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# Newark College of Engineering Graduate Programs 1973-74 Academic Year

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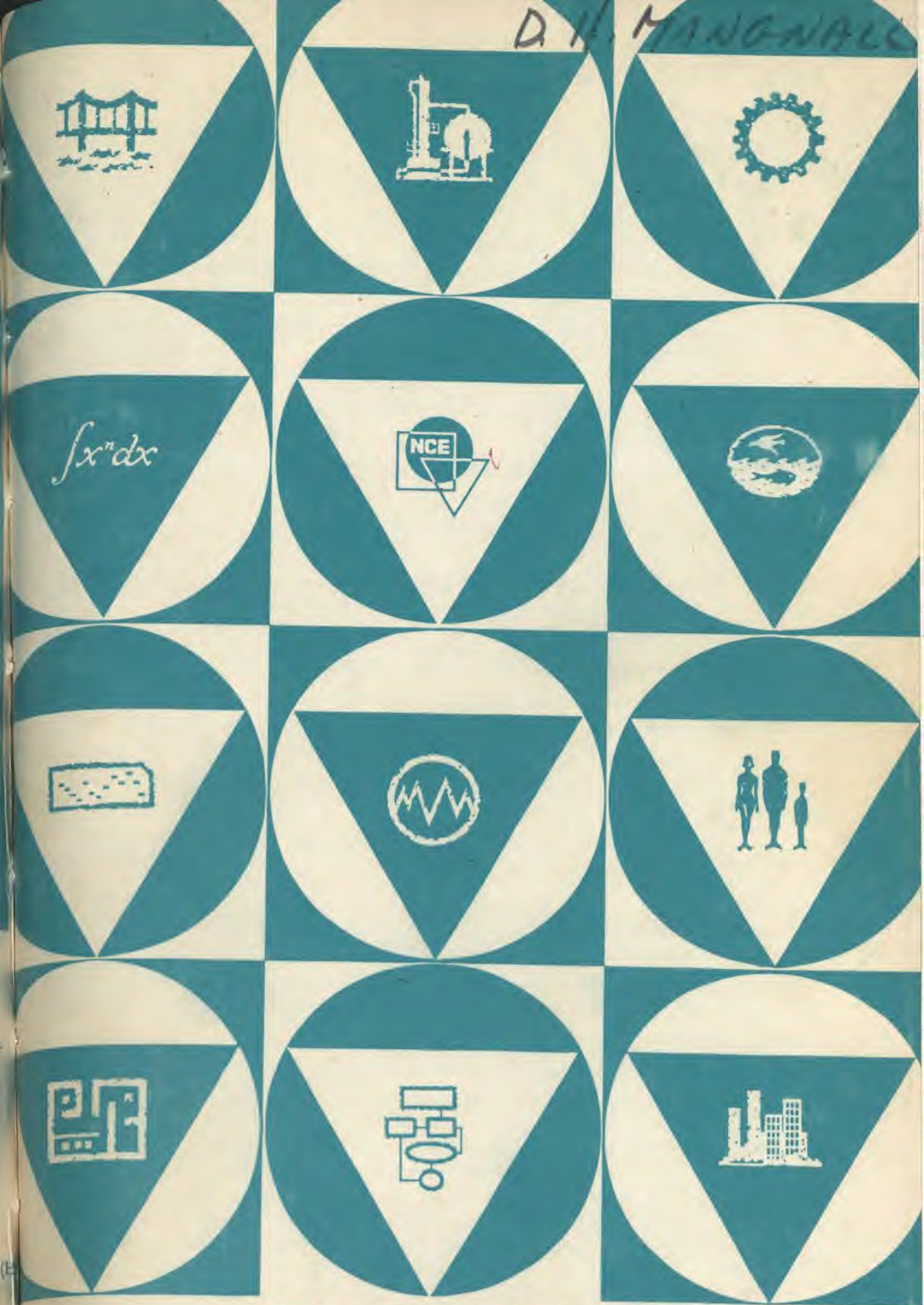


# NEWARK COLLEGE OF ENGINEERING

## GRADUATE PROGRAMS

## 1973-74 ACADEMIC YEAR

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# CATALOG OF GRADUATE PROGRAMS

## 1973-1974 ACADEMIC YEAR

Published by
The Board of Trustees of Schools for Industrial Education of Newark, N. J.

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# GRADUATE DIVISION CALENDAR: 1973-74

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

## 1973

| | |
|---|---|
| Registration — Fall Semester | In accordance with instructions to be issued. |
| Fall Semester Begins | September 12 |
| Last date on which all requirements are to be completed and "Application for Candidacy" filed for October 1 degree | September 14 |
| Awarding of October Degrees *in absentia* | October 1 |
| Columbus Day (Not a holiday) | October 8 |
| Veterans' Day (Not a holiday) | October 22 |
| Thanksgiving Holidays | November 21 to 24, inclusive |
| Christmas Holidays | December 20 to January 2, inclusive |

## 1974

| | |
|---|---|
| Fall Semester Ends | January ~~12~~ |
| Registration — Spring Semester | In accordance with instructions to be issued. |
| Spring Semester Begins | January 30 |
| Last date on which graduates may file "Application for Candidacy" for Spring Commencement | February 1 |
| Washington's Birthday Holiday | February 18 |
| Spring Vacation | March 18 to 23, inclusive |
| Good Friday Holiday | April 12 |
| Spring Semester Ends | May 21 |
| Memorial Day Holiday | May 27 |
| Commencement | May 31 |
| Registration — Summer Session* | June 7 |
| Summer Session Begins | June 10 |
| Independence Day Holiday | July 4 |
| Summer Session Ends | August 1 |

*The Summer Session announcement will be available on or about April 1.

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Associate Professor of Chemical Engrg.

GEORGE B. THOM, M.E., M.S., M.A.*
Professor Emeritus of Mech. Engrg.

STAN S. THOMAS, B.M.E., M.S., Ph.D.*
Associate Professor of Industrial Engrg.

NISSIM M. TOWFIK, B.S., A.M.
Associate Professor of Physics.

ARE TSIRK, B.C.E., M.C.E., Ph.D.*
Associate Professor of Civil Engrg.

ROBERT W. VAN HOUTEN, B.S.C.E., Sc.D., D.Eng., D.Sc., Litt.D., L.L.D.*
*President Emeritus*

ROMAN W. VORONKA, B.S., M.S.
Assistant Professor of Mathematics.

WERNER J. WENISCH, B.S., M.S., Ph.D.
Associate Professor of Chemistry.

GERALD WHITMAN, B.S., B.E.E., M.S., Ph.D.
Assistant Professor of Electrical Engrg.

GEORGE L. WILLIAMS, B.S., M.S.
Associate Professor of Applied Mech.

WILLIAM E. WILLIAMS, B.A., M.S., Ph.D.
Adjunct Professor of Mgt. Engrg.

CHARLES E. WILSON, JR., B.S., M.S.M.E., M.S.E.M., Ph.D.*
Associate Professor of Mechanical Engrg.

JOSEPH WINSTON, B.S., M.S.
Associate Professor of Electrical Engrg.

CARL WOLF, B.B.A., M.S.I.E., Ph.D.*
Associate Professor of Mgt. Engrg.

MAURO H. ZAMBUTO, Ph.D.
Professor of Electrical Engineering

FRIEDA ZAMES, B.S., M.S., Ph.D.
Assistant Professor of Mathematics.

THEODORE ZANER, B.S., M.A., Ed.D.
Professor of Organizational Sciences

HENRY ZATZKIS, B.S., M.S., Ph.D.
Distinguished Professor of Mathematics.

* *Licensed Professional Engineer.*

# GENERAL INFORMATION

Since 1919 Newark College of Engineering 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 this College was organized and is maintained to meet this demand; to fulfill its academic obligations to the field or science and technology and to fulfill, to an equal extent, its obligations to the public and industrial community of the city, state and nation.

By authorization of the New Jersey Board of Higher Education, the Board of Trustees of the College is empowered to confer the degrees of Master of Science in Chemical, Civil, Electrical, Environmental, Industrial, 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 mathematics, or who wish to diversify their engineering studies by including two engineering areas.

The College has also been authorized to offer the degree of Doctor of Engineering Science in the Departments of Chemical, Civil, 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 College, 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 degree programs described above, the Graduate Division administers a group of in-service institutes in chemistry, mathematics, and physics which are open to qualified high school teachers. Details of the offerings and admission information for this program may be found on page 115.

## COUNCIL FOR HIGHER EDUCATION IN NEWARK

Requirements for admission to the Graduate Division and the qualifications for the degrees are set forth in this catalog. Sufficient courses for the completion of all requirements are offered at the College, and it is expected that, in general, the work will be taken at this College or, with approval, at one of the neighboring publicly supported institutions which, together with Newark College of Engineering, comprise the Council for Higher Education in Newark. These include the Graduate School of Business Administration, School of Law (Newark) and Graduate School of Arts and Sciences of Rutgers—The State University, and the College of Medicine and Dentistry of New Jersey at Newark. In some cases, a limited number of credits may be accepted from other colleges.

## FOUNDATION AT NEWARK COLLEGE OF ENGINEERING

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 Newark College of Engineering. 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

### COLLEGE LIBRARY

The Robert W. Van Houten Library, centrally located on the campus, provides facilities for study, research and browsing. A collection of more than 84,000 volumes is available for student use, and 1,300 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 College Library, students have the privilege of borrowing material from the Newark Public Library and the Newark-Rutgers Library. Other libraries in the area, such as those of the Chemists' Club and the Engineering Societies, may be used for reference purposes. Interlibrary 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 College, 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 encouraged to use the computer in their course work and in research carried out by them in connection with their master's projects and theses, or doctoral dissertations. Many courses are offered at the College for training in the use of the computer.

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 and for help in determining appropriate solution methods for particular problems.

## 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 Newark College of Engineering. 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 Newark College of Engineering 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 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 the student's record but no credit will be granted for the course.

## GRADES

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

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

| | |
|---|---|
| Tuition (Residents fo 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

### ADMISSION 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 24.)

### THESIS FEES

Each student registering for thesis, dissertation, or professional project is charged a THESIS FEE of $5.00 at the time of registering.

Each student who submits a master's thesis is required to pay a MASTER'S THESIS FEE of $15.00 for binding the required three copies of his thesis.

### DOCTORAL DISSERTATION FEE

A DOCTORAL DISSERTATION FEE of $50.00 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 Newark College of Engineering 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 a 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 College 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 29.)

## FINANCIAL SUPPORT

### FULL-TIME STUDY

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 $3500, 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:

National Defense Education Act (Title IV) Fellowships
National Science Foundation Traineeships
NCE Alumni Association Doctoral Fellowships
Merck and Company Fellowships
Esso Education Foundation Fellowships
E. I. Du Pont de Nemours and Company, Inc. Fellowships
Englehard Memorial Fellowships
Diamond Shamrock Corp. Summer Fellowships
Graduate Assistantships
Teaching Fellowships
Research Assistantships

The College teaching fellows are supported in part by the Foundation at Newark College of Engineering, 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.

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

Newark College of Engineering 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 eight years subsequent to discharge; this time cannot be extended. Veterans who qualify under the above conditions should file an application form with the Veterans Administration.

# MASTER OF SCIENCE 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:

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 Mechanical Engineering
Master of Science in Computer Science
Master of Science

## 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 Master of Science in Environmental Engineering is an interdisciplinary engineering program open to students from a variety of undergraduate engineering backgrounds.

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.

## Engineering Science Programs

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*—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 sections of this catalog covering chemistry and mathematics. As individual student need dictates and as interest develops, adviser assignment and program design may be planned on a cross-departmental basis.

## 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 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 College 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.

| Systems Area | Department |
|---|---|
| Biomedical Systems | Electrical Engineering<br>Mechanical Engineering |
| Communications Systems | Computer Science<br>Electrical Engineering |
| Control Systems | Chemical Engineering<br>Electrical Engineering<br>Industrial and Management Engineering<br>Mechanical Engineering |
| Computer Application Systems | Computer Science |
| Information Systems | Computer Science |
| Management Systems | Industrial and Management Engineering |
| Man-Machine Systems | Industrial and Management Engineering |
| Machine Systems | Mechanical Engineering |
| Power Systems | Electrical Engineering<br>Mechanical Engineering |
| Processing Systems | Chemical Engineering<br>Computer Science |
| Transportation Systems | Civil and Environmental Engineering<br>Organizational and Social Sciences |
| Urban Systems | Civil and Environmental Engineering<br>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 College. In order to meet most effectively the educational needs of students with interests 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.

## ADMISSION

Applicants for admission to programs leading to a designated master's degree in one of the engineering fields (see Section A, page 19, 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 College. 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 16).

### 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 OF SCIENCE PROGRAMS

A. The degree, Master of Science in Chemical, Civil, Electrical, Industrial, or Mechanical Engineering or in Computer Science 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 100 to 199 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 100 to 199 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 100 to 199 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 100 to 199 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.

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 Newark College of Engineering. 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, Newark College of Engineering. 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 College 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 degree of Master of Science as conferred by this College a candidate must attain an average grade of B or better in his graduate course work. This requirement

will be 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 College's requirements for thesis submission is available at the College Bookstore.

# 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 College 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 forms 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 300 or 400 level. Course work at the 100 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, Newark College of Engineering 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 Newark College of Engineering.

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.

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.

An applicant offering transcripts and evidence of degrees from a foreign university must follow the procedure outlined in the preceding paragraph.

## 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 residence.
4. A minimum of thirty-six credits of original research or design, culminating in a dissertation which meets the publication requirements of the College. These requirements are outlined in a booklet available at the College 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

## 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 provided by the Graduate Division 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 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 25, 27 and 30 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.

### WITHDRAWALS FROM COLLEGE—SELECTIVE SERVICE

A student who is forced to withdraw from college because of induction by Selective Service is entitled to a *pro rata* refund as of the date of his induction. In order to obtain a refund in a case of induction, a student should submit a copy of his notice of induction with the notice of withdrawal.

