plasticity and viscous fluid theories.
- 790. DOCTORAL DISSERTATION AND RESEARCH. Credits as designated, 1st or 2nd sem. Department Faculty.**
Required of all candidates for the degree of Doctor of Engineering Science in the Department of Mechanical Engineering. A minimum of 36 credits is required. The student must register for at least 6 credits of dissertation per semester. Registration for additional credits may be permitted beyond the six, with the approval of the adviser, to be a maximum of 12 credits per semester.
Laboratory deposit: \$25.00 per semester, or such additional amount as may be necessary to provide laboratory facilities and equipment. Doctoral Dissertation fee: \$50.00, payable on submission of an approval dissertation.
- 791. DOCTORAL SEMINAR. No credit, 1st or 2nd sem. Department Faculty.**
A seminar in which faculty or others will present summaries of advanced topics suitable for research. In the course students and faculty will discuss research procedures, thesis organization, and content. Research students will present their own problems and research progress for discussion and criticism. *Required of all doctoral candidates registered for ME 790 and ME 792 unless requirement is waived, in writing, by thesis adviser. Open to all students registered for ME701.*
Seminar fee: \$35.00 per semester.
- 792. PRE-DOCTORAL RESEARCH. 3 credits per semester, 1st or 2nd sem.**
Prerequisite: Permission of department. Corequisite: ME 791. Permitted for students admitted to program leading to the degree of Doctor of Engineering Science in Mechanical Engineering. The research is carried on under the supervision of a designated member of the department faculty. If the student's research activity culminates in doctoral research in the same area, up to a maximum of 12 credits may be applied toward the 36 credits required under ME 790 after the student fulfills the requirements of Doctoral candidacy. Candidates registering for ME 792 must register also for ME 791 unless requirement is waived, in writing, by thesis adviser.
- 793. PROFESSIONAL PROJECT. Credits as designated, 1st or 2nd sem.**
Required of all candidates for the degree of Mechanical Engineer. A minimum total of 12 credits is required. The student must register for at least 6 credits of professional project per semester until completion of 12 credits. If the student is still actively engaged in the preparation of the project after completion of 12 credits, continued registration of three credits per semester will be required. Registration for 3 credits is permitted during the summer session.
Hours to be arranged.
If use of laboratory facilities or equipment is necessary, a laboratory deposit of \$50.00 must be maintained, or such additional amount as may be deemed necessary to provide laboratory facilities and equipment.

Department of Organizational and Social Sciences

The program of advanced studies offered is geared to the broad needs of students of all disciplines. Furthermore, courses may be grouped and coordinated to provide core programs and supplements to graduate degree requirements in areas such as urban affairs, organizational analysis and planning, and industrial relations.

MASTER OF SCIENCE

The degree of Master of Science, with a major emphasis in Urban Systems, is a cooperative program between the Department of Civil and Environmental Engineering and the Department of Organizational and Social Sciences. This degree is designed for the graduate of an engineering curriculum or the holder of a degree in a physical science field, or with a quantitative background in economics, or planning who has an interest in pursuing advanced study in urban analysis. The objective of this program is to prepare individuals to assume roles as program analysts in urban government, and students may specialize in such areas as urban engineering and urban systems management. Details of the program can be found on page

The degree of Master of Science, with a major emphasis in Management of Manpower Policies and Employment Relations, or Management of Public and Regulated Enterprises, or Management of Research, Development and Design, is a cooperative program between the Department of Industrial and Management Engineering and the Department of Organizational and Social Sciences. (See page 83). The degree is designed for the graduate of an industrial administration, engineering, science, or social sciences with quantitative emphasis, curriculum whose career is moving toward management of an industrial or technologically-oriented organization.

The degree *Master of Science*, with a major emphasis in Management of Manpower Policies and Employment Relations or Management of Public and Regulated Enterprises is administered by the Department of Organizational and Social Sciences. Application for entry into the programs must be supported by evidence of high attainment in undergraduate studies. As a minimum, each applicant must show satisfactory completion of approved courses in the areas of industrial administration, probability and statistics, accounting, and economics. Deficiencies in these areas may require the student to take undergraduate or graduate courses, which are to be completed before additional graduate courses may be taken.

Applicable elective courses may be chosen from the graduate course offerings of any department and, with prior approval, from the Newark campuses of Rutgers— The State University or the New Jersey School of Medicine and Dentistry. A student desiring to take courses at the above schools should acquaint himself with registration procedures, as their scholastic calendars may not coincide with those of NJIT. Further information may be obtained from the Graduate Division.

Students preparing for registration for Master's research must have obtained the consent of a prospective adviser prior to registration for OS 701.

MANAGEMENT OF MANPOWER POLICIES AND EMPLOYMENT RELATIONS

Required course: OS 701 (6 credits)

At least nine credits from the following:

EM 602—	Management Science	OS 681—	Personnel Management
IE 603—	Behavioral Science	OS 683—	Manpower Planning & Management Dev.
IE 607—	Seminar in Contemporary Management Prob.	OS 694—	Industrial Relations & Public Planning
OS 661—	Methods of Research in the Behavioral Sciences		

MANAGEMENT OF PUBLIC AND REGULATED ENTERPRISES

Required course: OS 701 (6 credits)

At least nine credits from the following:

EM 602—	Management Science	OS 694—	Industrial Relations & Public Planning
IE 603—	Behavioral Science	SS 521—	Urban Social Structure
IE 607—	Seminar in Contemporary Management Prob.	SS 603—	Public Finance
		SS 604—	Economic Analysis of Urban Areas

Plus fifteen credits of electives.

Current research activities in the Department might provide students with research topics in the following areas: manpower planning, training, and development; equal employment opportunity; wage and salary analysis; personnel policies; collective bargaining; management practices and behavioral research; action research in organizational development; public finance; municipal government planning and organization; problems of the urban economy; transportation economics; and technology assessment.

COURSES OF INSTRUCTION: SOCIAL SCIENCES

- SS 506. TECHNOLOGY ASSESSMENT. 3 credits, 1st sem. Bordman.**
Prerequisites: Undergraduate courses in economics and calculus or statistics. A framework for assessing the impact of technology on society, taking into account both present and future interactions of economic, social and environmental factors. The approach to existing problems will be multidisciplinary and analytical techniques for evaluation and forecasting will be utilized and demonstrated (i.e. benefit-cost analysis, and cross impact matrices).
- 521. URBAN SOCIAL STRUCTURE. 3 credits, 2nd sem.**
An introduction to the city as a social system. The study of the conflict relations among various segments of the urban population—race and religion—their implication. The changing systems of social stratification, urban family structure and the concept of a "culture of poverty." The impact of social and technological change upon urban society. The physical and environmental characteristics of a city as outputs of social systems as well as constraints upon behavior.
Offered 1976-77 and alternate years.

