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Newark College of Engineering Graduate Programs 1971-72 Academic Year

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NEWARK COLLEGE OF ENGINEERING

GRADUATE PROGRAMS

1971-72 ACADEMIC YEAR

DIRECTORY FOR CORRESPONDENCE

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TELEPHONE: Area Code 201, 645-5321

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

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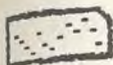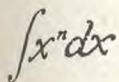For transcripts and student grades, address the Recorder. Telephone: 645-5139.

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Address the Administrator. Telephone: 645-5211.

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Address the Plant Engineer. Telephone: 645-5151.

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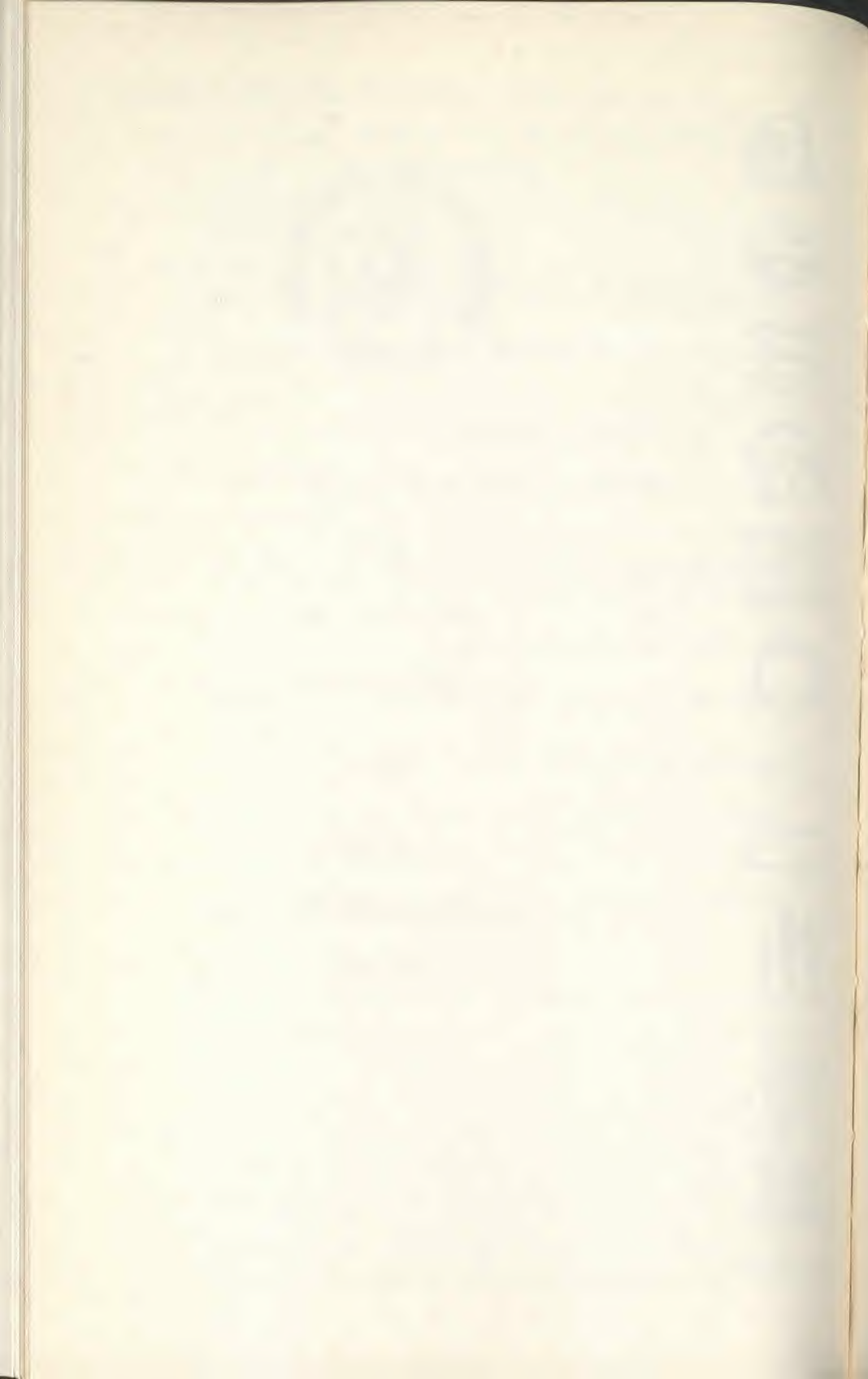
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CATALOG

OF

GRADUATE

PROGRAMS

1971-1972

ACADEMIC

YEAR

CONTENTS

GRADUATE DIVISION CALENDAR: 1971-72

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

1971

Registration — Fall Semester............In accordance with
instructions to be issued.