### WITHDRAWALS FROM COLLEGE—GENERAL

Students who withdraw from College 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.

### REFUNDS

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

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

| *Date of Receipt of Application* | *Percentage Refund* |
|---|---|
| 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 College 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 College. Several of these which will be of interest to graduate students are listed below.

### AWARDING OF THE 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.

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 toward which he is working 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 the Registrar's office.

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

### 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 College requires that this card be exhibited on request by authorized persons.

### DRESS

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

# DEPARTMENTAL REQUIREMENTS AND COURSES OF INSTRUCTION

## CLASSIFICATION OF COURSES

The courses 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 100 to 199 indicate courses normally offered for students who require such background for admission to 200, 300, or 400 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 200 to 299 indicate intermediate graduate courses.

Numbers from 300 to 399 indicate advanced graduate courses which have as prerequisites other graduate courses in the same field.

Numbers from 400 to 499 indicate courses on the doctoral level.

The courses here listed are those which have been approved in accordance with the policies of the College. 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 College 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 301, Thesis (6).
2. ChE 226, Mathematical Methods in Chemical Engineering (3).
3. Three courses (totaling 9 credits) from among the following:

   ChE 211, Thermodynamics
   ChE 212, Kinetics of Reactions
   ChE 223, Heat Transfer
   ChE 224, Transport Phenomena I
   ChE 234, 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 301, Thesis (6).
2. Nine 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 226, Mathematical Methods in Chemical Engineering
ChE 234, Chemical Process Dynamics and Control
ChE 301, Thesis
ChE 341, Modern Methods in Process and Plant Design

At least two of the following:

ChE 211, Thermodynamics
ChE 212, Kinetics of Reactions
ChE 223, Heat Transfer
ChE 224, Transport Phenomena I

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

ChE 231, Equilibrium Stage Processes
ChE 312, Optimization of Chemical Reactor Systems
ChE 331, Advanced Techniques in Equilibrium Separations
ChE 335, Optimization in Process Design and Control
CS 100, Introduction to Systems Analysis
CS 261, Systems Simulation
CS 262, Model Analysis and Simulation
EM 250, Introductory Operations Research

IE 233, Linear Programming
SS 203, Econometrics

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

ChE 301, Thesis

Three courses from the following forming a related group:

ChE 211, Thermodynamics
ChE 212, Kinetics of Reactions
ChE 234, Chemical Process Dynamics & Control
ChE 312, Optimization of Chemical Reactor Systems
ChE 335, Optimization in Process Design & Control
ChE 341, Modern Methods in Process & Plant Design

Five courses from the following forming a related group:

CS 261, Systems Simulation
CS 262, Model Analysis & Simulation
EM 214, Planning and Control of Products & Processes
EM 234, Planning and Management of Industrial Research
EM 235, Management of Design and Development
EM 240, Distribution Logistics
ME 246, Analysis and Synthesis for Design
EM 250, Introductory Operations Research
IE 233, Linear Programming
SS 203, Econometrics
SyS 100, Introduction to Systems Analysis

## MASTER OF SCIENCE PROGRAMS IN ENGINEERING SCIENCE

As part of the College'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 102, Advanced Organic Chemistry I
2. Chem 220, Advanced Inorganic Chemistry
3. Chem 258, Advanced Physical Chemistry
4. ESc 301, Thesis (6)
5. Fifteen credits of electives, 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.

## 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 400, 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 prerequisites:

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 151. 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.

ChE 175. STATISTICAL THERMODYNAMICS. 3 *credits, 2nd sem.* JOFFE.

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 211. THERMODYNAMICS. 3 *credits, 1st or 2nd sem.* JOFFE and 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.

ChE 212. 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.

ChE 220. 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 1974-75 and alternate years.

ChE 223. HEAT TRANSFER. 3 *credits, 1st sem.* SALAMONE.

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 201 may be substituted for ChE 223 with departmental approval.

ChE 224. TRANSPORT PHENOMENA I. 3 *credits, 1st sem.* CHEN and HUANG.

Prerequisite: B.S. in ChE or M.E.; ChE 226 or equivalent advanced mathematics. ChE 226 may be taken concurrently, but only with permission of the instructor. An advanceed treatment of molecular and turbulent momentum, energy, and mass transport. Emphasis is on the mathematical description of physical mechanisms in momentum and energy transport.

ChE 226. Mathematical Methods in Chemical Engineering. 3 *credits, 1st or 2nd 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 exchangers, and the general development of mathematical expressions in engineering applications.

ChE 228. Biochemical Engineering. 3 *credits, 2nd sem.* Greenstein.

Prerequisite: B.S. in ChE. The course covers the application of chemical engineering to biological processes. 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 1973-74 and alternate years.

ChE 231. Equilibrium Stage Processes. 3 *credits, 1st sem.* Cecchetti.

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 control are also discussed.

Offered 1974-75 and alternate years.

ChE 234. Chemical Process Dynamics and Control. 3 *credits, 2nd sem.* Perna and Chen.

Prerequisite: Undergraduate process dynamics or process control; ChE 226 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.

ChE 240. Chemical Process Development. 3 *credits, 1st or 2nd sem.* Keeffe.

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.

ChE 241. 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 the 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.

ChE 245. POLYMER ENGINEERING I. 3 *credits, 1st sem.* HAAS.

Prerequisite: B.S. in ChE., or B.S. in M.E. and Chem 140. A fundamental consideration of rheology. Non-Newtonian flow, models for non-Newtonians. Treatment of rheometers and rheometry. Behavior of viscoelastic and time-dependent fluids. Heat and mass transfer in molten or thermally softened polymers. Thermodynamic behavior of polymers with temperature and pressure.

Offered 1973-74 and alternate years.

ChE 246. POLYMER ENGINEERING II. 3 *credits, 2nd sem.* HAAS.

Prerequisite: ChE 245 or equivalent. Application of rheology, heat transfer, mass transfer and thermodynamics to the design of polymer processing equipment. Detailed consideration of extruders, calendering equipment, injection molders, other types of molding units, and other processing devices.

Offered 1973-74 and alternate years.

ChE 256. CATALYSIS. 3 *credits, 1st sem.* KREPS.

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 1973-74 and alternate years.

ChE 285. UNIT OPERATIONS FOR INDUSTRIAL WASTE TREATMENT. 3 *credits, 2nd sem.* PERNA.

Prerequisites: ChE 151 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 application of filtration methods, water-air processes for cooling and drying, adsorption and ion exchange.

ChE 286 INDUSTRIAL WASTE AND CONTROL. 3 *credits, 2nd sem.* LISKOWITZ.

Prerequisites: EnE 102 and ChE 285 (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.

ChE 301. 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 a 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.*

Thesis fee: $5.00 per semester in addition to tuition. If the use of laboratory facilities or equipment is necessary, a $50.00 deposit must be maintained.

ChE 311. PHASE EQUILIBRIUM. 3 *credits, 2nd sem.* TASSIOS.

Prerequisite: ChE 211. 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 1973-74 and alternate years.

ChE 312. Optimization of Chemical Reactor Systems. 3 *credits, 1st sem.* Hanesian.

Prerequisites: ChE 212, 226. 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 1974-75 and alternate years.

ChE 325. Transport Phenomena II. 3 *credits, 2nd sem.* Huang.

Prerequisite: ChE 224. A continuation of ChE 224 with emphasis on mass transport and on the evaluation of transport properties from kinetic theory considerations.

Offered 1973-74 and alternate years.

ChE 326. Applied Fluid Mechanics. 3 *credits, 2nd sem.* Huang.

Prerequisite: ChE 224. 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 1974-75 and alternate years.

ChE 331. Advanced Techniques in Equilibrium Separations. 3 *credits, 2nd sem.* Cecchetti.

Prerequisite: ChE 231. 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 1974-75 and alternate years.

ChE 335. Optimization in Process Design and Control. 3 *credits, 1st sem.* Berger.

Prerequisites: ChE 226 and ChE 234 or equivalents. Mathematical development of optimization techniques with applications to problems in chemical process 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 multistage chemical processes such as cross-current extraction and a stirred tank reactor sequence.

Offered 1973-74 and alternate years.

ChE 341. Modern Methods in Process and Plant Design. 3 *credits, 1st sem.* Roche.

Prerequisites: Previous course in process or plant design; ChE 211, 212, and 226. 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 1974-75 and alternate years.

ChE 357. CATALYTIC REACTOR DESIGN. *3 credits, 2nd sem.* KREPS.

Prerequisites: ChE 212, 256, and either ChE 223 or 224. 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 1973-74 and alternate years.

ChE 400. 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.

Thesis fee: $5.00 per semester in addition to tuition. 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 401. 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 ChE 400 unless requirement is waived, in writing, by dissertation adviser. Open to all students registered for ChE 301.*

Seminar fee: $27.00 per semester.

ChE 403. 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.

Thesis fee: $5.00 per semester in addition to tuition. 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 102. 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 intermediates (cations, anions, radicals and carbenes), and spectroscopy.

Chem 140. INTRODUCTION TO POLYMERS. 3 *credits, 1st sem.* SNYDER and WENISCH.

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.

Chem 151. BIOCHEMISTRY. 3 *credits, 2nd sem.* KRISTOL and SHILMAN.

Prerequisites: Undergraduate 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.

Chem 202. 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 1973-74 and alternate years.

Chem 203. ADVANCED ORGANIC CHEMISTRY LABORATORY I. 3 *credits, 1st sem.* WENISCH 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: $30.00.

Chem 206. PHYSICAL ORGANIC CHEMISTRY. 3 *credits, 1st sem.* SNYDER.

Prerequisite: Chem 102 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 1974-75 and alternate years.

Chem 208. 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.

Chem 210. 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 radioisotope utilization, calculations involved in designing a tracer experiment, as well as a study of specific application of radioisotopes to industrial problems.

Offered 1974-75 and alternate years.

Chem 211. RADIOISOTOPES LABORATORY. 3 *credits, 2nd sem.*

Prerequisite: Modern physics. The objective of the course is to establish a foundation in the field of radioisotopes for research and industry. It encompasses the study of counting systems: Geiger-Muller, scintillation, proportional, and fast and slow neutron counters. Application of these systems permits determination of nuclear processes: alpha decay, beta emission, gamma ray spectroscopy and neutron flux distribution. Isotopes of relatively short half-lives are prepared by activation experiments using a five-curie Pu-Be source in a neutron howitzer. These, and additional long-lived isotopes, are used to determine their nuclear properties. Area surveying and decontamination methods, using portable detection and monitoring equipment, acquaint the student with the theory and practices of radiological safety. Experiments will be chosen which are of particular interest to the chemist or chemical engineer.

**Laboratory fee: $30.00.**

Offered 1973-74 and alternate years.

Chem 220. 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.

Chem 221. 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 1974-75 and alternate years.

Chem 230. ADVANCED ANALYTICAL CHEMISTRY. 3 *credits, 1st sem.* DAUERMAN.

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 1973-74 and alternate years.

Chem 240. POLYMER CHEMISTRY. 3 *credits, 1st sem.* WENISCH 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 140 will not be granted degree credit for Chem 240.*

Chem 241. POLYMER PROPERTIES. 3 *credits, 2nd sem.* WENISCH.

Prerequisite: Chem 140 or 240 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 1974-75 and alternate years.

Chem 243. POLYMER LABORATORY. 3 *credits, 1st sem.* SNYDER and WENISCH.

Prerequisite: Chem 240 or 241. Experiments will be selected to illustrate the various methods that are used to prepare and characterize synthetic polymers. Preparations will include standard condensation and preradical types together with stereospecific polymerization. Characterization will include methods for determining molecular weight, glass transition temperature, cross-link density, creep, stress-relaxation, etc.

Laboratory fee: $30.00.

Chem 244. FUNDAMENTALS OF ADHESION. 3 *credits, 1st sem.* SNYDER.

Prerequisite: Chem 140 or 240 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, adsorption of polymers on surfaces, mechanisms of adhesion, bulk properties of the adhesives, and rheology of polymers used as adhesives.

Offered 1973-74 and alternate years.

Chem 258. 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.

Chem 259. ATOMIC AND MOLECULAR STRUCTURE. 3 *credits, 2nd sem.* KIMMEL.

Prerequisite: Chem 258 or equivalent. A course concerned with atomic and molecular structure and properties, and the relationships between structure and physical properties.

Offered 1973-74 and alternate years.

ESc 301. MASTER'S THESIS. 6 *credits. 1st* or 2 *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 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. 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.*

Thesis fee: $5.00 per semester in addition to tuition. 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 201, Civil Engineering Projects (3 credits); or CE 301, Master's Thesis (6 credits).
2. At least 18 credits of specialization, which include CE 201 or CE 301.
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 201, Civil Engineering Projects (3 credits); or CE 301, Master's Thesis (6 credits).
2. At least 12 credits of specialization, which include CE 201 or CE 301.
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, structural, urban or transportation engineering. Students interested in master's degree 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 with a major in urban systems leading to the Master of Science degree is the recommended objective of the graduate of an engineering curriculum or the holder of a degree in a physical science field, economics, or planning who has an interest in pursuing advanced study in urban analysis. This is a joint program of the Department of Civil and Environmental Engineering and the Department of Organizational and Social Sciences.

The applicant must offer evidence of high attainment in undergraduate studies, including an emphasis on analytical and quantitative approaches to problem-solving. Applicants are expected to have backgrounds that include familiarity with the calculus, statistics, and the computer.

Students opting for the program in urban systems must satisfy the general requirements for the master's degree as described on pages 19-20.