- SS 601. ECONOMETRICS. 3 credits, 1st sem.**
Prerequisite: Undergraduate course in economics. Econometric models are systems of equations describing relationships among economic variables. The stochastic properties of the variables require the application of statistical techniques. The combination of the modeling concept with statistical techniques offers a predicative basis for decision making in management, economics and related fields.
Offered 1977-78 and alternate years.
- 602. COST-BENEFIT ANALYSIS AND ECONOMIC DECISIONS. 3 credits. 2nd sem. Bordman.**
Prerequisite: A course in economics. An analysis of economic decisions that takes into account the external, secondary and intangible items resulting from actions. Examination will be made of the implications of an Income Statement as well as the entire consequence of a project or expenditure in relation to its effects on the firm's future benefits. The concept of national profitability, and the use of social cost-benefit analysis, will also be studied. The cost-benefit relationship for both the public and private sectors will be analyzed. Case studies based upon student industrial or public experience.
Offered 1976-77 and alternate years.
- 603. PUBLIC FINANCE. 3 credits, 1st sem. Edelbaum.**
Prerequisite: Undergraduate or graduate course in economics. Topics include principles underlying government fiscal policy and debt management; allocation of resources between the public and private sectors; economics and principles of taxation, examining specific types of taxes with respect to the tax base, structure of rates, incidence, and impact; and the interaction between government policies and the economic and financial systems.
Offered 1977-78 and alternate years.
- 604. ECONOMIC ANALYSIS OF URBAN AREAS. 3 credits, 1st sem. Edelbaum.**
Prerequisite: A course in economics. An examination of growth, development and structure of metropolitan areas. Problems of poverty, transportation, the economic base, land use, public finance, and the relations between central cities and suburban areas are examined, delineating the interrelationship between the physical requirements and the economic realities. Alternative courses of action are analyzed in relationship to potential engineering and economic solutions. A systems approach to the analysis is employed for demonstration purposes.
Offered 1976-77 and alternate years.
- 605. URBAN HOUSING ECONOMICS. 3 credits, 2nd sem. Edelbaum.**
Prerequisite: Undergraduate or graduate course in economics. An introduction to housing dynamics emphasizing economic approaches including market analysis, production economics, problems of maintenance in the aging standing stock, housing rehabilitation, and the role of the federal housing programs.
Offered 1977-78 and alternate years.
- 606. TECHNOLOGY FORECASTING. 3 credits, 2nd sem. Bordman.**
Prerequisite: Quantitative background in science, social science or engineering. Basic forecasting techniques such as regression analysis, scenario generating, Delphi conferencing and morphological analysis with particular case studies and problems pertaining to the forecasting of technological development. The relation of technological forecasting to the management process and the understanding of the technological development process. Demonstration of the techniques by application to contemporary fields of technological importance such as energy, communications, transportation, housing and computers.
Offered 1977-78 and alternate years.
- 607. MICROECONOMICS. 3 credits, 2nd sem.**
Prerequisites: A course in economics and one year of calculus. A study of production and allocation in market economies. Topics include indifference

and demand analysis, production and cost theory, theory of the firm, profit maximization, market structure analysis and distribution effects, and introduction to welfare economics. The course has a quantitative emphasis. Offered 1977-78 and alternate years.

608. MACROECONOMICS. 3 credits, 2nd sem.

Prerequisite: A course in economics. Theory of aggregate output, employment, and prices. Topics include national income accounts, classical and Keynesian general equilibrium models, growth and cycle models, and stabilization policies.

Offered 1976-77 and alternate years.

ORGANIZATIONAL SCIENCES

PSYCHOLOGY

OS 611. PSYCHOLOGY IN ENGINEERING. 3 credits, 1st sem. Rucker.

A survey of principles and applications of psychology related to engineers and supervisors. Topics include organizational goals and goal setting, human needs, the integration of individuals and organizational goals, approaches to better employee selection, performance appraisal and personal development, group relationships, employee communications, human factors engineering, principles of effective leadership in the selection and training of leaders.

Offered 1977-78.

BEHAVIORAL SCIENCE AND ORGANIZATION THEORY

661. METHODS OR RESEARCH IN THE BEHAVIORAL SCIENCES. 3 credits, 2nd sem. Zaner.

Prerequisite: Undergraduate or graduate statistics. An introduction to the procedures of scientific inquiry as applied in the behavioral sciences. Coverage includes structure, design, and terminology of behavioral research, types of research including experimental, ex post facto, survey, descriptive and action research; formulating hypotheses; sampling; gathering and analyzing data and evidence; and presenting final reports. Special emphasis is placed upon the use of behavioral research as a management technique in business and industry, particularly with respect to personnel. Offered 1977-78 and alternate years.

662. ORGANIZATION DESIGN AND DEVELOPMENT. 3 credits, 1st sem.

Prerequisite: Course in management or organization theory. Examination of planned approaches to changing the functions of organizations and to improving their effectiveness. Individual change, group methods, and organization design and development are emphasized. Theories of change and comparative studies of organizational development.

Offered 1976-77 and alternate years.

MANAGEMENT

671. TECHNIQUES OF EXECUTIVE CONTROL. 3 credits, 2nd sem. Gordon.

A study of the relation of planning and organization to achieve and maintain effective executive control. Investigation into the determination of goals, policies, and alternative courses of action together with the control techniques consistent with the firms objectives and management philosophy.

Offered 1977-78 and alternate years.

PERSONNEL

681. PERSONNEL MANAGEMENT. 3 credits, 1st sem. Zaner.

The background and operating concepts underlying the management of human resources in business, industry, and government. An analysis of the developing programs in the field of personnel including employment, wage and classification, training, employee and labor relations, and accident prevention. Particular attention is directed to cases and roles involving both line and staff managers.

- OS 682. PERSONNEL SELECTION. 3 credits, 2nd sem.**
Prerequisite: OS 681. The contributions of a variety of factors including employment policy, the development of manpower resources in and out of a company, job evaluation, criteria of job performance, interviews, application blanks, and psychological tests are studied. The evaluation of each factor is discussed.
Offered 1977-78 and alternate years.
- 683. MANPOWER PLANNING AND MANAGEMENT DEVELOPMENT. 3 credits, 2nd sem. Zaner.**
An intensive analysis of company goals and programs of manpower planning and management development. Coverage includes formulation and use of manpower inventories, skills files, career ladders and replacement schedules; development techniques such as consultant management, sensitivity training, the managerial grid, and performance appraisal. Participative methods including role-playing and case study technique are both studied and applied throughout the course.
Offered 1976-77 and alternate years.