Fall Semester Begins ....September 15

Awarding of October Degrees
  in absentia ....October 1

Columbus Day (Not a holiday) ....October 11

Veterans' Day (Not a holiday) ....October 25

Thanksgiving Holidays ....November 24 to 27, inclusive

Christmas Holidays ....December 21 to
January 1, inclusive

1972

Fall Semester Ends ....January 15

Registration — Spring Semester........In accordance with
instructions to be issued.

Spring Semester Begins ....February 2

Last date on which graduates
  may file "Application for
  Candidacy" for Spring
  Commencement ....February 4

Washington's Birthday Holiday ......February 21

Good Friday Holiday ....March 31

Spring Vacation................................April 1 to 8, inclusive

Spring Semester Ends ....May 23

Commencement ....June 2

Registration — Summer Session*......June 9

Summer Session Begins....................June 12

Summer Session Ends ....August 3

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

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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 State Board of Education, the Board of Trustees of the College is empowered to confer the degrees of Master of Science in Chemical, Civil, Electrical, Management, and Mechanical Engineering. 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, computer science, 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.

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. In some cases, a limited number of credits may be accepted from other colleges.

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 pages 107-108 of this catalog.

FOUNDATION FOR THE ADVANCEMENT OF GRADUATE STUDY IN 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 71,000 volumes is available for student use. Subscriptions to over 1,200 periodicals are maintained in addition to many indexing and abstracting services which give access to the literature of engineering and science.

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.

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 physical 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 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.

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.

D —Work of fair quality; but not acceptable for credit toward graduate degree.

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.

EXPENSES

TUITION AND REGULAR FEES

Tuition (Residents of New Jersey) .... $27.00 per credit
Tuition (Non-residents of New Jersey) .... $40.00 per credit
Registration Fee .... $7.00 per semester
General Fee .... $6.00 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 22.)

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 his 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 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 26.)

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 $3000, 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
Food Machinery and Chemical Corporation Fellowships
E. I. Du Pont de Nemours and Company, Inc. Fellowships
Diamond Shamrock Corp. Summer Fellowships
RCA Fellowship in Computer Science
College Graduate Assistantships
College Teaching Fellowships
College Research Assistantships

The College teaching fellows are supported in part by the Foundation for the Advancement of Graduate Study in 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.

Two broad categories of programs leading to the Master's degree are offered:

A. A student who continues to major in his undergraduate engineering discipline may receive a degree with designation of major engineering department: M.S. in Chemical Engineering, M.S. in Civil Engineering, M.S. in Electrical Engineering, M.S. in Industrial Engineering, or M.S. in Mechanical Engineering. If a student wishes to change engineering fields he may be admitted to a program leading to a designated degree by taking undergraduate prerequisites specified by the department. No graduate credit is earned for such courses. The general requirements for this degree are listed below in paragraph A of the section headed "Academic Requirements." The student's graduate program must be approved by the department of major studies. The specific requirements of the individual departments will be found under their listings in this catalog.

B. 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 who wish to pursue interdisciplinary programs, may receive the degree of Master of Science. The general requirements for this degree are listed in paragraph B of the section "Academic Requirements." In achieving the goal of meaningful flexibility in the design of a coherent interdisciplinary program, two options described below are available to the student working toward the degree of Master of Science:

(1) Engineering Programs—A student whose major field of interest is in work offered by one of the engineering departments must follow a program approved by that department. Specific departmental requirements will be found under the individual engineering department listings in this catalog.