Various options depending on the student's background and interest are available within the envelope of the urban systems program. Some typical programs of study are listed below to aid in program planning:

URBAN ENGINEERING

CE 201—Civil Engineering Projects
EM 250—Introductory Operations Research
EnE 222—Air Pollution Control
EnE 261—Urban Systems Engineering
EnE 265—Land Use Planning
EnE 361—Urban Transportation Planning
Math 261—Mathematical Statistics
SS 171—Urban Social Structure
SS 203—Econometrics
SS 262—Economic Analysis of Urban Areas

URBAN SYSTEMS MANAGEMENT

CE 201—Civil Engineering Projects
EM 202—Introduction to Management Science
EnE 261—Urban Systems Engineering
EnE 265—Land Use Planning
Math 261—Mathematical Statistics
OS 201—Industrial Relations and Public Planning
OS 223—Psychology in Engineering
OS 224—Methods of Research in the Behavioral Sciences
SS 171—Urban Social Structure
SS 262—Economic Analysis of Urban Areas

URBAN PLANNING

CE 201—Civil Engineering Projects
EM 250—Introductory Operations Research
EnE 222—Air Pollution Control
EnE 261—Urban Systems Engineering
EnE 265—Land Use Planning
EnE 361—Urban Transportation Planning
Math 261—Mathematical Statistics
OS 224—Methods of Research in the Behavioral Sciences
SS 171—Urban Social Structure
SS 262—Economic Analysis of Urban Areas

## 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 or 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 28-30. 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 109. 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 studied with particular emphasis on the assumptions, limitations and applications to actual problems.

Offered 1974-75 and alternate years.

Mech 206. THEORY OF ELASTICITY. 3 *credits, 2nd sem.* GRANIK.

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 1974-75 and alternate years.

CE 171. STRUCTURAL MODEL ANALYSIS. 3 *credits, 1st sem.* MONASA.

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 1974-75 and alternate years.

CE 185. 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 1974-75 and alternate years.

CE 201. 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 201 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 301.

CE 237. REINFORCED CONCRETE DESIGN I. 3 *credits, 1st sem.* SALEK.

Prerequisite: An undergraduate course in the theory and design of reinforced concrete. A review of basic concepts of elastic and ultimate load 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.

CE 238. REINFORCED CONCRETE DESIGN II. 3 *credits, 2nd sem.* SALEK.

Prerequisite: CE 237. 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 1974-75 and alternate years.

CE 261. 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 1973-74 and alternate years.

CE 262. 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 1973-74 and alternate years.

CE 263. 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 1974-75 and alternate years.

CE 264. DEEP FOUNDATIONS. 3 *credits, 2nd sem.* Department Faculty.

Prerequisite: Undergraduate course in soil mechanics. Covers the 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 1974-75 and alternate years.

CE 269. 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 1973-74 and alternate years.

CE 271. 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 nonprismatic members are developed. These methods are applied to continuous beams, frames, arches, rings and trusses. Computer methods are introduced.

CE 274. STRUCTURAL DYNAMICS. 3 *credits, 2nd sem.* TSIRK.

Prerequisites: Undergraduate vibration analysis and CE 271. 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 1974-75 and alternate years.

CE 281. 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.

CE 284. PROJECT PLANNING AND CONTROL. 3 *credits, 2nd sem.* Department Faculty.

Prerequisite or corequisite: CE 281. 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 1973-74 and alternate years.

CE 301. 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.*

Thesis fee: $5.00 per semester in addition to tuition. If the use of laboratory facilities or equipment is necessary, a $25.00 deposit must be maintained.

CE 335. PLASTIC ANALYSIS AND DESIGN. 3 *credits, 1st sem.* TSIRK.

Prerequisite: CE 271. 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 1974-75 and alternate years.

CE 336. ANALYSIS AND DESIGN OF SHELL STRUCTURES. 3 *credits, 2nd sem.* MONASA.

Prerequisites: CE 237 and 271. 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 1973-74 and alternate years.

CE 338. MATRIX METHODS IN STRUCTURES. 3 *credits, 2nd sem.* STACK-STAIKIDIS.

Prerequisite: CE 271. 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 1974-75 and alternate years.

CE 351. EARTH STRUCTURES. 3 *credits, 1st sem.* KHERA.

Prerequisite: CE 262. 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 1973-74 and alternate years.

CE 352. SEEPAGE AND WELL ANALYSIS. 3 *credits, 2nd sem.* MONAHAN.

Prerequisite: CE 261. 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 1973-74 and alternate years.

CE 353. SOILS DYNAMICS. 3 *credits, 1st sem.* CHAN.

Prerequisites: CE 261, 262. 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 1974-75 and alternate years.

CE 354. SOIL RHEOLOGY. 3 *credits, 2nd sem.* CHAN.

Prerequisites: CE 261, 262. 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 1974-75 and alternate years.

CE 370. Design of Metal Structures. 3 *credits, 2nd sem.* Monasa.

Prerequisite: CE 271. 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 1974-75 and alternate years.

CE 372. Design of Tall Buildings and Space Structures. 3 *credits, 2nd sem.* Tsirk.

Prerequisite: CE 272. 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 1973-74 and alternate years.

CE 374. Optimization of Structures. 3 *credits, 2nd sem.* Stack-Staikidis.

Prerequisites: CE 271, 338. 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 1973-74 and alternate years.

CE 375. Finite Element Methods in Structural and Continuum Mechanics. 3 *credits, 1st sem.* Tsirk.

Prerequisite: CE 111 or 222, CE 271 or 272. 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 1973-74 and alternate years.

CE 383. Systems in Building Construction. 3 *credits, 1st sem.* Peck.

Prerequisite: CE 281. The study of the interrelation between the design and construction of building structures. The concepts of modular construction and industrialized building and their combatibility with conventional methods of construction are considered.

Offered 1973-74 and alternate years.

CE 384. Methods Improvement in Construction. 3 *credits, 2nd sem.* Peck.

Prerequisite: CE 281. 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 1974-75 and alternate years.

CE 400. 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.

Thesis fee: $5.00 per semester in addition to tuition. 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.

CE 401. 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 400 unless requirement is waived, in writing, by dissertation adviser.*

Seminar fee: $27.00 per semester.

CE 403. 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.

Thesis fee: $5.00 per semester in addition to tuition. 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 102. ENVIRONMENTAL CHEMISTRY. 3 *credits, 1st or 2nd sem.* SONGONUGA 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.

EnE 201. 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 area is stressed.

Offered 1974-75 and alternate years.

EnE 204. ENVIRONMENTAL MICROBIOLOGY. 3 *credits, 1st or 2nd sem.* DRESNACK and LISKOWITZ.

Prerequisite: EnE 102 (May be taken concurrently). Biological and microbiological principles applicable to environmental and sanitary engineering are presented. Bacteriological examinations of water and wastewater are made in the laboratory.

Laboratory fee: $20.00.

EnE 205. POLLUTION ANALYSIS LABORATORY. 3 *credits, 1st sem.* TRATTNER.

Prerequisite: One year of undergraduate general chemistry. This course is designed to permit students to study and apply physical chemical methods of monitoring, detecting and controlling pollutants in the

major environmental areas of air, water and soil. Standardized procedures for sampling and determining organic and inorganic pollutants are studied and utilized.

Laboratory fee: $20.00.

EnE 206. POLLUTION: CHEMISTRY AND ECOLOGY. 3 *credits, 2nd sem.* TRATTNER.

Prerequisite: One year of undergraduate general chemistry. This course considers the nature and affects 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. Anti-pollution legislation is considered.

EnE 216. PHYSICAL AND CHEMICAL TREATMENT. 3 *credits, 2nd sem.* DRESNACK.

Prerequisite: EnE 102. 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 1974-75 and alternate years.

EnE 218. BIOLOGICAL TREATMENT. 3 *credits, 2nd sem.* Department Faculty.

Prerequisites: EnE 102, 204. 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.

EnE 219. ANALYSIS OF RECEIVING WATERS. 3 *credits, 1st sem.* DRESNACK.

Prerequisites or corequisites: EnE 102 and 204. 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 220. SOLID WASTE DISPOSAL SYSTEMS. 3 *credits, 2nd sem.* SONGONUGA.

Prerequisite: EnE 201. 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 1974-75 and alternate years.

EnE 222. AIR POLLUTION CONTROL. 3 *credits, 2nd sem.* LISKOWITZ.

Prerequisite: EnE 102 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.

Offered 1974-75 and alternate years.

EnE 223. WATER AND WASTEWATER ANALYSIS. 3 *credits, 1st sem.* CHENG and TRATTNER.

Prerequisites or corequisites: EnE 102 and 204. 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.

EnE 225. ADVANCED PROCESSES IN WATER POLLUTION CONTROL. 3 *credits, 1st sem.* OLENIK.

Prerequisites: EnE 223, 216, 218. Through the use of detailed laboratory experiments, various unit operations are studied. The unit operations considered are sedimentation, coagulation, and floculation, 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 advanced bench-scale laboratory procedures. Advanced design and synthesis are considered.

Laboratory fee: $20.00.

EnE 245. OPEN CHANNEL FLOW. 3 *credits, 1st sem.* DISKO.

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, and flood routing are considered. Application is made to natural rivers and estuaries.

Offered 1974-75 and alternate years.

EnE 246. HYDROLOGY. 3 *credits, 2nd sem.* DISKO and DRESNACK.

Prerequisite: CE 245 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 1974-75 and alternate years.

EnE 261. 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 1973-74 and alternate years.

EnE 263. TRAFFIC FLOW THEORY. 3 *credits, 1st sem.* KUPERSTEIN.

Prerequisites or corequisites: 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.

EnE 264. TRAFFIC ENGINEERING. 3 *credits, 2nd sem.* KRAFT and KUPERSTEIN.

Prerequisite: EnE 263. A course which studies the characteristics 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.

EnE 265. 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 of 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 1974-75 and alternate years.

EnE 266. MASS TRANSPORTATION SYSTEMS. 3 *credits, 2nd sem.* DEUTSCHMAN.

Prerequisite: EnE 263. An investigation of bus, rapid transit, commuter railroads, and airplane modes as related to integrated transportation systems. Existing equipment, economic, capacity, and terminal characteristics are discussed, as well as new systems and concepts. Long and short range modes are compared.

Offered 1974-75 and alternate years.

EnE 268. TRAFFIC SAFETY. 3 *credits, 2nd sem.* LEHMAN.

Prerequisite or corequisite: EnE 267. The course covers the characteristics of the driver-vehicle-road system and the applications of system behavioral principles to controls and designs for safety.

Offered 1973-74 and alternate years.

EnE 292. ENVIRONMENTAL IMPACT ANALYSIS. 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.

EnE 316. WATER RESOURCE SYSTEMS. 3 *credits, 2nd sem.* CHENG and DRESNACK.

Prerequisites: CE 217, 246. 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 1973-74 and alternate years.

EnE 345. ESTUARY AND COASTLINE HYDRAULICS. 3 *credits, 1st sem.* CHENG.

Prerequisite: CE 245. 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 1973-74 and alternate years.

EnE 361. URBAN TRANSPORTATION PLANNING. 3 *credits, 1st sem.* DEUTSCHMAN.

Prerequisite: EnE 265, 266. 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 1973-74 and alternate years.

EnE 362. TRANSPORTATION DESIGN. 3 *credits, 2nd sem.* KRAFT.

Prerequisite: EnE 361. Design problems which include airports, terminals, and highway intersections and interchanges are discussed.

Offered 1973-74 and alternate years.

# DEPARTMENT OF COMPUTER 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 thirty 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.

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

(1) CS 235, Computer Programming Languages.
(2) CS 300, Master's Project or CS 301, Master's Thesis.
(3) CS 310, 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 six credits in other departments.

### Areas of Specialization

Systems Design: CS 230, CS 231, CS 236, CS 251
Numerical Programming: Math 111, CS 221, CS 222

Formal Theory: CS 140, CS 240, CS 241
Systems Analysis: CS 100, CS 261, CS 262, CS 265

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

CS 230—Operating System Design
CS 231—Data Management System Design
CS 235—Computer Programming Languages
CS 236—Compiling System Design
CS 251—Data Communications
CS 261—Systems Simulation
CS 262—Model Analysis and Simulation
CS 300—Master's Project
CS 310—Computer Science Seminar
EE 232—Optimization Techniques
Math 261—Mathematical Statistics

Emphasis on special-purpose computing

CS 100—Introduction to System Analysis
CS 221—Numerical Analysis I
CS 222—Numerical Analysis II
CS 231—Data Management System Design
CS 235—Computer Programming Languages
CS 261—Systems Simulation
CS 300—Master's Project
CS 310—Computer Science Seminar
Math 111—Numerical Methods
Math 220—Matrix Theory
Math 261—Mathematical Statistics

Emphasis on computer systems theory

CS 140—Fundamentals of Logic and Automata
CS 235—Computer Programming Languages
CS 236—Compiling System Design
CS 240—Recursive Function Theory
CS 241—Formal Languages
CS 300—Master's Project
CS 310—Computer Science Seminar
EE 175—Introduction to Digital Circuits
EE 275—Synthesis of Digital Control Circuits
Math 220—Matrix Theory
Math 224—Abstract Algebra

## INFORMATION SYSTEM ANALYSIS

### Emphasis on management information systems

CS 230—Operating System Design
CS 231—Data Management System Design
CS 235—Computer Programming Languages
CS 261—Systems Simulation
CS 300—Master's Project
CS 310—Computer Science Seminar
IE 201—Measurement Methods for Management Systems
IE 203—Behavioral Science
IE 261—Man-Machine Systems
IE 269—Human Design Factors in Engineering
SS 203—Economics

### Emphasis on management and economics

CS 231—Data Management System Design
CS 235—Computer Programming Languages
CS 251—Data Communications
CS 261—Systems Simulation
CS 262—Model Analysis and Simulation
CS 300—Master's Project
CS 310—Computer Science Seminar
EM 293—Managerial Economics
IE 201—Measurement Methods for Management Systems
SS 203—Econometrics
SS 250—Cost-Benefit Analysis and Economic Decisions