LABOR

- 691. LABOR AND THE LAW. 3 credits, 1st sem. Kahng.**
The legal problems arising out of government regulation of labor-management relationships. Topics included are: the selection and designation of bargaining agents; the collective bargaining process; the administration and enforcement of collective bargaining agreements; and the activities of unions and employers in labor disputes. Also examined are federal and state laws regulating wages, hours, and benefits.
- 692. CONTEMPORARY COLLECTIVE BARGAINING. 3 credits, 2nd sem. Kahng.**
Analysis of the complex problems of achieving accommodation in labor-management relations. The analysis centers on managerial authority and the scope of collective bargaining, structural wage problems, the principal non-income objectives of collective bargaining, effective administration of collective agreement, methods of settling disputes, and the impact of public policy on collective bargaining.
- 693. LABOR-MANAGEMENT RELATIONS IN THE PUBLIC SECTOR. 3 credits, 1st sem. Stochaj.**
Prerequisites: Undergraduate course in labor relations or its equivalent. An examination and analysis of labor-management relations in the rapidly-growing public sector of the economy. Investigation of federal executive orders and the various state and local laws regulating the right of the employees to organize and bargain collectively with public management. Examination of the similarities and differences between labor-management relations in the public and private sectors with respect to such items as unit determination, the management response, bargainable issues, the bargaining process, types of agreements, and means of dispute settlement.
Offered 1976-77 and alternate years.
- 694. INDUSTRIAL RELATIONS AND PUBLIC PLANNING. 3 credits, 1st sem. Helfgott.**
An analysis of governmental procedures utilized in handling crisis and confrontations in industrial relations. The increasing role of public planning as a problem solving technique in industrial relations. The economic effects of government intervention into labor relations and the labor market. The impact of legislation and regulation on such matters as wages and hours, working conditions, and discrimination in employment. The interaction between industrial relations and the economic climate, and the role of planning in dealing with problems of manpower training and utilization, wage-price inflation, and economic growth.
Offered 1977-78 and alternate years.

OS 701. INDEPENDENT RESEARCH. 6 credits, Department Faculty.

Prerequisite: Matriculation for the M.S., adequate graduate courses in the field of the proposed research, and the research advisor's approval. Independent research in an academic or professional field leading to a thesis satisfying the requirements of the M.S. degree. It may be a research undertaking or a developmental experience at an appropriate professional level. The research report should be a scholarly paper which could serve as useful data and/or conclusions to other researchers and/or professionals interested in further study or concerned with the operational problems in the area involved. *With the permission of the Department, the independent research may be scheduled over one to four consecutive terms. A student must register for a minimum of 3 credits per semester. Credit will be limited, however, to the 6 credits indicated.*

If the use of laboratory facilities or equipment is necessary, a \$25.00 deposit must be maintained.

Department of Physics

Phys 540. MODERN PHYSICS. 3 credits, 1st sem.

Prerequisites: Differential equations. The course deals with wave and particle nature of light, matter, and energy; experimental determination of the values of important physical constants; particle beams in electric and magnetic fields; the special theory of relativity; assemblies of particles, wave-particle experiments leading to quantum concepts and wave mechanics; the Schrodinger equation applied to simple problems; atomic structure and spectra; molecules; binding and energy bands in solids; and electrical; thermal, and magnetic properties of solids.

550. INTRODUCTION TO ELECTRON MICROSCOPY. 3 credits, 1st sem.

This is a practical course in electron microscopy. Individualized instruction in the operation of transmission and scanning electron microscopes is given. A portion of the course is devoted to specimen preparation techniques.

Laboratory Fee: \$15.00.

630. SOLID STATE PHYSICS. 3 credits, 2nd sem.

Prerequisite: Differential equations and modern physics. A study of crystals and X-ray diffraction; thermal; dielectric and ferroelectric properties of solids; diamagnetic, paramagnetic, ferromagnetic phenomena; superconductivity.

Offered 1977-78 and alternate years.

631. DYNAMICS OF A PARTICLE. 3 credits, 1st sem.

Prerequisite: Undergraduate analytical or engineering mechanics. The course includes a brief review of Newtonian mechanics; Lagrangian method; Hamilton's equation and phase space; canonical transformations; Poisson brackets and relation to quantum mechanics; Hamilton-Jacobi equation; and applications. Offered 1976-77 and alternate years.

632. ELEMENTS OF NUCLEAR ENGINEERING. 3 credits, 2nd sem.

Prerequisite: Bachelor's degree in engineering or physics. The production, detection, and interaction of neutrons with matter in a nuclear reactor; nuclear fission; discussion of various types of reactors, reactor theory, including the slow-down of neutrons, the multiplication factor, diffusion theory, Fermi age, criticality factor and critical reactor dimensions; a brief consideration of radiation shielding and reactor instrumentation and control.

Offered 1976-77 and alternate years.

633. QUANTUM MECHANICS. 3 credits, 2nd sem.

Prerequisite: Phys 540 or 635. Among the topics covered are the Schrodinger equation, the free particle, the linear harmonic oscillator, one-dimensional potential barrier problems, three-dimensional problems

including the rotator, the oscillator, the hydrogen atom and time-independent and time-dependent perturbation theory.

Phys 634. NUCLEAR PHYSICS. 3 credits, 2nd sem.

Prerequisite: Phys 540. A brief introduction to atomic physics gives insight into the vector model of the atom, the Pauli principle and electron spin. The remainder of the course is concerned with the constitution of the nucleus, isotopes, natural radioactivity and the laws of radioactive transformations, induced nuclear disintegration, induced radioactivity, alpha, beta, gamma decay, nuclear reactions and forces, and nuclear structure.
Offered 1977-78 and alternate years.

635. THEORETICAL PHYSICS. 3 credits, 1st sem.

Prerequisite: Differential equations. An introduction to those concepts forming the basis of all physics, stressing the logical development of physics from a particle point of view to a field view point. Problems in simple mechanical systems; fluid-flow and heat flow fields; waves in various media; the solution of the wave equation; initial value and boundary value problems, and the electromagnetic field.
Offered 1977-78 and alternate years.

Inter-Disciplinary Studies in Environmental Engineering

MASTER OF SCIENCE PROGRAMS

Effective control of environmental pollution requires the application of a broad range of technical skills. In recognition of the need of interdisciplinary approaches to environmental problems, the College has organized the administration of its master's degree programs around an inter-departmental faculty group, the Environmental Engineering Committee, rather than centering it in one academic department.

A student enrolling in one of the programs within the purview of the Environmental Engineering Committee will be assigned an adviser within one of the academic departments on the basis of his or her background and special interests. The degree requirements are indicated below.

MASTER OF SCIENCE IN ENVIRONMENTAL ENGINEERING

A student seeking this degree must have an undergraduate degree in engineering. The following guidelines will be used in formulating the student's program of study:

A. General guidelines

Each program of study must satisfy the general Graduate Division academic requirements (see page 16, section A) of:

1. 18 credits of specialization
2. 12 credits of electives including 6 credits outside of department of specialization
3. Master's thesis or project (included in specialization requirement).

B. Specific program requirements

The student with his or her adviser will plan a program of

course work. Students lacking preparation for some courses may be required either to make up this deficiency without credit or to include more than thirty credits in their programs.

Each program must include the following courses:

1. EnE 560—Environmental Chemistry
2. EM 631—Legal Aspects in Environmental Engineering
3. Master's project or thesis.

AREAS OF INTEREST

In selecting courses to fulfill the specialization and elective requirements indicated above, students with advisers' approval will select courses on the basis of their specific areas of interest within the environmental engineering field. The following areas of interest illustrate the flexibility which is available under the general guidelines for formulating individual programs of study.

This list is not intended to limit the possibilities. The student, in conference with his or her adviser, may select from one of the areas indicated or from other areas in line with career objectives and prior preparation.