(2) Engineering Science Program—A student whose major field of interest is in work outside of the engineering departments will be assigned an adviser appropriate to his interests. 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, computer science, mathematics, and physics. As individual student need dictates and as interest develops, adviser assignment and program design may be planned on a cross-departmental basis. Fields of current interest in which work leading to the degree Master of Science may be taken are indicated below:

Environmental Science and Environmental Engineering
Major emphasis in courses offered by the Department of Civil and Environmental Engineering. Possible minor interests in almost all other departments. See also Urban Systems, below.

Materials Science
Details of this program are described in the section "Department of Physics."

Polymer Engineering
Major emphasis in courses offered by the Department of Chemical Engineering and Chemistry. Possible minor interests in mechanical engineering or materials science.

Systems Engineering
Each of the engineering departments and the Department of Computer Science offer a variety of courses appropriate to an interest in systems. Acceptable programs may be designed with a major in any one of these departments.

Transportation Systems and Transportation Engineering
Major emphasis in courses offered by the Department of Civil and Environmental Engineering. Possible minor interests in organizational and social sciences.

Urban Systems
Details of this program are described in the catalog sections under the Department of Civil and Environmental Engineering and the Department of Organizational and Social Sciences.

ADMISSION

Applicants for admission to a Master's program must present as minimum qualifications a baccalaureate degree in engineering, or in physics, chemistry or mathematics. An undergraduate degree in engineering offered for admission must have been granted in an ECPD accredited program; a degree in physics, chemistry, or mathematics must have been granted by a

regionally-accredited college or university. Students with degrees from foreign colleges or universities are advised to contact the Graduate Division regarding special procedures to be followed. (See also Eng 101, page 107.)

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. Appointments cannot be made between June 20 and September 1. 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. A Master of Science degree in Chemical, Civil, Electrical, Industrial, or Mechanical Engineering will require of the student the following:

1. Graduation from an ECPD and regionally accredited college of engineering with undergraduate work in the area of specialization desired. If the student wishes to change fields, he may do so by taking certain *undergradu-*

ate prerequisites as determined by the advisor for the department under which he desires to study.

2. 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.

3. 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.

4. 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 Master of Science degree will require of the student the following:

1. Graduation from an ECPD and regionally accredited college of engineering; or, graduation from a regionally accredited college or university with a bachelor's degree with a major in Chemistry, Physics, or Mathematics, and a minor in Mathematics or Science.

2. 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.

3. 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.

4. 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 of Science degree with a maximum allowance of nine credits. 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 $A = 4, B = 3, C = 2, D = 1, F = 0$.

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.

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.

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 exam-

ination 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.
5. Demonstration of technical reading ability in at least one foreign language useful to the research or design.
6. 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 22, 24 and 27 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

Matriculation fees, registration fees, and all other fees except laboratory fees and general fees, are under no condition returnable.

The percentage of tuition, and laboratory and general fees 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 1. 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 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.

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 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. 3 *credits, 2nd sem.* HANESIAN.

Prerequisite: Undergraduate reaction kinetics. The theory of absolute reaction rates is discussed. The kinetics of homogeneous reactions is studied, and applications are made to batch and flow processes. Uncatalyzed heterogeneous reactions are considered. Considerable attention is devoted in this course to reactor design.

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.

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.* GRISKEY.

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 1971-72 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.

ChE 234. CHEMICAL PROCESS DYNAMICS AND CONTROL. 3 *credits, 2nd sem.* PERNA.

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 five 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.* KREPS *and* 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 five students each semester.

Hours by arrangement: 1 hour conference, 4 hours design per week.

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

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 1971-72 and alternate years.

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

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 1971-72 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 1971-72 and alternate years.

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 310. MOLECULAR THERMODYNAMICS. *3 credits, 2nd sem.* JOFFE.

Prerequisite: ChE 211. Molecular and statistical concepts are used to provide a theoretical basis for the correlation of thermodynamic prop-

erties. Regular solution theory is considered. Applications are made to the calculation of physical and thermodynamic properties of pure fluids and of their mixtures and to phase equilibria.

Offered 1972-73 and alternate years.

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 1971-72 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 1972-73 and alternate years.

ChE 325. TRANSPORT PHENOMENA II. 3 *credits, 2nd sem.* GRISKEY and 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 1971-72 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 1972-73 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.