### Emphasis on organizational systems

CS 231—Data Management System Design
CS 235—Computer Programming Languages
CS 251—Data Communications
CS 261—Systems Simulation
CS 262—Model Analysis and Simulation
CS 300—Master's Project
CS 310—Computer Science Seminar
IE 203—Behavioral Science
IE 261—Man-Machine Systems
OS 202—Manpower Planning and Mgt. Development
OS 277—Techniques of Executive Control

### Emphasis on quantitative managerial decision-making

CS 231—Data Management System Design
CS 235—Computer Programming Languages
CS 251—Data Communications
CS 261—Systems Simulation
CS 262—Model Analysis and Simulation
CS 300—Master's Project
CS 310—Computer Science Seminar
EM 202—Introduction to Management Science
EM 250—Introductory Operations Research
IE 205—Mathematical Programming in Management Science
IE 233—Linear Programming

## COMPUTER APPLICATION ANALYSIS

### Emphasis on Computer Communication Systems

CS 230—Operating System Design
CS 231—Data Management System Design
CS 235—Computer Programming Languages
CS 251—Data Communications
CS 265—Graph Theory
CS 300—Master's Project
CS 310—Computer Science Seminar
EE 256—Linear Systems
EE 261—Control System Components
EE 264—Discrete Systems
Math 268—Probability

### Emphasis on electromechanical component design

CS 221—Numerical Analysis I
CS 222—Numerical Analysis II
CS 230—Operating System Design
CS 251—Data Communications
CS 235—Computer Programming Languages
CS 300—Master's Project
CS 310—Computer Science Seminar
EE 256—Linear Systems
EE 261—Control System Components
ME 205—Analytical Methods in Machine Design
ME 218—Instrumentation

### Emphasis on traffic analysis

CS 221—Numerical Analysis I
CS 222—Numerical Analysis II
CS 235—Computer Programming Languages
CS 261—Systems Simulation
CS 262—Model Analysis and Simulation
CS 300—Master's Project
CS 310—Computer Science Seminar
EnE 266—Mass Transportation Systems
EnE 267—Traffic Engineering
EnE 268—Traffic Safety
Math 261—Mathematical Statistics

### Emphasis on design of chemical processes

CS 221—Numerical Analysis I
CS 222—Numerical Analysis II
CS 230—Operating System Design
CS 231—Data Management System Design
ChE 234—Chemical Process Dynamics and Control
ChE 240—Chemical Process Development
Chem 208—Instrumental Analysis
CS 235—Computer Programming Languages
CS 251—Data Communications
CS 300—Master's Project
CS 310—Computer Science Seminar

## COURSES OF INSTRUCTION

**CS 100.** 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 engineering problems chosen from different disciplines and introduces mathematical tools only as needed to find practical solutions to these problems. Includes topics from network and transmission lines, dynamic analysis of systems, transport processes, control theory, and dimensional analysis.

**CS 110.** 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.

**CS 115.** 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, through treatment of algorithm design, error analysis and debugging using advanced features of FORTRAN IV, a study of programming facilities available on the operating system, and other algorithmic languages. Students specializing in computer science may not take this course for credit.

**CS 140.** FUNDAMENTALS OF LOGIC AND AUTOMATA. 3 *credits, 1st sem.* Department Faculty.

Prerequisite: Undergraduate calculus. This course develops the methods and theory of logic and automata. Included are propositional calculus, semantical tableaux, qualification theory, finite-state machines, regular expressions, Kleene's theorem, and infinite state machines.

**CS 221.** NUMERICAL ANALYSIS I. 3 *credits, 1st sem.* FOX.

Prerequisite: Math 111 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.

CS 222. NUMERICAL ANALYSIS II. 3 *credits, 2nd sem.* FOX.

Prerequisite: Math 111 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.

CS 230. OPERATING SYSTEM DESIGN. 3 *credits, 1st sem.* MOSHOS.

Prerequisite: CS 110 or familiarity with organization of at least one computer system. An intensive study of computer operating system design. Job control and program preparation facilities for stand alone, multiprogramming, and multiprocessing systems.

CS 231. DATA MANAGEMENT SYSTEM DESIGN. 3 *credits, 2nd sem.* MOSHOS.

Prerequisite: CS 110 or familiarity with organization of at least one computer system. This is a companion course to CS 230. Included are design of input/output control, physical memory control, data management, and related topics.

CS 235. COMPUTER PROGRAMMING LANGUAGES. 3 *credits, 1st sem.* ANDERSON.

Prerequisite: CS 110 or familiarity with organization of at least one computer system. Theory and design of computer language systems. Included are formal definition and classification of languages according to their syntax and use, theory of syntax analysis, survey of procedure and problem oriented languages and their translators.

CS 236. COMPILING SYSTEM DESIGN. 3 *credits, 2nd sem.* MOSHOS.

Prerequisite: CS 235. An intensive study of compiler and object time system design. Included are design of lexical analysis, semantic generator, object time programs and systems for translator writing. Consideration is also given to code optimization, error reporting, debugging aids and pre- and post-processors.

CS 240. RECURSIVE FUNCTION THEORY. 3 *credits, 2nd sem.* BAILEY.

Prerequisite: CS 140 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 1972-73 and alternate years.

CS 241. FORMAL LANGUAGES. 3 *credits, 2nd sem.* BAILEY.

Prerequisite: CS 140 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 1973-74 and alternate years.

CS 251. DATA COMMUNICATIONS. 3 *credits, 2nd sem.* MOSHOS.

Prerequisite: CS 110 or familiarity with organization of at least one computer system. This course deals with the problems in designing data communication networks. Topics include the characteristics of common carrier facilities, encoding techniques for transmission, and surveys of terminal equipment, communication computers and their interfaces.

CS 261. SYSTEMS SIMULATION. 3 *credits, 1st sem.* FOX and SCHER.

Prerequisite: Statistics and knowledge of FORTRAN programming. An introductory study of computer simulation techniques used in the solution of engineering and systems problems. Topics include the formulation of a model for computer simulation solution, data gathering, parameter estimation, model validation and selected topics in methodology, such as the generation of random numbers from appropriate distributions and the analysis of simulation results. Computer languages used include FORTRAN, GPSS, as well as a digital-analog simulation language. Applications are selected from engineering and industrial systems.

CS 262. MODEL ANALYSIS AND SIMULATION. 3 *credits, 2nd sem.* FOX and SCHER.

Prerequisite: Introductory course in simulation. Emphasis on the design of simulation experiments, both with respect to validation of the model, and to the production and analysis of simulation results. The simulation language SIMSCRIPT II is the main computer programming language used, but various statistical and linear programming computer routines are employed in the analysis and comparative testing of models. Techniques used include spectral analysis of time series generated as results of simulation runs.

CS 265. 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 graph-theoretic models to engineering problems and the use of computers to represent and analyze these models.

CS 300. 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 in areas of basic Engineering Science who do not take ESc 301, Master's Thesis. The work will normally be initiated in a course in the Engineering 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 CS 310, Computer Science Seminar, concurrentiy, and to present their papers orally. A student whose work in ESc 300 is of exceptional quality may be permitted to extend the Master's Project into a Master's Thesis, ESc 301. 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.

CS 301. 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 CS 310, 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.*

Thesis fee: $5.00 per semester in addition to tuition. If the use of laboratory facilities or equipment is necessary, a $25.00 deposit must be maintained.

CS 310. COMPUTER SCIENCE SEMINAR. *No credit, 1st and 2nd sem.* Department Faculty.

Presentations covering active areas of research in computer 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. Seminar meetings are open to all NCE students and staff.

Seminar fee: $27.00 per semester.

CS 391. SELECTED TOPICS IN COMPUTER SCIENCE I. 3 *credits, 1st sem.* Department Faculty.

Prerequisites: CS 235, Math 261. This special interest course will be given when suitable interest develops. Advanced notice of forthcoming topics will be given.

CS 392. SELECTED TOPICS IN COMPUTER SCIENCE II. 3 *credits, 2nd sem.* De partment Faculty.

Prerequisites: CS 235, Math 261. A continuation of CS 391.

# 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 equations 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:

CS 110—Digital Computer Programming
EE 120—Electromagnetic Field Theory
EE 140—Electronic Circuits
EE 150—Circuit Analysis
EE 163—Introduction to Control Systems
EE 175—Introduction to Digital Circuits
EE 180—The Analog Computer as Used in Elec. Engrg.
Math 173—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 300—Master's Project or EE 301—Master's Thesis.
   2. EE 256—Linear Systems.
   3. Math 258—Operational Mathematics.

4. The 18 credits of specialization, which include EE 300 or EE 301 and EE 256, must be limited to no more than two related areas.
5. 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:
   1. EE 300—Master's Project or EE 301—Master's Thesis.
   2. EE 256—Linear Systems.
   3. Math 258—Operational Mathematics.
   4. The 15 credits of specialization, which include EE 300 or EE 301 and EE 256, must be limited to no more than two related areas.
   5. 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 integrated 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 239—Feedback Amplifiers I
EE 248—Wave Shape Control
EE 252—Network Theory I
EE 258—Integrated Circuits I
EE 339—Feedback Amplifiers II
EE 352—Network Theory II
EE 353—Electric Filter Design
EE 358—Integrated Circuits II

Area II. CONTROL SYSTEMS

ChE 234—Chemical Process Dynamics and Control
EE 232—Optimization Techniques
EE 261—Control System Components
EE 264—Discrete Systems
EE 266—Control System Laboratory
EE 273—Random Processes in Electrical Engineering I
EE 280—Analog Computers
EE 291—Large Power Control Systems
EE 365—Introduction to Nonlinear Systems
EE 366—Stability Theory of Nonlinear Systems
EE 466—Optimal Control Theory
EE 467—Stochastic Control Theory
ME 218—Instrumentation
ME 331—Adv. Control of Electro-Mechanical Networks

Area III. ELECTRONIC COMPUTER SYSTEMS

EE 232—Optimization Techniques
EE 248—Wave Shape Control
EE 250—Transistor Circuits
EE 264—Discrete Systems
EE 275—Design of Digital Control Circuits
EE 280—Analog Computer Techniques
EE 281—Digital Computer Methods in Electrical Engrg.
EE 282—Computer-Aided Network Design
EE 380—Hybrid Computation

Area IV. COMMUNICATION SYSTEMS

EE 222—Wave Propagation
EE 242—Communication Systems I
EE 246—Microwave Systems
EE 273—Random Processes in Electrical Engineering I
EE 342—Communication Systems II
EE 344—Communications System Design
EE 373—Random Processes in Electrical Engineering II

EE 375—Digital Communication
EE 376—Information Theory
EE 377—Statistical Decision Theory
EE 378—Algebraic Coding for Information Transmission
EE 379—Principles of Phase Lock and Frequency Feedback
EE 432—Seminar in Communication Systems

Area V. COMMUNICATION DEVICES

EE 222—Wave Propagation
EE 246—Microwave Systems
EE 250—Transistor Circuits
EE 258—Integrated Circuits I
EE 323—Theory of Guided Waves
EE 358—Integrated Circuits II
EE 446—Lasers and Masers

Area VI. FIELDS AND WAVES

EE 222—Wave Propagation
EE 323—Theory of Guided Waves
EE 348—Quantum Electronics
EE 349—Introduction to Quantum Field Theory
EE 424—Advanced Antenna Theory
EE 449—Radiation and Noise in Quantum Electronics

Area VII. ELECTRONIC SYSTEMS RELIABILITY

EE 239—Feedback Amplifiers I
EE 241—Reliability Problems in Electronics
EE 250—Transistor Circuits
EE 274—Noise in Electric Circuits
EE 451—Seminar on Reliability
Phys 211—Transistor Physics
Phys 310—Microelectric Physics

Area VIII. ELECTRIC POWER SYSTEMS

EE 210—Power System Steady-State Analysis
EE 211—Transients in Power Systems
EE 212—Computer Methods in Power System Analysis
EE 221—Protection of Power Systems
EE 260—Dynamics for Electromech. Energy Conversion
EE 270—Advanced Electromechanical Energy Conversion I
EE 292—Conduction in Plasma
EE 310—Economic Control of Interconnected Systems
EE 393—Stability Theory of Electric Power Systems
EE 395—Magnetohydrodynamic Power Generation
EE 490—Advanced Electromechanical Energy Conversion II

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 courses:

CS 100—Introduction to System Analysis
CS 230—Operating System Design
CS 231—Data Management System Design
CS 235—Computer Programming Languages
EnE 217—Water Pollution Control
EnE 261—Urban Systems Engineering
EnE 266—Mass Transportation Systems
EM 214—Planning and Control of Products & Processes
EM 240—Distribution Logistics
EM 250—Introductory Operations Research
IE 203—Behavioral Science
IE 205—Math. Programming in Management Science
ME 218—Instrumentation
ME 246—Analysis and Synthesis for Design

EnE 267—Traffic Engineering
EnE 268—Traffic Safety
ME 250—Noise Control
ME 251—Thermal Pollution of Water and Air
ME 331—Advanced Control of Electro Mechanical Networks

INTER-DISCIPLINARY SYSTEMS PROGRAM

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

Program 1

ChE 285—Unit Operations for Industrial Waste Treatment
EE 232—Optimization Techniques
EE 256—Linear Systems
EE 273—Random Processes in Electrical Engineering I
EE 300—Master's Project
EE 365—Introduction to Non-Linear Systems
EnE 217—Water Pollution Control
Math 258—Operational Mathematics
ME 250—Noise Control
ME 251—Thermal Pollution of Water and Air

Program 2

EE 232—Optimization Techniques
EE 256—Linear Systems
EE 264—Discrete Systems
EE 273—Random Processes in Electrical Engineering I
EE 300—Master's Project
EnE 263—Traffic Flow Theory
EnE 266—Mass Transportation Systems
EnE 267—Traffic Engineering
Math 261—Mathematical Statistics
Math 262—Statistical Inference

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

## DOCTORAL PROGRAM

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 research 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 300 and 400 levels 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, 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.