INDUSTRIAL WASTE POLLUTION CONTROL

ChE 551— Principles of Mass Transfer	EnE 665— Biological Waste Treatment
ChE 685— Unit Operations for Industrial Waste Treatment	EnE 666— Steam and Estuary Analysis
ChE 686— Industrial Waste Control	EnE 668— Air Pollution Control
EM 631— Legal Aspects in Environmental Engineering	EnE 669— Waste Water Laboratory
EnE 560— Environmental Chemistry	ME 661— Thermal Pollution of Water and Air
EnE 661— Environmental Microbiology	Project or thesis in the department of the student's choice.

WATER RESOURCES AND WATER TREATMENT

ChE 551— Principles of Mass Transfer	EnE 665— Biological Waste Treatment
ChE 685— Unit Operations for Industrial Waste Treatment	EnE 669— Waste Water Laboratory
EM 631— Legal Aspects in Environmental Engineering	CE 620— Open Channel Flow
EnE 560— Environmental Chemistry	CE 621— Hydrology
EnE 661— Environmental Microbiology	CE 720— Water Resources system
	Project or thesis in the department of the student's choice.

MUNICIPAL WASTE TREATMENT

ChE 551— Principles of Mass Transfer	EM 631— Legal Aspects in Environmental Engineering
ChE 685— Unit Operations for Industrial Waste Treatment	EnE 560— Environmental Chemistry

EnE 661— Environmental Microbiology	EnE 667— Solid Waste Disposal Systems
EnE 665— Biological Waste Treatment	EnE 669— Waste Water Laboratory Project or thesis in the department of the student's choice.
EnE 669— Steam and Estuary Analysis	

AIR POLLUTION CONTROL

ChE 551— Principles of Mass Transfer	EnE 668— Air Pollution Control
ChE 685— Unit Operations for Industrial Waste Treatment	ME 662— Air Pollution Control and Design
ChE 686— Industrial Waste and Control	ME 643— Combustion
EM 631— Legal Aspects in Environmental Engineering	ME 661— Thermal Pollution of Water and Air
EnE 560— Environmental Chemistry	ME 666— Engineering Meteorology
	Project or thesis in the department of the student's choice.

ADDITIONAL ELECTIVES

In addition to the above list of courses, the following graduate courses are also available to students with interest in environmental engineering:

EnE 671—Environmental Impact Analysis	EnE 670—Adv. Processes in Water Pollution Control
EE 673—Random Signal Analysis I	ME 660—Noise Control
EnE 660—Introduction to Solid Waste Problems	SS 602—Cost-Benefit Analysis and Economic Decision
EnE 663—Pollution: Chemistry and Ecology	SS 605—Technological Innovation and Public Administration

Also, the environmental engineering student who wishes to develop competence in engineering statistics, linear programming, and system simulation, may take graduate courses offered by the Industrial Engineering and Computer Science departments in these areas.

PROGRAMS LEADING TO THE DEGREE OF MASTER OF SCIENCE

Students with undergraduate backgrounds in biology or the physical sciences and related fields or in engineering may opt for a program of study within the broad environmental field leading to the degree, Master of Science. The general academic requirements for the degree will be found on page 16, Section B. The student will be assigned to a departmental adviser by the Environmental Engineering Committee, depending on the student's background and interests. A program of study will be designed by the student and adviser which will typically include courses from the specialty areas listed above as well as from other courses in related areas.

Master of Science Program in Applied Science

A PROGRAM FOR SECONDARY SCHOOL TEACHERS OF SCIENCE AND MATHEMATICS

This program was developed in response to many requests from secondary and junior high school teachers of science and mathematics for academic work designed to strengthen their subject matter backgrounds and provide insights into practical applications and societal impact of modern science. It has been planned as a multi-disciplinary program. The Institute has organized it around an inter-departmental faculty committee, the Applied Science Committee, rather than a single academic department. A student enrolling in this program will be assigned an adviser from one of the academic departments on the basis of the student's background or special interests. One of the aims of the Applied Science Committee is to tailor a program to meet the needs of the individual student. The degree requirements are indicated below.

The following guidelines will be used in formulating the student's program of study:

A. General Guidelines

A minimum of ten 3-credit courses including three required courses, one of which is a 3-credit master's project.

Four courses in an area of concentration.

Three elective courses.

B. Specific Program Requirements

The student with his adviser will plan a program of course work. A student lacking preparation for some courses may be required either to make up this deficiency without credit or to include more than thirty credits in their program. Each program must include the following courses:

1. HU 621—History and Philosophy of Science
2. SS 506—Technology Assessment
3. AS 700—Master's Project

AREAS OF INTEREST

In selecting courses to fulfill the specialization and elective requirements indicated above, students with adviser's approval will select courses on the basis of their specific areas of interest. The list below is not intended to limit the possibilities. The student, with his adviser's consent, may select from one of the areas indicated or from other areas consistent with career objectives or prior preparation. The courses in Group 1 of each of the subject areas below are normally limited to students in this program. Descriptions of these courses will be found immediately after the listing below. The courses in Group 2 are offered in the regular graduate program. The course descriptions for Group 2 courses will be found in the departmental listings of this catalog.

CHEMISTRY AND ENVIRONMENTAL CHEMISTRY

Group 1.

Chem 624— Modern Organic Chemistry	Chem 627— Modern Physical Chemistry
Chem 625— Geochemistry	Chem 628— Radiation and the Environment
Chem 626— Chemistry of Contemporary Materials	

Group 2.

Chem 502— Advanced Organic Chemistry I	Chem 641— Polymer Properties
Chem 540— Introduction to Polymers	Chem 643— Polymer Laboratory
Chem 571— Biochemistry	Chem 651— Radioisotopes Theory and Application
Chem 602— Advanced Organic Chemistry II	Chem 658— Adv. Physical Chem.
Chem 603— Advanced Organic Laboratory	Chem 659— Atomic and Molecular Structure
Chem 606— Physical Organic Chemistry	Chem 661— Instrumental Analysis
Chem 610— Advanced Inorganic Chemistry	Chem 664— Advanced Analytical Chemistry
Chem 611— Solid State Inorganic Chemistry	EnE 560— Environmental Chem.
	EnE 663— Pollution: Chemistry and Ecology

MATHEMATICS AND COMPUTER SCIENCE

Group 1.

Math 521— Applied Calculus I	CS 521— Survey of Computer and Information Science
Math 522— Applied Calculus II	
Math 528— Linear Algebra	

Group 2.

Math 511— Numerical Methods	Math 630— Matrix Theory
Math 551— Applied Mathematics I	Math 661— Mathematical Statistics
Math 573— Differential Equations	CS 510— Computer Programming

PHYSICS

Group 1.

Phys 520— Mechanics I	Phys 528— Selected Topics in Classical Physics II
Phys 521— Mechanics II	Phys 531— Contemporary Topics in Applied Physics I.
Phys 523— Electricity & Magnetism I	Phys 532— Contemporary Topics in Applied Physics II.
Phys 524— Elec. & Magnetism II	
Phys 527— Selected Topics in Classical Physics I	

Group 2.