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 1971-72 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 1971-72 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 mechanis-
tic, 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 elasto-
meric 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 biochem-
istry. 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.* PERLMUT-
TER and TRATTNER.

Prerequisite: Undergraduate organic chemistry. Organic chemistry is
treated from the point of view of reaction mechanisms. Reactions cov-
ered include nucleophilic and electrophilic aliphatic and aromatic
substitution, addition, elimination, thermal and photochemical rearrange-
ments, and oxidation and reduction reactions.

⊤ Offered 1972-73 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 1972-73 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 pre-
sented. 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, 1st sem.*

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 1972-73 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 1972-73 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 1972-73 and alternate years.

Chem 230. ADVANCED ANALYTICAL CHEMISTRY. *3 credits, 2nd sem.* SHILMAN and BISHOP.

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.

Chem 240. POLYMER CHEMISTRY. *3 credits, 2nd 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.*

Offered 1972-73 and alternate years.

Chem 241. POLYMER PROPERTIES. 3 credits, 1st 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 1972-73 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 pre-radical 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 1971-72 and alternate years.

Chem 258. ADVANCED PHYSICAL CHEMISTRY. 3 credits, 1st sem. Department Faculty.

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 1972-73 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 $25.00 deposit must be maintained.

DEPARTMENT OF CIVIL
AND ENVIRONMENTAL ENGINEERING

MASTER OF SCIENCE PROGRAMS

MASTER OF SCIENCE IN CIVIL ENGINEERING

The degree *Master of Science in Civil Engineering* is intended for the civil engineering graduate, or equivalent, who wishes to further his civil engineering training by choosing a major program of civil engineering specialization.

For the *M.S. in C.E.* degree, each student shall elect (1) eighteen credits of course work and thesis or course work only in his civil engineering specialization; (2) six credits of related electives; and (3) six credits of elective course work in mathematics or computer science.

MASTER OF SCIENCE

The degree *Master of Science* for students majoring in civil engineering is intended primarily for science or non-civil engineering graduates, but also for civil engineering graduates who desire to follow a program of specialization in civil engineering together with a diversified but coherent program of work in other fields.

For the M.S. degree, each student shall elect (1) twelve credits of course work and thesis or course work only in his civil engineering specialization; and (2) eighteen credits of course work consisting of no more than three different pairs of related courses in civil engineering, mathematics, computer science, chemistry, physics, mechanics, and/or management of which six credits of course work shall be reasonably related to his civil engineering specialization. Typical programs for students wishing to major in urban systems are described on pages 43-44.

FIELDS OF SPECIALIZATION

All programs of civil engineering specialization shall be in either construction, sanitary, soils and foundations, structural, or transportation engineering, and all shall include a minimum of three hours of a project and/or a thesis.

Should a student elect a thesis or civil engineering project when design courses are part of his required major, the thesis or civil engineering project shall not parallel the work of the design courses.

In designing their graduate programs, students majoring in civil or environmental engineering will want to consider courses offered by other departments. The list below is a selected (but not exclusive) group of courses which may be considered in satisfying degree requirements.

MATHEMATICS

Math 111—Numerical Methods
Math 151—Applied Mathematics I
Math 173—Differential Equations I
Math 174—Differential Equations II
Math 220—Matrix Theory
Math 252—Applied Mathematics II

Math 261—Mathematical Statistics
Math 262—Statistical Inference
Math 268—Probability
Math 271—Approximate Methods in
    Engineering Analysis

COMPUTER SCIENCE

CS 221—Numerical Analysis I

CS 222—Numerical Analysis II

CHEMISTRY AND CHEMICAL ENGINEERING

Chem 151—Biochemistry

ChE 234—Chemical Process Dynamics
    and Control

INDUSTRIAL AND MANAGEMENT ENGINEERING

EM 202—Introduction to Manage-
    ment Science
EM 203—Analytical Engineering
    Statistics
EM 250—Introductory Operations
    Research

IE 204—Advanced Analytical
    Engineering Statistics
IE 205—Mathematical Programming
    in Management Science
IE 233—Linear Programming
IE 269—Human Design Factors in
    Engineering

ORGANIZATIONAL AND SOCIAL SCIENCES

OS 224—Methods of Research in the
    Behavioral Sciences
SS 171—Urban Social Structure
SS 203—Econometrics

SS 250—Cost-Benefit Analysis &
    Economic Decisions
SS 262—Economic Analysis of Urban
    Areas

MECHANICAL ENGINEERING

ME 223—Experimental Stress
    Analysis

MASTER OF SCIENCE PROGRAM IN 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 in sections B2, B3 and B4 on pages 20-21.