Should the 36 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 examination will be given only after the submission of the final draft dissertation.

### COURSES OF INSTRUCTION

EE 120. 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.

EE 140. ELECTRONIC CIRCUITS. 3 *credits, 2nd sem.*

Prerequisite: EE 150 or equivalent. Untuned electronic amplifiers, with linear and nonlinear circuits. Feedback amplifiers and oscillators. Amplitude modulation. Rectifiers and filters.

EE 150. 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.

EE 163. 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.

EE 175. 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.

EE 180. THE ANALOG COMPUTER AS USED IN ELECTRICAL ENGINEERING. 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 "set up" and solution checks are studied. The analog computer is utilized in engineering design and analysis.

EE 210. 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 the 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 1973-74 and 1976-77.

EE 211. 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 1975-76 and 1978-79.

EE 212. 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 1974-75 and 1977-78.

EE 221. PROTECTION OF POWER SYSTEMS. 3 *credits, 1st sem.*

Prerequisite: EE 210. 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, and heating and harmonic effects.

Offered 1974-75 and 1977-78.

EE 222. WAVE PROPAGATION. 3 *credits, 2nd sem.*

Prerequisite: Undergraduate field theory. Electromagnetic field theory; rectangular waveguides; the differential antenna; linear antennas; and antenna arrays are covered.

EE 232. OPTIMIZATION TECHNIQUES. 3 *credits, 1 sem.*

Prerequisite: Differential equations. Several analytic 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 1973-74 and alternate years.

EE 239. FEEDBACK AMPLIFIERS I. 3 *credits, 1st sem.*

Prerequisites: EE 140, EE 150, and Math 258 or equivalents. A course in the analysis and synthesis of electronic feedback systems. Elementary feedback review. Mathematical definition of feedback parameters. Transistors as feedback elements. Analysis and design criteria. Mathematical analysis of impedance, admittance, noise and distortion in feedback networks. Fractionated and external feedback gain. Non-linear feedback systems.

Offered 1974-75 and alternate years.

EE 241. RELIABILITY IN ELECTRONICS. 3 *credits, 1st sem.*

The 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. Effect of problems caused by switching time and recombination velocities in solid state are considered. For electron tubes cathodic failure mechanism are studied, along 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.

EE 242. 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, inter-channel crosstalk, and other parameters.

EE 246. 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 1974-75 and alternate years.

EE 248. WAVE SHAPE CONTROL. 3 *credits, 2nd 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.

EE 250. 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 252. NETWORK THEORY I. 3 *credits, 1st sem.*

Prerequisite: EE 256. The topics included are elements of topology, network matrices, network transformations using matrices, driving point and transfer impedance representation, analytic properties, properties of network functions, scattering parameters and synthesis of two-element-kind, single port networks.

EE 256. 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 of system problems are obtained.

EE 258. INTEGRATED CIRCUITS I. 3 *credits, 1st sem.*

Prerequisite: Undergraduate semiconductor circuits. Topics covered include characteristics of integrated circuit devices such as field-effect transistors and capacitors, bipolar transistors, and Shottky-barrier diodes; introduction to I.C. circuit fabrication technologies; operational amplifier design and applications; TTL, ECL, MOS, and complementary MOS logic circuit design.

Offered 1973-74 and alternate years.

EE 260. DYNAMICS OF ELECTROMECHANICAL ENERGY CONVERSIONS. 3 *credits, 2nd sem.*

Prerequisites: EE 120 and undergraduate electric machines. The course covers dynamic behavior of lumped parameter systems, study of a continuum electromechanics, such as magnetic diffusion and the stress-tensor; and dynamics of electromechanical continua in two and three dimensional systems.

Offered 1974-75 and 1977-78.

EE 261. CONTROL SYSTEM COMPONENTS. 3 *credits, 2nd sem.*

Prerequisite: EE 163. The steady-state and transient characteristics of commonly used magnetic components such as servomotors, rate generators, synchros, eddy-current and inertia dampers, polarized torquemotors, hysteresis clutches and particle clutches are covered. Emphasis is placed on problems affecting the performance of the complete system of which the component is a part.

Offered 1973-74 and alternate years.

EE 264. Discrete Systems. 3 *credits, 1st sem.*

The fundamental aspects of discrete systems, including their state-variable representation, the Z-transform and advanced Z-transform, are introduced and applied to the analysis and synthesis of sampled-data control systems. Included are discussions on pulse modulation, sampling, predictors and computer-control systems. Stability of discrete systems is considered, as well as design and performance for both deterministic and stochastic signals.

Offered 1974-75 and alternate years.

EE 266. Control System Laboratory. 3 *credits, 2nd sem.*

Prerequisite: EE 163 or equivalent. A labortory 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 1974-75 and alternate years.

EE 270. 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 1975-76 and 1978-79.

EE 273. Random Processes in Electrical Engineering I. 3 *credits, 1st sem.*

This course is an introduction to random processes; Axiomatic formulation of probability theory; discussion of random variables and random processes; statistical averages, characteristic functions; time dependent random variables; ensemble statistics; concepts of stationarity and ergodicity; correlation coefficients and correlation and autocorrelation functions and their relation to power spectra; Gaussian processes; response of linear systems to random inputs; detection of signals in noise; optimum filtering and Wiener filters; signals and noise in communications systems.

Offered 1974-75 and alternate years.

EE 274. Noise in Electrical Circuits. 3 *credits, 2nd sem.*

Prerequisite: EE 140. The common types of noise classified as to origin and characteristics; methods of analytical evaluation and procedures for measurement; effects on amplifier sensitivity and the design of minimal noise circuits.

Offered 1974-75 and alternate years.

EE 275. Synthesis of Digital Control Circuits. 3 *credits, 2nd sem.*

Prerequisite: Undergraduate course in digital circuits. Advanced design techniques for combinational circuits including multi-input and 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.

EE 280. Analog Computer Techniques. 3 *credits, 1st sem.*

Prerequisite: EE 180, or undergraduate course in analog computation. Topics considered include: solution of linear, adjoint, and differential equations; nonlinear systems of linear and differential equations; generation of fundamental sets; matrix functions; generation of explicit, implicit and bivariable functions; transfer functions in differential form with initial conditions without use of differentiators; error reduction techniques; optimization procedures and concepts of Lyapunov.

EE 281. DIGITAL COMPUTER METHODS IN E.E. 3 *credits, 2nd sem.*

Prerequisite: EE 150 or equivalent. The course assists the engineering student in using and evaluating the formalized discrete procedures in solving electrical engineering problems. Illustrative topics as iterated networks, higher order side band modulation, voltage controlled capacitors, and response of nonlinear circuits with initial conditions are considered.

EE 282. COMPUTER-AIDED NETWORK DESIGN. 3 *credits, 2nd sem.*

Prerequisites: EE 256 and knowledge of at least one scientific-oriented computer language, such as Fortran. The object of this course is to study the computational techniques upon which some of the basic digital-computer network-analysis programs depend. Included in the course are a review of basic network topology, topological matrices, topological network formulas, flowgraph techniques, state-variable methods, and Branin's link-at-a-time algorithm. Also considered are problems of integration and eigenvalue calculation. Application of these techniques in such programs as ECAP, CALAHAN, CORNAP, and NASAP is discussed.

Offered 1974-75 and alternate years.

EE 291. LARGE POWER CONTROL SYSTEMS. 3 *credits, 2nd sem.*

Prerequisites: EE 160, 163 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 serves 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 1974-75 and alternate years.

EE 292. CONDUCTION IN PLASMA. 3 *credits, 1st sem.*

Prerequisite: EE 260. 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 1973-74 and 1976-77.

EE 300. 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 301, Master's Thesis. With the approval of his project adviser, a student may register for 1½ credits in each of two successive semesters. 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.

EE 301. 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.*

Thesis fee: $5.00 per semester in addition to tuition. If the use of laboratory facilities or equipment is necessary, a $25.00 deposit must be maintained.

EE 310. Economic Control of Interconnected Systems. 3 *credits, 2nd sem.*

Prerequisite: EE 210. 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 team and hydro-electric power systems with emphasis on digital computers.

Offered 1974-75 and 1977-78.

EE 323. Theory of Guided Waves. 3 *credits, 1st sem.*

Prerequisite: EE 222. 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 1974-75 and alternate years.

EE 339. Feedback Amplifiers II. 3 *credits, 2nd sem.*

Prerequisite: EE 239. The course includes transients in feedback circuits; stability and physical realizability; stability criteria and their mathematical foundations, critique, and extension; active impedance synthesis; Bode theorem and analysis criteria; corrective networks; and amplifier design.

Offered 1974-75 and alternate years.

EE 342. Communication Systems II. 3 *credits, 2nd sem.*

Prerequisite: EE 242. Continuation of EE 242 covering topics in pulse and digital modulation theory. The course includes sampling principle, pulse modulation, PCM, delta modulation, multiplexing techniques, OOK, FSK, digital FM, PSK and DPSK, matched filtering, correlation and maximum likelihood reception, and suboptimum systems.

Offered 1974-75 and 1977-78.

EE 344. Communications Systems Design. 3 *credits, 2nd sem.*

Prerequisite: EE 242. This course covers communication systems design, the design and performance evaluation of multichannel communication systems, such as line of sight, tropospheric communication systems, and satellite communication systems. Such topics as propagation characteristics, diversity, and multihop systems are discussed. The factors affecting the performance of communication systems are discussed in some detail, such as intermodulation noise, thermal noise, and equalization of baseband noise in multichannel FM radio systems. Communication systems using earth satellites are covered in great detail, including space communication.

Offered 1973-74 and 1976-77.

EE 348. Quantum Electronics. 3 *credits, 1st sem.*

Prerequisites: Phys 230 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, and lasers.

Offered 1973-74 and alternate years.

EE 349. Introduction to Quantum Field Theory. 3 *credits, 2nd sem.*

Prerequisites: EE 222, Phys 230. 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 1973-74 and alternate years.

EE 352. Network Theory II. 3 *credits, 2nd sem.*

Prerequisite: EE 252. Included are general methods of driving-point impedance synthesis, ladder networks and two terminal pairs, and approximation methods.

Offered 1973-74 and alternate years.

EE 353. Electric Filter Design. 3 *credits, 1st sem.*

Prerequisite: EE 252. The course deals with the theory and design of reactance filters composed of inductors, and 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 1974-75 and alternate years.

EE 358. Integrated Circuits II. 3 *credits, 2nd sem.*

Prerequisite: EE 258. A continuation of study of I.C. logic circuits and systems; semiconductor memories; linear integrated circuit design; reliability and testing; research topics of interest such as charge-coupled devices, silicon-on-sapphire, and optical integrated circuits.

Offered 1973-74 and alternate years.

EE 365. Introduction to Nonlinear Systems. 3 *credits, 1st sem.*

Prerequisite: EE 263 or EE 256. 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 1973-74 and alternate years.

EE 366. Stability Theory of Nonlinear Systems. 3 *credits, 2nd sem.*

Prerequisite: EE 365 or EE 256. 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 1973-74 and alternate years.

EE 373. Random Processes in Electrical Engineering II. 3 *credits, 2nd sem.*

Prerequisite: EE 273. This course is a continuation of EE 273 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, and nonlinear operations.

Offered 1975-76 and 1978-79.

EE 375. DIGITAL COMMUNICATION. 3 *credits, 2nd sem.*

Prerequisite: EE 242 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 1975-76 and 1978-79.

EE 376. INFORMATION THEORY. 3 *credits, 2nd sem.*

Prerequisite: EE 242. This course covers a review of probability; measurement of information for a discrete source; discrete channels, information rate of a channel, and channel capacity; coding theorems; systems with memory; and continuous channels. Applications and practical considerations are included.

Offered 1974-75 and 1977-78.

EE 377. STATISTICAL DECISION THEORY IN COMMUNICATIONS. 3 *credits, 1st sem.*

Prerequisite: EE 273 or equivalent. Review of detection, estimation, and modulation theory; hypothesis testing problem; Bayes decision criteria, minimax and $Pr(\epsilon)$ tests; Neyman-Pearson tests; receiver operating characteristics; M-hypothesis, model; Bayes estimation; non-random parameter estimation; bounds; Cramer-Rao inequality; the general Gaussian problem; covariance matrices; performance bounds and approximations are topics covered.

Offered 1973-74 and 1976-77.

EE 378. ALGEBRAIC CODING FOR INFORMATION TRANSMISSION. 3 *credits, 1st sem.*

Prerequisite: EE 273 or 177. This course deals with the use of algebraic codes to improve the performance of an information transmission system. Topics included are the coding problem; groups, rings, fields, and vector spaces; linear algebraic codes; Galois fields, and polynomial algebra; cyclic codes; specialized codes; and practical realization of coding.

Offered 1974-75 and 1977-78.

EE 379. PRINCIPLES OF PHASE LOCK AND FREQUENCY FEEDBACK. 3 *credits, 1st sem.*

Prerequisite: EE 242. The 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 applicable in a wide range of applications, including low-level signal reception, tracking, phase extraction, filtering, and frequency synchronization. The course emphasizes applications in FM communication.

Offered 1975-76 and 1978-79.

EE 380. HYBRID COMPUTATION. 3 *credits, 2nd sem.*

Prerequisite: EE 280 and knowledge of at least one scientific oriented computer language, such as Fortran. This course provides the student with the concepts and programming techniques of hybrid computation and simulation. Topics discussed are the iterative analog computer, hybrid computer components, accuracy of the hybrid computer, software and applications of hybrid computers.

Offered 1973-74 and alternate years.