Phys 540— Modern Physics	Phys 621— Nuclear Physics and Radioisotope Techniques
Phys 610— Theoretical Physics	Phys 635— Nuclear Physics
Phys 612— Dynamics of a Particle	Phys 630— Quantum Mechanics
Phys 614— Solid State Physics	
Phys 620— Physics of the Atom	

The courses which are described below are offered for students in the Applied Science master's program. Unless otherwise noted, degree credit for these courses is normally restricted to students in the Applied Science program.

AS 700.

MASTER'S PROJECT. 3 credits, 1st or 2nd sem.

An approved project which is, or can be, related to the introduction of science, mathematics or engineering concepts into secondary school activities. Approval to register for the project must be obtained from the project adviser. The project should be of such caliber as to warrant publication or dissemination in educational or scientific circles. If the use of laboratory facilities or equipment is necessary, a \$50.00 deposit must be maintained.

CHEMISTRY AND ENVIRONMENTAL CHEMISTRY (APPLIED SCIENCE PROGRAM)

- Chem 624. MODERN ORGANIC CHEMISTRY. 3 credits, 1st sem. or 2nd sem.**
Prerequisite: One year of general chemistry. The course considers the scope of modern organic chemistry and how it relates to the contemporary world. The material covered ranges from a review of basic bonding theory and reactions to research on complex mechanistic and structural problems, from the exploration of natural sources of simple organics and their eventual commercial use in making medicines, plastics and products used in such areas as agriculture and construction.
- 625. GEOCHEMISTRY. 3 credits, 1st sem. or 2nd sem.**
Prerequisite: One year of general chemistry. Primarily a study of the chemistry of the lithosphere. Topics discussed include the origin of the earth and its chemical evolution, organic geochemistry, and extraterrestrial geochemistry.
- 626. CHEMISTRY OF CONTEMPORARY MATERIALS. 3 credits, 1st or 2nd sem.**
Prerequisite: One year of general chemistry. An introduction to structure and chemical, electrical and mechanical properties of metallic, ceramic and polymeric materials and their use in science and engineering.
- 627. MODERN PHYSICAL CHEMISTRY. 3 credits, 1st or 2nd sem.**
Prerequisite: One year of general chemistry. The course considers relevant topics in thermodynamics, equilibrium, kinetics, states of matter, and surface chemistry including their applications in technology and the environment.
- 628. RADIATION AND THE ENVIRONMENT. 3 credits, 1st or 2nd sem.**
Prerequisite: One year of general chemistry. The course covers both the harmful and useful aspects of radiation. A brief introduction to nuclear physics and radioactivity is followed by consideration of the problems or radiation units, interaction of radiation with biological systems, dosimetry, and radiation regulations. The numerous applications of radiation and radioactive material, with emphasis upon nuclear power, its effluents, and its effect on the environment will also be discussed.

HUMANITIES (APPLIED SCIENCE PROGRAM)

- Hu 621. HISTORY AND PHILOSOPHY OF SCIENCE. 3 credits, 2nd sem.**
This course attempts to study the nature of science through its historical development. First, it traces the philosophical developments up to and including the modern period. Second, the course will show the applications of these developments, via case studies of the work of scientists and the interdependence between that work and the cultural matrix in general. Third, the nature of scientific truth is investigated in the age of physical relativity. The course concludes with a summary of past and present scientific development and attempts to structure an ethical basis for future scientific decisions.

MATHEMATICS AND COMPUTER SCIENCE (APPLIED SCIENCE PROGRAM)

- Math 521. APPLIED CALCULUS I. 3 credits, 1st sem.**
This course considers selected topics drawn from differential and integral calculus. The development of mathematical models of physical and geometrical situations will be studied, particularly, those applications involving related rates and extreme values. Applications of introductory differential equations to elementary problems in physics and chemistry are also considered.

- Math 522. APPLIED CALCULUS II. 3 credits, 2nd sem.**
This course considers further material involving the application of calculus to problems such as moments, fluid force, work and many other situations which can be analyzed by means of the infinite summation process. Numerical integration will be studied. An introduction to differential equations and their applications will also be included.
- 624. LINEAR ALGEBRA. 3 credits, 1st sem.**
Prerequisite: Undergraduate calculus. This course considers those topics in linear algebra which will develop the secondary school teacher's background in mathematics. The topics include determinants, matrices, and their applications to the solution of systems of linear equations, linear transformations. The course is designed to help the student acquire an understanding of the wide applicability of the subject.
- CIS 521. SURVEY OF COMPUTER AND INFORMATION SCIENCE. 3 credits, 2nd sem.**
An introduction to the utilization of computers for the processing of information. The course will survey applications and advanced topics in Information and Computer Science, such as organization information systems, simulation, gaming artificial intelligence, and computer communications. A broad perspective is provided on this discipline and the many uses to which computer systems are being put. The course also offers a brief introduction to the BASIC language.

PHYSICS

(APPLIED SCIENCE PROGRAM)

- Phys 520. MECHANICS I. 3 credits, 1st sem.**
This course emphasizes the fundamental concepts and basic methods for the treatment of equilibrium and accelerated motion. Newton's Laws and the Free Body Diagram are applied to problems in statics and dynamics. The subject of vectors, vector quantities and their application in mechanics is studied extensively.
Not offered, 1976-77.
- 521. MECHANICS II. 3 credits, 2nd sem.**
Prerequisite: Mechanics I or equivalent. The laws of conservation of energy and conservation of momentum are developed and applied in the study of work and energy, power, impulse and momentum, collisions, recoil and rocket propulsion. There is the study of angular motion, torque, moment of inertia; work and energy in rotational motion; and the application of Newton's laws and the law of conservation of angular momentum to problems in rotational dynamics
Not offered, 1976-77.
- 523. ELECTRICITY AND MAGNETISM I. 3 credits, 1st sem.**
Prerequisite: Mechanics II or equivalent. The basic concepts of electric charge, electric field, Gauss's law, electric potential, potential energy difference, current, resistance, and emf are studied. This course also considers the law of conservation of charge and Kirchoff's laws, direct current circuits and instruments. Class operations include demonstration lectures, related supervised computation problems and recitations.
Not offered, 1976-77.
- 524. ELECTRICITY AND MAGNETISM II. 3 credits, 2nd sem.**
Prerequisite: Electricity and Magnetism I, or equivalent. This course considers the magnetic field; force on moving charges, force on current carrying conductor, and torque on a current-carrying coil. It covers the Hall effect, magnetic field due to moving charges, induced emf, Faraday's and Lenz's laws, mutual and self-inductance. R-L, L-C, and R-L-C circuits, ferromagnetism and permanent magnets are studied. The course also considers alternating currents, circuits with resistance, inductance, and capacitance, average and RMS values, phasors, power, resonance, and transformers. Class operations include demonstration lectures, supervised computation problems and recitation. Not offered, 1976-77.