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 Manage-
　　　　ment 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

ENVIRONMENTAL ENGINEERING
CE 201—Civil Engineering Projects
EM 203—Analytical Engineering
　　　　Statistics
EnE 201—Introduction to Solid
　　　　Waste Problems
EnE 215—Water Quality Evaluation
EnE 217—Water Pollution Control

EnE 222—Air Pollution Control
EnE 261—Urban Systems Engineering
EnE 265—Land Use Planning
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

DOCTOR OF SCIENCE 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 23 and 24. The candidate must satisfactorily complete all courses that the Department may specify.

QUALIFYING EXAMINATION

The candidate must satisfactorily complete a two-part qualifying examination. The first part of this examination is designed to test his general knowledge of civil engineering and mathematics and must be taken the February following admission. The second part of the examination, which will be both written and oral, is designed to test his knowledge of the specific area of his

specialization and must be taken within three years of the first part. The candidate must demonstrate his proficiency in reading an appropriate foreign language.

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

CE 151. SOILS ENGINEERING I. *3 credits, 1st sem.* Department Faculty.

Prerequisite: Undergraduate course in soil mechanics. This course is specifically oriented toward the student who is majoring in some field *other* than soil mechanics and foundations (e.g., construction engineering or structures). Discussions of application (case histories) are pursued immediately after sufficient theory is developed. The major emphasis of the course is in settlement of structures.

Laboratory fee: $20.00.

Offered 1972-73 and alternate years.

CE 152. SOILS ENGINEERING II. *3 credits, 2nd sem.* Department Faculty.

Prerequisite: CE 151. This is a companion course to Soils Engineering I. The major emphasis is on the study of shear strength theory as related to the bearing capacity of routine structures. Complex foundation problems are discussed in the context of when to consult a specialist.

Offered 1972-73 and alternate years.

CE 153. ENGINEERING GEOLOGY. *3 credits, 1st sem.* MONAHAN.

Prerequisites: Undergraduate courses in soil mechanics and 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. Some field trips are planned.

Offered 1971-72 and alternate years.

CE 172. STRUCTURAL MODEL ANALYSIS. *3 credits, 2nd 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 work makes use of Begg's deformeter, brittle lacquer, and electric resistance gauges for the measurement of strains.

Offered 1971-72 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 1972-73 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. A student who has done an exceptional quality of work in either CE 201 or CE 202 may, upon his own initiative and with the approval of his adviser, substitute the work of either course as the equivalent of the first three credits for a Master's Thesis, CE 301.

CE 202. CIVIL ENGINEERING PROJECTS II. 3 *credits, 1st* or *2nd sem.* Department Faculty.

A continuation of CE 201.

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.

CE 251. SOIL MECHANICS I. 3 *credits, 1st sem.* Department Faculty.

Prerequisite: Undergraduate course in soil mechanics. This course is a review of basic soil properties and applied mineralogy and a study of stress distribution and consolidation with laboratory techniques of consolidation testing.
Laboratory fee: $20.00

CE 252. SOIL MECHANICS II. 3 *credits, 2nd sem.* Department Faculty.

Prerequisite CE 251. A study of the most recent advances in the field of shear strength of soils and associated practical problems. Laboratory techniques of triaxial shear testing are included.
Laboratory fee: $20.00

CE 253. FOUNDATION ENGINEERING I. 3 *credits, 1st sem.* Department Faculty.

Prerequisites: CE 251 and an undergraduate course in the design of structures. Fundamentals of applied soil mechanics, criteria for the design of foundations and selection of foundation types are studied.

CE 254. FOUNDATION ENGINEERING II. 3 *credits, 2nd sem.* Department Faculty.

Prerequisite: CE 253. The course consists of problems in the design of foundations and earth structures, including structural foundation elements.