EE 391. SELECTED TOPICS IN ELECTRICAL ENGINEERING. 3 *credits, 1st sem.*

Prerequisites: EE 256, Math 258, and departmental approval. This special area course will be given when suitable interest develops. Advance notice of forthcoming topics will be announced.

EE 392. SELECTED TOPICS IN ELECTRICAL ENGINEERING. 3 *credits, 2nd sem.*
See prerequisites and description for EE 391, above.

EE 393. STABILITY THEORY OF ELECTRIC POWER SYSTEMS. 3 *credits, 2nd sem.*
Prerequisites: EE 210 and 270. 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 in studies on power systems. It also deals with synchronous machines, excitation systems, damping, and saturation.
Offered 1975-76 and 1978-79.

EE 395. MAGNETOHYDRODYNAMIC POWER GENERATION. 3 *credits, 2nd sem.*
Prerequisite: EE 292. 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 1973-74 and 1976-77.

EE 400. DOCTORAL DISSERTATION AND RESEARCH. *Credits as designated, 1st or 2nd sem.*
*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 400 must register concurrently for EE 401 unless requirement is waived, in writing, by dissertation adviser.

Thesis fee: $5.00 per semester in addition to tuition. If use of laboratory facilities or equipment is necessary, a laboratory deposit of $25.00 per semester must be maintained, or such additional amount as may be necessary to provide laboratory facilities and equipment.

EE 401. 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 400 and EE 402 unless requirement is waived, in writing, by dissertation adviser. Open to all doctoral students and students registered for EE 301.*
Seminar fee: $27.00 per semester.

EE 402. PRE-DOCTORAL RESEARCH. 3 *credits per semester, 1st or 2nd sem.*
Prerequisite: Permission of the department. Corequisite: EE 401. 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 400 after the student fulfills requirements of doctoral candidacy. Candidates registering for EE 402 must register concurrently for EE 401 unless requirement is waived, in writing, by thesis adviser.

EE 403. 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.

Thesis fee: $5.00 per semester in addition to tuition. 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.

EE 432. Seminar in Communication Systems. 3 *credits, 2nd sem.*

Prerequisite: EE 242. 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 1973-74 and 1976-77.

EE 446. Lasers and Masers. 3 *credits, 2nd sem.*

Prerequisite: EE 348. 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 paramagnets, three level solid and gas masers, noise, and degrees of coherence.

Offered 1973-74 and alternate years.

EE 451. Seminar on Reliability Problems and Research. 3 *credits, 2nd sem.*

Prerequisite: EE 241 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 1973-74 and alternate years.

EE 466. Optimal Control Theory. 3 *credits, 1st sem.*

Prerequisites: EE 232 and 256, 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 1974-75 and alternate years.

EE 467. Stochastic Control Theory. 3 *credits, 2nd sem.*

Prerequisites: EE 256 and 273, or equivalents. Classical steady-state statistical design in the Wiener sense of both continuous and discrete systems subject to constraints; stochastic control systems and Kalman filter theory; the application of multilevel techniques in stochastic systems; and an introduction to adaptive, learning, and dual-control systems.

Offered 1974-75 and alternate years.

EE 490. Advanced Electromechanical Energy Conversion II. 3 *credits, 2nd sem.*

Prerequisites: EE 222 and 270. Derivation of circuit models of rotating systems based on the cross-sectional space wave method and the study of generalized Maxwell-Lorentz equations as applied to coupled rotational bodies.

Offered 1975-76 and 1978-79.

# DEPARTMENT OF INDUSTRIAL AND MANAGEMENT ENGINEERING

Graduate programs in the department of Industrial and Management Engineering are designed to meet the specific needs of the student. Each student's program is designed in cooperation with the student's adviser, and will lead to one of two degrees: the Master of Science in Industrial Engineering or the Master of Science.

In the case of the Master of Science, the student may pursue one of a number of specialized programs in the field of Industrial and Management Engineering, or in other related fields. For example, the specialized programs in the Management of Manpower Policies and Employment Relations, and the Management of Public and Regulated Enterprises are offered in cooperation with the Department of Organizational and Social Sciences.

## MASTER OF SCIENCE PROGRAMS

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 systems, and operational assurance.

The degree *Master of Science* is the recommended objective for the graduates of an engineering curriculum or for those who have majored in mathematics or the physical sciences or with a quantitative background in the social sciences and whose careers are in, or moving toward, management in an engineering-scientific oriented enterprise.

For either degree, the applicant must offer evidence of high attainment in undergraduate studies, particularly in those areas which are fundamental to the graduate courses he proposes to take.

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 courses, which are to be completed before additional graduate courses may be taken:

EM 101—Industrial Management
EM 102—Engineering Cost Analysis
EM 103—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.

Each student is required to prepare a program of studies, which is to be approved by his adviser. Deviations from the approved program of studies are also to be approved by the student's adviser.

The student's attention is also called to the fact that with prior approval he can choose courses for the elective part of his program from the 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.

A student desiring to take courses at Rutgers should acquaint himself with the registration procedures early, as the Rutgers and NCE semester registration, beginning, and terminating points do not coincide with each other. Further information may be obtained from the Graduate Division.

## MASTER OF SCIENCE IN INDUSTRIAL ENGINEERING

For the degree *Master of Science in Industrial Engineering,* candidates must include the following fifteen course credits as part of the eighteen credits of specialization required for the degree in any of the four programs of specialization:

IE 204—Advanced Analytical Engineering Statistics (3)
IE 221—Applications of Digital Computers in Industrial Engineering (3)
IE 241—Operations Analysis of Systems (3)
IE 301—Master's Thesis (6)

Elective courses may be chosen from the offerings of any department or 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 to complete the minimum of thirty credits. A program of more than the minimum number of credits may be necessary, depending upon the student's thesis objectives and preparation. The following are suggested electives grouped by area of specialization:

### DECISION THEORY

EM 214—Planning & Control of Products & Processes
EM 240—Distribution Logistics
EM 255—Management of Info. Syst.
EM 293—Managerial Economics
IE 203—Behavioral Science
IE 205—Mathematical Programming in Management Science
IE 207—Seminar in Contemporary Management Problems
IE 233—Linear Programming
Math 111—Numerical Methods
Math 220—Matrix Theory
Math 261—Mathematical Statistics
Math 262—Statistical Inference
Math 268—Probability
SS 203—Econometrics
SS 250—Cost-Benefit Analysis & Economic Decisions
SyS 100—Intro. to Systems Anal.

### SYSTEMS ENGINEERING

CS 110—Computer Programming
CS 221—Numerical Analysis I
CS 222—Numerical Analysis II
EM 293—Managerial Economics
EnE 266—Mass Transportation Systems

CS 230—Operating System Design
CS 231—Data Management System Design
EM 205—Engineering Reliability
EM 206—Maintainability Engrg.
EM 214—Planning & Control of Products & Processes
EM 240—Distribution Logistics
EM 255—Management of Info. Syst.
EnE 316—Water Resource Systems
IE 201—Measurement Methods for Management Science
IE 203—Behavioral Science
IE 207—Seminar in Contemporary Management Problems
IE 261—Man-Machine Systems
Math 220—Matrix Theory
SyS 100—Intro. to Systems Anal.

MAN-MACHINE SYSTEMS

EM 293—Managerial Economics
EnE 267—Traffic Engineering
IE 261—Man-Machine Systems
IE 269—Human Design Factors in Engineering
Math 261—Mathematical Statistics
Math 262—Statistical Inference
IE 203—Behavioral Science
IE 207—Seminar in Contemporary Management Problems
OS 223—Psychology in Engineering
OS 224—Methods of Research in the Behavioral Sciences
OS 277—Techniques of Executive Control

OPERATIONAL ASSURANCE

EE 232—Optimization Techniques
EE 241—Reliability in Electronics
EE 451—Seminar on Reliability Problems & Research
EM 203—Analytical Engineering Statistics
EM 205—Engineering Reliability
EM 206—Maintainability Engrg.
EM 207—Product Liability Control
EM 213—Manufacturing Engineering
EM 214—Planning & Control of Products & Processes
EM 272—Industrial Quality Control
IE 203—Behavioral Science
IE 207—Seminar in Contemporary Management Problems
Math 261—Mathematical Statistics
Math 262—Statistical Inference
Math 361—Mathematics of Reliability

## MASTER OF SCIENCE

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

EM 202—Introduction to Management Science (3)
and a choice of either
EM 301—Master's Thesis (6)
or
EM 315—Design of an Enterprise (3) and
EM 316—Seminar in the Design of an Enterprise (3).

Elective courses may be chosen from the offerings of any department or 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 to complete the minimum of thirty credits of correlated courses required of the candidate for the degree of Master of Science.

For those students desiring specialized programs within the Master of Science degree, the following specializations are available:

ENGINEERING MANAGEMENT

Required courses: EM 301 or EM 315 and EM 316.

At least nine credits from the following:

EM 202—Intro. to Management Sci.
EM 260—Financing an Industrial Enterprise
EM 293—Managerial Economics
EM 371—Industrial Costing and Mgt. Control
IE 203—Behavioral Science
IE 207—Seminar in Contemporary Management
OS 201—Industrial Relations and Public Planning
OS 242—Contemporary Collective Bargaining
OS 273—Personnel Management

Plus fifteen credits of electives.

MANAGEMENT SYSTEMS

Required courses: EM 301 or EM 315 and EM 316.

At least nine credits from the following:

CS 230—Operating System Design
CS 231—Data Mgt. Systems Design
EM 202—Intro. to Mgt. Science
EM 250—Introductory Operations Research
EM 255—Management of Info. Syst.
IE 201—Measurement Methods for Management Systems
IE 221—Applications of Digital Computers in I.E.
IE 241—Operations Anal. of Systems
IE 261—Man and Machine Systems
SyS 100—Intro. to Systems Anal.

Plus fifteen credits of electives.

MANAGEMENT OF RESEARCH, DEVELOPMENT AND DESIGN

Required courses: EM 301, or EM 315 and EM 316.

At least nine credits from the following:

EM 202—Introduction to Management Science
EM 203—Analytical Engineering Statistics
EM 207—Product Liability Control
EM 235—Management of Engineering Research & Development
IE 203—Behavioral Science
IE 207—Seminar in Contemporary Mgt. Problems
IE 221—Applications of Digital Computers in I.E.
OS 202—Manpower Planning & Mgt. Development
OS 224—Methods of Research in the Behavioral Sciences

Plus fifteen credits of electives.

MANAGEMENT OF MANPOWER POLICIES AND EMPLOYMENT RELATIONS

This program is presented in conjunction with the Department of Organizational and Social Sciences. If the thesis is chosen, it will normally be done with an adviser from that department.

Required courses: EM 301, or EM 315 and EM 316.

At least nine credits from the following:

EM 203—Analytical Engineering Statistics
IE 203—Behavioral Science
IE 207—Seminar in Contemporary Mgt. Problems
OS 202—Manpower Planning & Mgt. Development
OS 224—Methods of Research in the Behavioral Sciences
OS 273—Personnel Management

Plus fifteen credits of electives.

MANAGEMENT OF PUBLIC AND REGULATED ENTERPRISES

This program is presented in conjunction with the Department of Organizational and Social Sciences. If the thesis is chosen, it will normally be done with an adviser from that department.

Required courses: EM 301, or EM 315 and EM 316.

At least nine credits from the following:

EM 203—Analytical Engineering Statistics
IE 203—Behavioral Science
IE 207—Seminar in Contemporary Mgt. Problems
OS 201—Industrial Relations & Public Planning
OS 264—Technological Innovation & Public Administration
SS 171—Urban Social Structure
SS 261—Public Finance
SS 262—Economic Analysis of Urban Areas

Plus fifteen credits of electives.

HEALTH AND SAFETY ENGINEERING

This program is designed to educate the graduate engineer for specialization in the field of health and safety engineering. 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 233—Legal Aspects of Health and Safety
EM 301—Design Thesis
IE 214—Safety Engineering Methods
IE 215—Elements of Occupational Health

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

*Suggested Electives*

Chem 208—Instrumental Analysis
Chem 210—Radio Isotopes Theory and Applications
EM 202—Introduction to Management Science
EM 203—Analytical Engineering Statistics
EM 205—Engineering Reliability
EM 206—Maintainability Engineering
EM 207—Product Liability Control
EM 213—Manufacturing Engineering
EM 272—Industrial Quality Control
EnE 201—Introduction to Solid Waste Problems
EnE 206—Pollution: Chemistry and Ecology
EnE 220—Solid Waste Disposal Systems
EnE 222—Air Pollution Control
EnE 267—Traffic Engineering
EnE 268—Traffic Safety
IE 203—Behavioral Science
IE 261—Man-Machine Systems
IE 269—Human Design Factors in Engineering
ME 250—Noise Control
ME 251—Thermal Pollution of Water and Air
OS 223—Psychology in Engineering
OS 224—Methods of Research in the Behavioral Sciences
OS 273—Personell Management

# COURSES OF INSTRUCTION IN INDUSTRIAL ENGINEERING

IE 201. MEASUREMENT METHODS FOR MANAGEMENT SYSTEMS. 3 *credits,* 1*st sem.*

Prerequisite: Undergraduate mathematics for management science or EM 202. A quantitative study of various analytical methods for designing and evaluating systems employed in the management of complex enterprises. Study covers decision-making under conditions of uncertainty and efficiency measurement methodology for obtaining optimal system performance.

Offered 1973-74 and alternate years.

IE 203. BEHAVIORAL SCIENCE. 3 *credits,* 1*st* or 2*nd sem.* FICKS, SEILER and WILLIAMS.

Prerequisite: Undergraduate probability and statistics or EM 103. 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-subordinate relationships and formal and informal organizations. The student investigates organization models and analyzes the technical and social structure of organizations.

IE 204. ADVANCED ANALYTICAL ENGINEERING STATISTICS. 3 *credits,* 2*nd sem.* MARPET.

Prerequisite: EM 203. 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 1974-75 and alternate years.