- Phys 527. SELECTED TOPICS IN CLASSICAL PHYSICS I. 3 credits, 1st sem.**
 Topics of study will include: Vectors and their application to forces, equilibrium and Newton's 1st and 3rd Laws of Motion; center of gravity; motion with constant acceleration, Newton's 2nd Law of Motion and its application; circular motion; work, energy, the Law of Conservation of Energy; impulse, momentum, the Law of Conservation of Momentum; angular motion, the Law of Conservation of Angular Momentum. The concepts of electric field, electric potential, potential differences; Kirchoff's Laws, capacitance and the Conservation of Charge; direct current circuits, the magnetic field; force on moving charge, force on current carrying conductor; production of magnetic fields; induced electromotive force and Faraday's Law.
- 528. SELECTED TOPICS IN CLASSICAL PHYSICS II. 3 credits, 2nd sem.**
 Topics of study will include: Simple and angular harmonic motion; traveling waves; standing waves on strings, rods, and in pipes; acoustical phenomena, the Doppler effect; heat and temperature; geometric optics; prism dispersion, reflection and refractions at a spherical surface, thick and thin lens phenomena, optical instrumentation; physical optics: interference, diffraction and polarization; the photoelectric effect.
- 531. CONTEMPORARY TOPICS IN APPLIED PHYSICS I. 3 credits, 1st sem.**
 Topics in applied physics that are of significant relevance to current science and technology are discussed. Topics that typically will be covered are: modern electronic and optical instrumentation; optical and acoustical holography; electron microscopes, non-scanning and scanning; the paradoxes of quantum and relativity physics; concepts in geophysics; plasma physics with fusion as a new energy source; nuclear energy; Her-nate energy sources; physics and cybernetics; physics and philosophy.
- 532. CONTEMPORARY TOPICS IN APPLIED PHYSICS II. 3 credits, 2nd sem.**
 Topics in applied physics that are of significant relevance to current science and technology are discussed. Topics that typically will be covered are: Physics in daily living; contemporary applications of materials science; physics in electronic instrumentation; superconductivity and lossless transmission lines; physics and cybernetics; biophysics; astrophysics, physics in feedback systems; the impact and philosophy of the quantum theory; the domain and limits of science.
- 620. PHYSICS OF THE ATOM. 3 credits, 1st sem.**
 Prerequisites: Mechanics I and II (or equivalent); Electricity and Magnetism I and II (or equivalent); Geometric and Physical Optics (or equivalent). The atomic view of matter, electricity, and radiation; kinetic theory, special relativity, wave and particle duality, de Broglie waves, the Bohr atom, and the Heisenberg uncertainty principle. Also the atomic view of solids.
- 621. NUCLEAR PHYSICS AND RADIOISOTOPE TECHNIQUES. 3 credits, 2nd sem.**
 Prerequisite: Physics of the Atom. The structure of the atomic nucleus, nuclear forces, laws governing nuclear reactions, radioactive transformations, the nature of radioisotopes. The meaning and interpretations of measurements involved with radioisotopes techniques are emphasized.





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- Henry Zatskis**, *Chairman, Department of Mathematics*, B.S., M.S., Ph.D.