IE 205. MATHEMATICAL PROGRAMMING IN MANAGEMENT SCIENCE. 3 *credits,* 2*nd sem.* MAXIM.

Prerequisite: EM 233 and operations research. 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 1973-74 and alternate years.

IE 207. SEMINAR IN CONTEMPORARY MANAGEMENT PROBLEMS. 3 *credits,* 1*st sem.* MIHALASKY.

Prerequisites: Undergraduate courses in economics and management. Readings, 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.

IE 214. SAFETY ENGINEERING METHODS. 3 *credits,* 1*st 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 1974-75 and alternate years.

IE 215. ELEMENTS OF OCCUPATIONAL HEALTH, 3 *credits,* 2*nd sem.* RAM.

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 1974-75 and alternate years.

IE 221. Applications of Digital Computers in Industrial Engineering. 3 *credits, 1st sem.* Harris.

Prerequisites: Computer programming experience and EM 202. 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.

IE 233 Linear Programming. 3 *credits, 1st sem.*

Prerequisite: Introductory course in management science or EM 202. 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. The use of modern, high-speed electronic computers is treated as a tool in solving multivariable problems.

IE 241. Operations Analysis of Systems. 3 *credits, 2nd sem.*

Prerequisites: EM 202 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 1973-74 and alternate years.

IE 261. Man-Machine Systems. 3 *credits, 2nd sem.* Gage.

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.

IE 269. Human Design Factors in Engineering. 3 *credits, 1st sem.* Ficks.

Prerequisite: Probability and statistics or EM 103. 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, design of displays life cycle. The resulting interaction between individuals, groups and machine systems is examined in terms of system acquisition management. The course surveys current research in the biological sciences as pertains to man-machine systems.

Offered 1973-74 and alternate years.

IE 301. 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.*

Thesis fee: $5.00 per semester in addition to tuition. If the use of laboratory facilities or equipment is necessary, a $25.00 deposit must be maintained.

## COURSES OF INSTRUCTION IN MANAGEMENT ENGINEERING

EM 101. INDUSTRIAL MANAGEMENT. 3 *credits, 1st* or *2nd sem.* MUNDEL.

*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.

EM 102. ENGINEERING COST ANALYSIS. 3 *credits, 1st or 2nd sem.* COPPINGER.

*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 of industrial management.

EM 103. METHODS AND APPLICATIONS OF INDUSTRIAL STATISTICS AND PROBABILITY. 3 *credits, 1st* or *2nd sem.* MARPET.

*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.

EM 202. MANAGEMENT SCIENCE. 3 *credits, 1st* or *2nd sem.* PEKARSKY.

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.

EM 203. ANALYTICAL ENGINEERING STATISTICS. 3 *credits, 1st sem.* PEKARSKY.

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.

EM 205. ENGINEERING RELIABILITY. 3 *credits, 1st sem.* CALABRO.

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 1973-74 and alternate years.

EM 206. MAINTAINABILITY ENGINEERING. 3 *credits, 2nd sem.* CALABRO.

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 1973-74 and alternate years.

EM 207. PRODUCT LIABILITY CONTROL. 3 *credits, 2nd sem.* JACOBS.

Prerequisite: Statistics. A presentation of the laws and engineering techniques applicable to minimizing products 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.

EM 213. MANUFACTURING ENGINEERING. 3 *credits, 1st sem.* FARAGO.

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.

EM 214. PLANNING AND CONTROL OF PRODUCTS AND PROCESSES. 3 *credits, 1st sem.* GOLDSTEIN.

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.

EM 231. 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.

Offered 1973-74 and alternate years.

EM 233. 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 1973-74 and alternate years.

EM 235. MANAGEMENT OF ENGINEERING RESEARCH AND DEVELOPMENT. 3 *credits, 2nd sem.* PAGANO.

Prerequisites: Principles of management and statistics, or EM 101 and 103. 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.

EM 240. DISTRIBUTION LOGISTICS. 3 *credits, 2nd sem.*

Prerequisite: EM 202. 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 1973-74 and alternate years.

EM 250. INTRODUCTORY OPERATIONS RESEARCH. 3 *credits, 2nd sem.* AIELLO.

Prerequisite: Introductory course in management science or EM 202. 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.

EM 255. MANAGEMENT OF INFORMATION SYSTEMS. 3 *credits, 2nd sem.* GOLDSTEIN.

Prerequisite: Computer programming experience. Treating information flow in an organization as an integrated system, the course discusses the engineering of electronic information processing systems which will optimize managerial requirements. Consideration is given to feasibility studies, systems studies, the selection, installation, staffing, operating and controlling of typical electronic data handling systems. Problems involving information acquisition, processing, retrieval and distribution are treated.

EM 260. FINANCING AN INDUSTRIAL ENTERPRISE. 3 *credits, 1st* or *2nd sem.* HARKINS.

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.

EM 272. INDUSTRIAL QUALITY CONTROL. 3 *credits, 1st sem.* JACOBS.

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 1973-74 and alternate years.

EM 293. MANAGERIAL ECONOMICS. 3 *credits, 1st sem.* WOLF.

Prerequisites: Undergraduate economics and accounting or EM 102. 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 301. 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.*

Thesis fee: $5.00 per semester in addition to tuition. If the use of laboratory facilities or equipment is necessary, a $25.00 deposit must be maintained.

EM 315. Design of an Enterprise. 3 *credits, 1st* or *2nd sem.* Danco and Rigassio.

Prerequisites: Undergraduate economics, industrial management, accounting, engineering economy, and probability and statistics, nine credits of EM courses of level 200 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.

EM 316. Seminar in the Design of an Enterprise. 3 *credits, 1st or 2nd sem.* Danco and Rigassio.

Prerequisite: EM 315. Each student will select an enterprise on the basis of the industry investigated in EM 315. 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.

EM 371. Operations Cost and Management Control. 3 *credits, 2nd sem.* Wolf.

Prerequisites: Six credits of EM courses of 200 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 PROGRAMS IN ENGINEERING SCIENCE

Programs permitting concentration in applied mathematics are offered as part of the College's offerings in Engineering Science. It is expected that those applying for these programs will have undergraduate backgrounds in engineering, mathematics, physics, or computer science.

The emphasis in the programs is on practical applications of advanced mathematics appropriate to research, development, and related activities. Each student will plan a course of study with his adviser built around a set of basic required courses and a group of electives, the whole designed to develop a comprehensive foundation in applied mathematics.

## MASTER OF SCIENCE

For students wishing to concentrate their studies in applied mathematics the following courses must be included in meeting the requirements for the master's degree:

1. Math 145 and 146 *or* Math 151 and 252.
2. Math 256.
3. Six credits in related elective courses.
4. ESc 300 or ESc 301.

Candidates whose undergraduate records indicate the need for basic prerequisite work may be required to take undergraduate and introductory graduate courses in addition to the thirty credits required for the M.S. degree.

## COURSES OF INSTRUCTION

Math 111. NUMERICAL METHODS. 3 *credits, 1st sem.* LIONE.

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.

Math 145. ADVANCED CALCULUS I. 3 *credits, 1st sem.*

Prerequisites: 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.

Math 146. ADVANCED CALCULUS II. 3 *credits, 2nd sem.*

Prerequisite: Math 145 or equivalent. This course is a continuation of Math 145 and considers such topics as partial differentiation, transformations, implicit function theorem, multiple integrals, and line and surface integrals.

Math 151. 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.

Math 173. DIFFERENTIAL EQUATIONS I. 3 *credits, 1st* or *2nd sem.* KOREN.

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

Math 174. DIFFERENTIAL EQUATIONS II. 3 *credits, 2nd sem.*

Prerequisite: Math 173 or equivalent. A companion course to Math 173, dealing with partial differential equations, with emphasis on those of physics and their solutions by means of Fourier series, Bessel functions, and Legendre polynomials.

Offered 1974-75 and alternate years.

Math 177. 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.

Math 220. 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.

Math 224. 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 1974-75 and alternate years.

Math 248. 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.

Math 252. APPLIED MATHEMATICS II. 3 *credits, 2nd sem.*

Prerequisite: Math 151 or equivalent. Subject matter includes tensor analysis, calculus of variations, integral equations, Green's functions, and conformal mapping.

Math 256. FUNCTIONS OF A COMPLEX VARIABLE I. 3 *credits, 1st sem.* KATZEN.

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.

Math 257. Functions of a Complex Variable II. 3 *credits, 2nd sem.* Katzen.

Prerequisite: Math 256. 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 1973-74 and alternate years.

Math 258. Operational Analysis. 3 *credits, 1st* or *2nd sem.*

Prerequisites: Undergraduate differential equations, complex variables. Operational methods related to problems in physics and engineering. Topics include Fourier series and integrals; Laplace transform; Z-transform; operator inversion; Dirac delta-function and generalized functions; matrix theory and spectral decomposition; and Hermitian operators. Applications to boundary value problems, mechanical vibrations, electrical circuits, and control theory are included.

Math 261. Mathematical Statistics. 3 *credits, 1st or 2nd sem.* Barkan and Brower.

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 262. Statistical Inference. 3 *credits, 2nd sem.* Flatow.

Prerequisite: Math 261 or equivalent. This course considers inferences about populations based on samples, design of experiments, elementary decision theory, and minimax principle.

Math 268. Probability. 3 *credits, 2nd sem.*

Prerequisite: Math 177 or 261, 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 covergence; 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.

Math 271. Approximate Methods in Engineering Analysis. 3 *credits, 2nd sem.*

Prerequisite: Undergraduate partial differential equations or Math 151 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.

Math 275. Partial Differential Equations of Applied Mathematics. 3 *credits, 2nd sem.* Peyser.

Prerequisite: Math 174 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.

Math 276. ADVANCED ORDINARY DIFFERENTIAL EQUATIONS. 3 *credits, 1st sem.* RAUSEN.

Prerequisites: Undergraduate differential equations or Math 173, and Math 145 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.

Offered 1974-75 and alternate years.

Math 320. TENSOR ANALYSIS. 3 *credits, 2nd sem.*

Prerequisites: Strength of materials, vector analysis, and Math 220 or equivalents. A treatment of tensors as multilinear functionals over a vector space with applications to kinematics and dynamics of continuous media. Reviews and summaries of works exploiting tensor analysis by course participants supplement formal course procedures.

Offered 1973-74 and alternate years.

Math 346. A FIRST COURSE IN ANALYSIS. 3 *credits, 1st sem.*

Prerequisite: Math 145 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 1973-74 and alternate years.

Math 361. MATHEMATICS OF RELIABILITY. 3 *credits, 2nd sem.* BARKAN.

Prerequisite: Math 261 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 1973-74 and alternate years.

ESc 300. MASTER'S PROJECT. 3 *credits, 1st or 2nd sem.* Department Faculty.

Prerequisite: Matriculation for the M.S. degree. An extensive paper involving design, construction, and analysis, or theoretical investigation is required of all candidates for the Master of Science degree in areas of basic Engineering Science who do not take ESc 301, Master's Thesis. The work will normally be initiated in a course in the Engineering Science area with the knowledge and approval of the course instructor who will become the student's project adviser. A student whose work in ESc 300 is of exceptional quality may be permitted to extend the Master's Project into a Master's Thesis, ESc 301. *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.

ESc 301. 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. 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.*

Thesis fee: $5.00 per semester in addition to tuition.

# 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 300, Mechanical Engineering Design or ME 301, 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, and control engineering. 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 300, Master's Project (3 credits) or ME 301, 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 300, Master's Project (3 credits) or ME 301, 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 100—Introduction to Systems Analysis
CS 261—System Simulation
EE 232—Optimization Techniques

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

BIOMEDICAL ENGINEERING SYSTEMS

ChE 228—Biochemical Engineering
ME 170—Introduction to Biomechanical Engineering
ME 171—Biomechanics of Human Structure and Motion
ME 218—Instrumentation

ELECTRO-MECHANICAL CONTROL SYSTEMS

EE 466—Optimal Control Theory
ME 237—Control of Electro-Mechanical Systems
ME 248—Design of Automatic Machinery
ME 331—Advanced Control of Electro-Mechanical Systems

MACHINE SYSTEMS

ME 205—Analytical Methods in Machine Design
ME 220—Advanced Mechanical Vibrations
ME 246—Analysis and Synthesis for Design
ME 248—Design of Automatic Machinery

POWER GENERATION SYSTEMS

ME 110—Combustion Engine Emissions and Their Control
ME 227—Power Plant Design
ME 251—Thermal Pollution of Water and Air
ME 255—Combustion

## 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 300 or 400 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 understanding of fundamental concepts, while the oral portion is intended 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 | Heat Transfer |
| Dynamics and Vibration | Stress Analysis |
| Elasticity | Thermodynamics |
| Fluid Mechanics | 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 be scheduled throughout the academic year so that there will be time to prepare for individual examinations. 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.

ME 105. 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.

ME 110. 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 113. 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.

ME 170. 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.

ME 171. 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.

ME 201. HEAT TRANSFER. 3 *credits, 1st sem.*

Prerequisites: Undergraduate fluid mechanics, heat transfer, and vector analysis or Math 151 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 223 may be substituted for ME 201 with departmental approval.

ME 203. GAS TURBINES. 3 *credits, 2nd sem.*

Prerequisites: Undergraduate courses in differential equations and ME 113 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 1973-74 and alternate years.

ME 205. Analytical Methods in Machine Design. 3 *credits, 1st sem.*

Prerequisites: Undergraduate differential equations, senior machine design, and Math 151 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 flywheel 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.

ME 216. 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, 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 1974-75 and alternate years.

ME 217. 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 1973-74 and alternate years.

ME 218. 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 hydro-pneumatic.

Laboratory fee: $15.00.

Offered 1974-75 and alternate years.

ME 220. 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 1974-75 and alternate years.