Faculty of the Graduate Division

- Allentuch, Arnold**, Professor of Mechanical Engineering and Associate Dean for Research in the Graduate Division (1966). Worcester Polytechnic Institute, B.S., 1953; Cornell University, M.S., 1959; Polytechnic Institute of Brooklyn, Ph.D., 1962. Executive Director of The Foundation at NJIT.
- Andersen, L. Bryce**, Professor of Chemical Engineering (1963). University of Minnesota, B.S., 1950; M.S., 1951; M.A., 1952; University of Illinois, Ph.D., 1954.
- Anderson, Robert E.**, Professor of Electrical Engineering and Acting Chairman of the Department (1949). Newark College of Engineering, B.S., 1939; University of New Hampshire, M.S., 1948.*
- Andersen, Peter G.**, Associate Professor of Computer & Information Science (1971). Massachusetts Institute of Technology, B.S., 1962; Ph.D., 1964.
- Andrushkiw, Roman I.**, Assistant Professor of Mathematics (1964). Stevens Institute of Technology, B.E., 1959. Newark College of Engineering, M.S.E.E., 1964; University of Chicago, M.S., 1967; Stevens Institute of Technology, Ph.D., 1973.
- Ayoub, Henry R.**, Associate Professor of Electrical Engineering (1957). Alexandria University, B.S., 1947; M.S., 1948. Newark College of Engineering, M.S., 1959.
- Bailey, James L.**, B.A., M.A., Ph.D., Associate Professor of Computer Science.
- Ball, Warren**, Professor of Electrical Engineering (1968). Nova Scotia Tech., B.S., 1944; University of Toronto, M.S., 1946; Cornell University, Ph.D., 1957.
- Barkan, Herbert**, Professor of Mathematics (1946). Brooklyn College, B.A., 1944; Columbia University, M.A., 1945.
- Bart, Ernest N.**, Assistant Professor of Chemical Engineering (1968). New York University, B.Ch.E., 1957; M.Ch.E., 1960; Ph.D., 1971.
- Berenbom, Joshua**, Assistant Professor of Mathematics (1974). Polytechnic Institute of Brooklyn, B.S., 1965; M.S., 1967; Ph.D., 1973.
- Blackmore, Denis**, Associate Professor of Mathematics (1971). Polytechnic Institute of New York, B.S., 1965; M.S., 1966; Ph.D., 1971.
- Bordman, Sanford**, Professor of Economics (1968). City College of New York, B.S., 1949; City University of New York, Ph.D., 1969.
- Buteau, Leon J., Jr.**, Professor of Materials Science (1959). Newark College of Engineering, B.S.M.E., 1958; Stanford University, M.S., 1959; University of Florida, Ph.D., 1963.
- Cagnati, Vincent N.**, Assistant Professor of Chemistry (1958). Columbia University, B.A., 1949; Stevens Institute of Technology, M.S., 1952.
- Chan, Paul C.**, Assistant Professor of Civil and Environmental Engineering (1966). Chu Hai College, B.Sc., 1958; Worcester Polytechnic Institute, M.Sc., 1962; Texas A & M University, Ph.D., 1968.
- Chase, Hamilton**, Associate Professor of Mathematics (1968). City College of New York, B.E.E., 1947; New York University, M.S., 1950; Case Institute of Technology, Ph.D., 1964.*
- Chen, Hung T.**, Professor of Chemical Engineering (1966). National Taiwan University, B.S., 1958; M.S., 1962; Polytechnic Institute of New York, Ph.D., 1964.
- Chen, Rong-Yaw**, Associate Professor of Mechanical Engineering (1966). National Taiwan University, B.S., 1957; University of Toledo, M.S., 1963; North Carolina State University, Ph.D., 1966.*
- Cheng, Su Ling**, Associate Professor of Civil and Environmental Engineering (1966). Purdue University, B.S., 1959; M.S., 1962; University of Florida, Ph.D., 1966.*
- Cheremisinoff, Paul N.**, Associate Professor of Environmental Engineering (1973). Pratt Institute, B.Ch.E., 1949; Stevens Institute of Technology, M.S., 1952.
- Chow, Chung-Wei**, Associate Professor of Electrical Engineering (1960-62). Chiao-Tung University, B.S., 1947; Oregon State College, M.S., 1960.
- Ciesla, Matthew**, Associate Professor of Applied Mechanics (1957). Newark College of Engineering, B.S.M.E., 1957; M.S.M.E., 1959; New York University, Ph.D., 1968.*
- Cochin, Ira**, Associate Professor of Mechanical Engineering (1964). City College of New York, B.S., 1949; New York University, M.S., 1952; The Cooper Union, Ph.D., 1969.
- Cohen, Simon**, Assistant Professor of Mathematics (1974). Polytechnic Institute of Brooklyn, B.S., 1964; M.S., 1966; Ph.D., 1971.
- Cornely, Roy H.**, Assistant Professor of Electrical Engineering (1971). Drexel Institute, B.S., 1960; University of Pennsylvania, M.S., 1962; Rutgers University, Ph.D., 1972.
- Craig, Robert J.**, Assistant Professor of Civil Engineering (1975). Purdue B.S.C.E., 1966; M.S.C.E., 1969; Ph.D., 1973.
- Dauerman, Leonard**, Associate Professor of Chemistry (1969). City College, B.S., 1953; Purdue, M.S., 1955; Rutgers University, Ph.D., 1962; Rutgers Law School, J.D., 1973.
- De Lucia, Robert**, Assistant Professor of Electrical Engineering (1967). Stevens Institute of Technology, B.S., 1961; M.S., 1963; Ph.D., 1971.*
- Denno, Khalil I.**, Professor of Electrical Engineering (1969). University of Baghdad, B.S., 1955; Rensselaer Polytechnic Institute, M.S., 1959; Iowa State University, Ph.D., 1967.*
- Deutschman, Aaron D.**, Associate Professor of Mechanical Engineering (1963). Polytechnic Institute of Brooklyn, B.M.E., 1943; M.M.E., 1947; New York University, M.S., 1968.
- Deutschman, Harold**, Professor of Civil and Environmental Engineering (1972). City College of New York, B.S.C.E., 1961; University of Missouri, M.S., 1962; Northwestern University, Ph.D., 1969.
- Dickey, Donald W.**, Professor of Electrical Engineering (1949). Pennsylvania State, B.S., 1940; Columbia University, M.S., 1948.*
- Dresnack, Robert**, Professor of Civil and Environmental Engineering (1966). City College of New York, B.S.C.E., 1961; M.S.C.E., 1963; New York University, Ph.D., 1966.*
- Droughton, John V.**, Associate Professor of Mechanical Engineering and Associate Chairman for Graduate Studies (1960). Rutgers University, B.S., 1959; Newark College of Engineering, M.S., 1962; Rutgers University, Ph.D., 1969.
- Edelbaum, George**, Assistant Professor of Economics (1969). New York University, B.S., 1967; Columbia University, M.D., 1969.
- Farber, Elliot**, Associate Professor of Physics (1967). Brooklyn College, B.S., 1954; Columbia University, M.S., 1956; Stevens Institute of Technology, Ph.D., 1966.
- Fink, Tobin**, Associate Professor of Physics (1966). University of Colorado, B.S., 1959; M.S., 1961; Rutgers University, Ph.D., 1968.
- Flatow, Paul**, Associate Professor Mathematics (1963). Columbia University, B.S.E.E., 1947.
- Florio, Pasquale J., Jr.**, Assistant Professor of Mechanical Engineering (1966). Newark College of Engineering, B.S., 1959; M.M.E., 1960; New York University, Ph.D., 1967.
- Foster, Achilles, E.**, Professor of Mathematics and Assistant Chairman of Mathematics Department (1952). University of Tennessee, B.S., 1943; M.A., 1944; University of Kentucky, Ph.D., 1951.
- Frank, Joseph**, Assistant Professor of Electrical Engineering (1968). City College of New York, B.S., 1952; Columbia University, M.S., 1960; Brooklyn Polytechnic, Ph.D., 1975.*
- Gaal, Richard A.**, Assistant Professor of Mechanical Engineering (1955). Newark College of Engineering, B.S., 1955; M.S.M.E., 1957; New York University, M.S. (Aero), 1959.
- Gage, Howard**, Assistant Professor of Industrial Engineering (1972). City College of New York, B.M.E., 1960; New York University, M.M.E., 1965; Ph.D., 1972.
- Goldstein, Irving R.**, Professor of Management Engineering (1947). Newark College of Engineering, B.S., 1939; Stevens Institute of Technology, M.S., 1947.*
- Golub, Eugene**, Associate Professor of Civil and Environmental Engineering (1968). Cooper Union, B.C.E., 1962; Columbia University, M.S., 1964; Polytechnic Institute of Brooklyn, Ph.D., 1969.
- Granik, Gerald**, Professor of Applied Mechanics (1952). Newark College of Engineering, B.S., 1950; M.S., 1954; Stevens Institute of Technology, M.S. (Math), 1958; Sc.D., 1965.
- Greenberg, Murray**, Associate Professor of Management Engineering (1970). Cooper Union, B.M.E., 1949; New York University, M.I.E., 1954; Dr. Eng. Sc., 1959.*
- Greenstein, Teddy**, Assistant Professor of Chemical Engineering (1967). City College of New York, B.Ch.E., 1960; M.Ch.E., 1962; New York University, Ph.D., 1967.
- Hanesian, Deran**, Professor of Chemical Engineering and Chairman of the Department of Chemical Engineering and Chemistry (1963). Cornell University, B.Ch.E., 1952; Ph.D., 1961.
- Heilgott, Roy B.**, Distinguished Professor of Economics and Chairman of the Organizational and Social Sciences Department (1968). City College of New York, B.S., 1948; Columbia University, M.A., 1949; New School for Social Research, Ph.D., 1957.
- Herman, Harry**, Professor of Mechanical Engineering (1964). The Cooper Union, B.M.E., 1948; Columbia University, M.S., 1956; Polytechnic Institute of Brooklyn, Ph.D., 1964.*
- Hrycak, Peter**, Professor of Mechanical Engineering (1965). University of Minnesota, B.S., 1954; M.S., 1955; Ph.D., 1960.
- Hsieh, Jui S.**, Professor of Mechanical Engineering (1960). Wuhan University, B.E., 1943; University of Kentucky, M.S., 1950; Ohio State University, Ph.D., 1955.
- Huang, Ching-Rong**, Associate Professor of Chemical Engineering (1966). National Taiwan University, B.S., 1954; Massachusetts Institute of Technology, M.S., 1958; University of Michigan, M.S. (Math), 1965; Ph.D., 1966.
- Jacobs, Richard M.**, Associate Professor of Industrial Engineering (1969). Syracuse University, B.S., 1949; M.S., 1952.*
- Jerome, Carl**, Assistant Professor of Mathematics (1974). City College of New York, B.S., 1965; Courant Institute, M.S., 1968; Ph.D., 1974.
- Kahn, Anthony**, Associate Professor of Industrial Relations (1964). Kwansai-Gakuin University (Japan), L.L.B., 1954; Kansai University (Japan), L.L.M., 1956; Tulane University, M.C.L., 1958; Yale Law School, L.L.M., 1962.
- Kappraff, Jay M.**, Assistant Professor of Mathematics (1974). Polytechnic Institute of Brooklyn, B.Ch.E., 1958; Iowa State University, M.S., 1960; New York University, Ph.D., 1974.
- Katzen, Martin**, Associate Professor of Mathematics (1963). City College of New York, B.S., 1960; M.S., 1964; City University of New York, Ph.D., 1968.
- Kebbekus, Barbara B.**, Assistant Professor of Chemistry (1974). Rosemont College, A.B., 1960; Pennsylvania State University, Ph.D., 1974.
- Khera, Raj P.**, Associate Professor of Civil and Environmental Engineering (1966). Ohio State University, M.S.; Northwestern University, Ph.D., 1967.*
- Kimmel, Howard S.**, Professor of Chemistry (1966). Brooklyn College, B.S., 1959; West Virginia University, M.S., 1961; City University of New York, Ph.D., 1967. Associate Chairman of the Department.

*Licensed Professional Engineer

- Kirchner, Robert P.**, Associate Professor of Mechanical Engineering (1962). Newark College of Engineering, B.S., 1962; M.S., 1964; Rutgers University, Ph.D., 1968.*
- Klapper, Jacob**, Professor of Electrical Engineering (1967). City College of New York, B.S., 1956; Columbia University, M.S., 1958; New York University Ph.D., 1965.*
- Konove, Carl**, Professor of Mathematics (1937). Newark College of Engineering, B.S.Ch.E., 1937; Montclair State College, M.A., 1941. Assistant Chairman of Mathematics Department.
- Kristol, David S.**, Assistant Professor of Chemistry (1966). Brooklyn College, B.S., 1958; New York University, M.S., 1966; Ph.D., 1969.
- Kuharetz, Boris**, Associate Professor of Physics (1959). Columbia University, B.S., 1951; M.S., 1961.
- Kuo, Marshall**, Professor of Electrical Engineering (1965). National Taiwan University, B.S., 1953; Texas A & M, M.S., 1958; University of Michigan, Ph.D., 1964.
- Kuperstein, Ira S.**, Assistant Professor of Civil and Environmental Engineering (1970). City College of New York, B.C.E., 1963; M.C.E., 1968; New York University, Ph.D., 1973.*
- Lambert, Donald G.**, Associate Professor of Chemistry (1967). Oklahoma State University, B.S., 1956; Virginia Polytechnic Institute, M.S., 1963; Ph.D., 1965.
- Landsman, Leon D.**, Associate Professor of Physics (1958). Columbia University, B.A., 1951; M.A., 1956.
- La Verda, Michael J.**, Associate Professor of Economics (1956). Upsala College, B.B.A., 1952; Rutgers University, M.B.A., 1954.
- Lehman, Frederick G.**, Distinguished Professor of Civil Engineering and Acting Dean of Newark College of Engineering (1947). City University of New York, B.C.E., 1938; Massachusetts Institute of Technology, S.M., 1939; Sc.D., 1960.*
- Levy, Martin J.**, Professor of Mechanical Engineering (1958). Pennsylvania State University, B.S.M.E., 1957; Newark College of Engineering, M.S.M.E., 1956; Stevens Institute of Technology, D.Sc., 1963.*
- Lieb, Murray, B.S.**, M.S., Ph.D.,*, Associate Professor of Mathematics.
- Lione, Michael**, Associate Professor of Mathematics (1954). University of Newark, B.A., 1942; New York University, M.S., 1950.
- Liskowitz, John W.**, Associate Professor of Environmental Engineering (1970). Rutgers University, B.S., 1952; Ph.D., 1962.
- Marpert, Mark**, Assistant Professor in Management Engineering (1969). The Cooper Union, B.S., 1967; Stevens Institute of Technology, M.S., 1970.*
- Marshall, Robert S.**, Associate Professor of Mechanical Engineering (1968). Stevens Institute of Technology, M.E., 1960; Polytechnic Institute of Brooklyn, M.S., 1964; Rutgers University, Ph.D., 1968.*
- Martin, James L.**, Associate Professor of Mechanical Engineering (1965). Virginia Military Institute, B.S.C.E., 1952; Rutgers University, M.S., 1957; Pennsylvania State University, Ph.D., 1964.*
- McCormick, John E.**, Associate Professor of Chemical Engineering (1962). Iowa State University, B.Sc., 1948; University of Cincinnati, Ph.D., 1957.*
- Meola, Robert R.**, Professor of Electrical Engineering (1947). Newark College of Engineering, B.S., 1946; Stevens Institute of Technology, M.S., 1949.
- Meyer, Andrew U.**, Professor of Electrical engineering (1965) studies in Germany, B.S., Northwestern University, M.S., 1958; Ph.D., 1961.*
- Michels, Walter J.**, Professor of Mechanical Engineering (1955). Polytechnic Institute of Brooklyn, B.M.E., 1946; M.S., 1953; Associate Chairman of the Department.*
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- Miller, Edward**, Professor of Mechanical Engineering (1948). Newark College of Engineering, B.S., 1948; University of Delaware, M.M.E., 1949; Columbia University, M. A., 1951; Stevens Institute of Technology, M.S., 1952; New York University, M.Aero.E., 1959.*
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- Winston, Joseph**, Associate Professor of Electrical Engineering (1949). Newark College of Engineering, B.S., 1943; Stevens Institute of Technology, M.S., 1949.*
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- Michalski, Gilbert, A.A.**, B.A., M.S. Adjunct Professor of Management Engineering.
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- Michalsky, Gilbert**, Adjunct Professor of Industrial and Management Engineering (1975). Pace, B.A., 1966.
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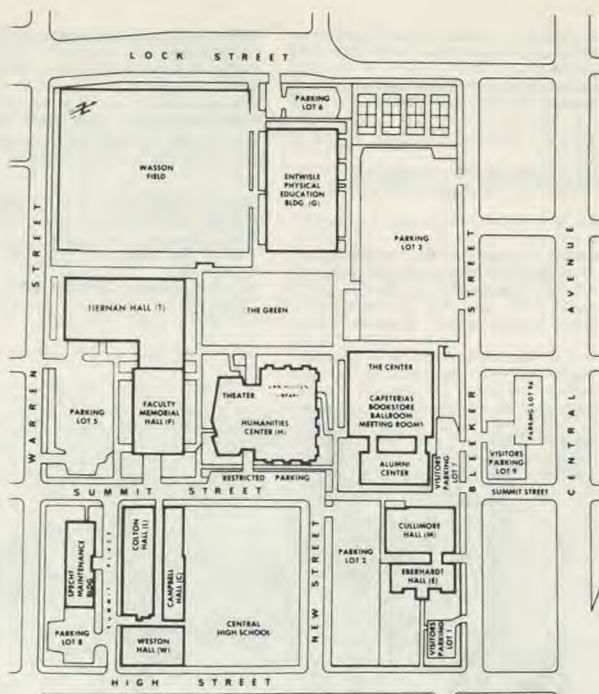
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6 CAMPBELL HALL (C) — 110 SUMMIT STREET

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9 COLTON HALL (L) — SUMMIT PLACE

10 FACULTY MEMEORIAL HALL (F) — 111 SUMMIT STREET

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