ME 221. Matrix-Tensor Methods in Mechanical Engineering. 3 *credits, 2nd sem.*

Prerequisites: Undergraduate differential equations, fluid mechanics and vector analysis or Math 151 or equivalent. Engineering analysis applica-

tions 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.

ME 222. DYNAMICS OF INCOMPRESSIBLE FLUIDS. 3 *credits, 1st sem.*

Prerequisites: Vector analysis or Math 151 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.

ME 223. 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 1974-75 and alternate years.

ME 224. 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 Moiré 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 1973-74 and alternate years.

ME 225. 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 1974-75 and alternate years.

ME 227. 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 1973-74 and alternate years.

ME 230. Dynamics of Machinery. 3 *credits, 2nd sem.*

Prerequisites: Undergraduate differential equations, machine design, and vector analysis or Math 151 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 1973-74 and alternate years.

ME 234. Design of Plates and Shells. 3 *credits, 2nd sem.*

Prerequisites: Mechanics of deformable bodies and vector analysis or Math 151 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.

ME 235. Random Vibrations. 3 *credits, 2nd sem.*

Prerequisites: Mechanics of deformable bodies, mechanical vibrations and vector analysis or Math 151 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 1974-75 and alternate years.

ME 237. 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 1975-76 and alternate years.

ME 238. Gas Dynamics. 3 *credits, 1st sem.*

Prerequisites: Vector analysis or Math 151 and ME 113 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 1973-74 and alternate years.

ME 242. 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 artifcial 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 1973-74 and alternate years.

ME 246. 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.

ME 248. 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 1974-75 and alternate years.

ME 250. 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 absorption; applications to structures, machinery, ground transportation, and aircraft; and noise measurement.

Offered 1974-75 and alternate years.

ME 251. 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 experimental techniques in thermal pollution control studies.

Offered 1974-75 and alternate years.

ME 265. 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, junctures, 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 vesels. ASME pressure vessel codes will be consulted throughout the course.

Offered 1973-74 and alternate years.

ME 300. Mechanical Engineering Design. 3 *credits, 1st or 2nd sem.* Department Faculty.

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 301, 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.

ME 301. 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.*

Thesis fee: $5.00 per semester in addition to tuition. If the use of laboratory facilities or equipment is necessary, a $25.00 deposit must be maintained.

ME 311. CONDUCTION HEAT TRANSFER. 3 *credits, 2nd sem.*

Prerequisite: ME 201. 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 1973-74 and alternate years.

ME 313. VISCOELASTICITY. 3 *credits, 1st sem.*

Prerequisite: Theory to 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 1974-75 and alternate years.

ME 314. CONVECTION HEAT TRANSFER. 3 *credits, 2nd sem.*

Prerequisite: ME 201. 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 1974-75 and alternate years.

ME 316. THERMAL STRESSES. 3 *credits, 2nd sem.*

Prerequisites: Vector analysis or Math 151 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 1973-74 and alternate years.

ME 317. 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, advanced thermodynamics, analysis of M.E. systems, design optimization, and case studies in design.

ME 318. SELECTED TOPICS IN MECHANICAL ENGINEERING II. 3 *credits, 2nd sem.*

See course description for ME 317, above.

ME 319. MECHANICS OF VISCOUS FLUIDS. 3 *credits, 2nd sem.*

Prerequisite: ME 222. 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 1975-76 and alternate years.

ME 331. Advanced Control of Electro-Mechanical Networks. 3 *credits, 2nd sem.*

Prerequisite: ME 237, or EE 256, 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-stablized platform, and a moderately complex computer. In each case considered, methods are developed for determining, in closed form, the characteristic equation, the transition matrix, response to various simultaneous inputs, and the performance of the perturbed model of the ideal system.

Offered 1975-76 and alternate years.

ME 400. 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.

Thesis fee: $5.00 per semester in addition to tuition. 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 approved dissertation.

ME 401. 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 400 unless requirement is waived, in writing, by thesis adviser. Open to all students registered for ME 301.*

Seminar fee: $27.00 per semester.

ME 402. Pre-Doctoral Research. 3 *credits per semester, 1st or 2nd sem.* Department Faculty.

Prerequisite: Permission of department. Corequisite: ME 401. 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 400 after the student fulfills the requirements of Doctoral candidacy. Candidates registering for ME 402 must register also for ME 401 unless requirement is waived, in writing, by thesis adviser.

ME 403. Professional Project. *Credits as designated, 1st or 2nd sem.* Department Faculty.

*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.

Thesis fee: $5.00 per semester in addition to tuition. 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.

ME 405. Theory of Deformable Solids in Mechanical Engineering I. 3 *credits, 1st sem.*

Prerequisite: Math 320. 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.

ME 406. Theory of Deformable Solids in Mechanical Engineering II. 3 *credits, 2nd sem.*

Prerequisite: ME 405. This course considers methods of solution for various problems formulated in ME 405. 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 407. Inelastic Behavior of Continuous Media. 3 *credits, 1st sem.*

Prerequisite: Math 320. The course embodies applications of the developments of Math 320. The tensor methods developed in Math 320 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.

# DEPARTMENT OF ORGANIZATIONAL AND SOCIAL SCIENCES

The program of advanced studies offered is geared to the broad needs of engineers and scientists 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. Among the types of programs of specialization are urban engineering, urban systems management, and environmental systems analysis. Details of the program can be found on pages 48-49.

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. This degree is designed for the graduate of an engineering curriculum or the holder of a degree in a physical science, mathematics, or the quantitative social sciences whose career is moving toward management in an engineering-scientific oriented organization. The program is administered by the Department of Industrial and Management Engineering. Students electing the options in Manpower Policies and Employment Relations or Management of Public and Regulated Enterprises would normally be advised by the faculty members of the two cooperating departments. Details of the program can be found on pages 82-84.

Current research activities in the Department might provide students with thesis 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; and transportation economics.

# COURSES OF INSTRUCTION IN ORGANIZATIONAL SCIENCE

OS 201. INDUSTRIAL RELATIONS AND PUBLIC PLANNING. 3 *credits, 2nd 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 1973-74 and alternate years.

OS 202. 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 appraisal. Participative methods including role-playing and case study technique are both studied and applied throughout the course.

Offered 1974-75 and alternate years.

OS 204. ORGANIZATION DESIGN AND DEVELOPMENT. 3 *credits, 1st sem.* REINHARTH.

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 1974-75 and alternate years.

OS 223. 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.

OS 224. METHODS OF 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 1973-74 and alternate years.

OS 241. 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.

OS 242. 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 agreements, methods of settling disputes, and the impact of public policy on collective bargaining.

OS 243. 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 1974-75 and alternate years.

OS 264. TECHNOLOGICAL INNOVATION AND PUBLIC ADMINISTRATION. 3 *credits, 2nd sem.*
Prerequisites: Undergraduate or graduate courses in political science and management and/or organization theory. Innovations in systems analysis, transportation, housing, power generation and distribution, pollution abatement, refuse disposal, and organizational design and development. Implications for improved public administration and service. Interrelationships among the legislative, judicial, and executive functions in introducing and administering technological change in the public sector. The case method is used.
Offered 1974-75 and alternate years.

OS 273. 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 engineering and scientific personnel.

OS 276. PERSONNEL SELECTION. 3 *credits, 2nd sem.*
Prerequisite: OS 273. 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 1973-74 and alternate years.

OS 277. TECHNIQUES OF EXECUTIVE CONTROL. 3 *credits, 1st sem.* REINHARTH.
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 1973-74 and alternate years.

# COURSES OF INSTRUCTION IN SOCIAL SCIENCE

SS 171. 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 1974-75 and alternate years.

SS 181. TECHNOLOGY ASSESSMENT. 3 *credits, 2nd 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 multi-disciplinary and analytical techniques for evaluation and forecasting will be utilized and demonstrated (i.e., benefit-cost analysis, and cross impact matrices).

SS 203. ECONOMETRICS. 3 *credits, 1st sem.* BORDMAN.

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 1973-74 and alternate years.

SS 250. 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 relationships for both the public and private sectors will be analyzed. Case studies based upon student industrial or public experience.

Offered 1974-75 and alternate years.

SS 261. PUBLIC FINANCE. 3 *credits, 2nd sem.*

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 1973-74 and alternate years.

SS 262. ECONOMIC ANALYSIS OF URBAN AREAS. 3 *credits, 1st sem.* BORDMAN.

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 inter-relationships 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 1974-75 and alternate years.

# DEPARTMENT OF PHYSICS
## COURSES OF INSTRUCTION

**Phys 120. Modern Physics.** 3 *credits, 1st sem.*

Prerequisite: 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 Schroedinger equation applied to simple problems; atomic structure and spectra; molecules; binding and energy bands in solids; and electrical, thermal, and magnetic properties of solids.

**Phys 210. 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 1973-74 and alternate years.

**Phys 212. 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 equations and phase space; canonical transformations; Poisson brackets and relation to quantum mechanics; Hamilton-Jacobi equation; and applications.

Offered 1974-75 and alternate years.

**Phys 214. 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 and ferromagnetic phenomena; and superconductivity.

Offered 1973-74 and alternate years.

**Phys 221. Nuclear Physics.** 3 *credits, 2nd sem.*

Prerequisite: Phys 120. 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 1973-74 and alternate years.

**Phys 222. Elements of Nuclear Engineering.** 3 *credits, 2nd sem.*

Prerequisites: Bachelor's degree in engineering or physics and the consent of the instructor. 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 slowing-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 1974-75 and alternate years.

**Phys 230. Quantum Mechanics.** 3 *credits, 2nd sem.*

Prerequisite: Phys 120 or Phys 210. Among the topics covered are the Schroedinger 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.

# INTERDISCIPLINARY 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 19, 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 102—Environmental Chemistry
2. EM 231—Legal Aspects in Environmental Engineering
3. Master's project or thesis.

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 151—Introductory Unit Operations
ChE 285—Chemical and Physical Operations
ChE 286—Industrial Waste Control
EM 231—Legal Aspects in Environmental Engineering
EnE 102—Environmental Chemistry
EnE 204—Environmental Microbiology
EnE 218—Biological Waste Treatment
EnE 219—Steam and Estuary Analysis
EnE 222—Air Pollution Control
EnE 223—Waste Water Laboratory
ME 251—Thermal Pollution of Water and Air
Project or thesis in the department of the student's choice.

### WATER RESOURCES AND WATER TREATMENT

ChE 151—Introductory Unit Operations
ChE 285—Chemical and Physical Operations
EM 231—Legal Aspects in Environmental Engineering
EnE 102—Environmental Chemistry
EnE 204—Environmental Microbiology
EnE 218—Biological Waste Treatment
EnE 223—Waste Water Laboratory
EnE 245—Open Channel Flow
EnE 246—Hydrology
EnE 316—Water Resources System
Project or thesis in the department of the student's choice.

### MUNICIPAL WASTE TREATMENT

ChE 151—Introductory Unit Operations
ChE 285—Chemical and Physical Operations
EM 231—Legal Aspects in Environmental Engineering
EnE 102—Environmental Chemistry
EnE 204—Environmental Microbiology
EnE 218—Biological Waste Treatment
EnE 219—Stream and Estuary Analysis
EnE 220—Solid Waste Disposal Systems
EnE 223—Waste Water Laboratory
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:

EE 273—Random Signal Analysis I
EnE 201—Introduction to Solid Waste Problems
EnE 205—Pollution Analysis Laboratory
EnE 206—Pollution, Chemistry and Ecology
ME 250—Noise Control
ME 253—Combustion
OS 250—Cost-Benefit Analysis and Economic Decision
OS 265—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 19, 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.

# COURSES SPONSORED BY THE FOUNDATION AT NEWARK COLLEGE OF ENGINEERING

## IN-SERVICE INSTITUTES

Under the sponsorship of the National Science Foundation and the Foundation for the Advancement of Graduate Study in Engineering, courses are offered to qualified teachers in the high schools of the City of Newark and other communities, enabling them to become familiar with the most recent advances in chemistry, mathematics, and physics. These courses are administered by the Graduate Division and the course offered in each field is designed to increase the teacher's knowledge of the field, to familiarize him with the techniques necessary for successful teaching in the field, and to provide a foundation for continued and more advanced work in the area of specialization selected. The courses offered are described below. Admission information may be obtained from the Director of In-Service Institutes, Newark College of Engineering, Newark, New Jersey 07102.

### COURSES OF INSTRUCTION

G 200. SEMINAR ON ENGINEERING EDUCATION. *No credit.* Selected Faculty.

Orientation, profile of the engineering student, the student and the learning process, history of engineering education, workshop on teaching methods, visual aids, test construction and validity, evaluation of student performance, psychology of the teacher, the teacher in student guidance, research. ***Required of all Teaching Fellows with no prior teaching experience.***

### IN-SERVICE INSTITUTES FOR HIGH SCHOOL TEACHERS

G 101. MATHEMATICS INSTITUTE. 6 *credits per year,* 1*st* and 2*nd sem.* KONOVE.

Designed to meet some of the recommendations of the Mathematical Association of America for the training of high school mathematics teachers. Course will include probability, statistics, general ideas of sets, variables, functions, and similarity of structure patterns.

G 109. HARVARD PROJECT PHYSICS. 6 *credits per year,* 1*st and* 2*nd sem.* LANDSMAN.

Designed to present the aims of the Harvard Project Physics Study Committee, this introductory course is intended to produce a one-year curriculum in physics for use in secondary schools and junior colleges. Using simultaneous groupings and sub-groupings, a thorough study is presented of printed materials, film loops, transparencies, and laboratory materials and equipment. Unit topics include concepts of motions, motion in the heavens, triumph of mechanisms, light and electromagnetism, models of the atom, and the nucleus.

ARTIST'S RENDERING OF NCE CAMPUS.

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2 THE CENTER — 150 BLEEKER STREET

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4 CULLIMORE HALL (M) — 70 SUMMIT STREET

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