CE 271. THEORY OF STRUCTURAL ANALYSIS I. 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 272. THEORY OF STRUCTURAL ANALYSIS II. 3 *credits, 2nd sem.* STACK-STAIKIDIS.

Prerequisite: CE 271. Influence line theory is applied to indeterminate structures with prismatic and nonprismatic members. The behavior of frames with continuous curved members, out-of-plane loading of curved members, secondary stresses, and buckling of frames and arches is studied.

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

Prerequisites: Undergraduate vibration analysis, 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 1972-73 and alternate years.

CE 281. CONSTRUCTION MANAGEMENT. 3 *credits, 1st sem.* OLSEN.

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.* OLSEN.

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 1971-72 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.* GRANIK.

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 1971-72 and alternate years.

CE 336. ANALYSIS AND DESIGN OF SHELL STRUCTURES. 3 *credits, 1st sem.* SALEK.

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 1971-72 and alternate years.

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

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 transforma-

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tions, the flexibility and stiffness method as applied to determinate and indeterminate structures, and analysis by substructures, incursion, and iteration.

Offered 1971-72 and alternate years.

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

Prerequisite: CE 252 or CE 254. 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 1971-72 and alternate years.

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

Prerequisite: CE 252 or CE 254. 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 1971-72 and alternate years.

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

Prerequisites: CE 252, Math 252. 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 1972-73 and alternate years.

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

Prerequisites: CE 252, Math 252. 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 1972-73 and alternate years.

CE 371. 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 1972-73 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 1971-72 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 or Mech 206. 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 1971-72 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 1971-72 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 1972-73 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 sem.* Songonuga.

Prerequisite: Undergraduate general chemistry. Basic physical and chemical principles applicable to environmental and sanitary engineering are presented and amplified in the laboratory.

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 1972-73 and alternate years.

EnE 204. ENVIRONMENTAL MICROBIOLOGY. *3 credits, 1st sem.* DRESNACK.

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. Antipollution legislation is considered.

EnE 214. WASTE-WATER EVALUATION. *3 credits, 2nd sem.* SONGONUGA.

Prerequisites: EnE 102, 204. The principles necessary for evaluation and control of water pollution are presented. Emphasis is placed on the biological aspects of water pollution control. The laboratory is utilized to assess the characteristics of waste-water.

Laboratory fee: $20.00.
Offered 1971-72 and alternate years.

EnE 215. WATER QUALITY EVALUATION. *3 credits, 2nd sem.* SONGONUGA.

Prerequisite: EnE 102 (May be taken concurrently). Consideration is given to the composition and impurities of natural waters and to the water quality criteria used to evaluate supplies. Laboratory determinations are made for the selection and control of treatment.

Laboratory fee: $20.00.
Offered 1972-73 and alternate years.

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 1972-73 and alternate years.

EnE 217. WATER POLLUTION CONTROL. *3 credits, 1st sem.* LISKOWITZ.

Prerequisite: B.S. degree in engineering or science. The basic principles for the analysis of water pollution in rivers, lakes, and estuaries are presented. Application is made to the oxygen balance of receiving waters and the determination of required levels of waste treatment.

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

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.
Offered 1971-72 and alternate years.

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 1972-73 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 1972-73 and alternate years.

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

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 1972-73 and alternate years.

EnE 246. HYDROLOGY. *3 credits, 2nd sem.* CHENG.

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 1972-73 and alternate years.

EnE 261. URBAN SYSTEMS ENGINEERING. *3 credits, 2nd sem.* DEUTSCHMAN.

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 1971-72 and alternate years.

EnE 265. LAND USE PLANNING. *3 credits, 1st sem.* DEUTSCHMAN.

Prerequisite: B.S. degree in architecture, engineering, or science. 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 1972-73 and alternate years.

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

Prerequisite: Undergraduate transportation engineering. 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 1972-73 and alternate years.

EnE 267. TRAFFIC ENGINEERING. 3 *credits, 1st sem.* KRAFT.

Prerequisite: Undergraduate statistics. 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 268. TRAFFIC SAFETY. 3 *credits, 2nd sem.* LEHMAN.

Prerequisite: EnE 267 or undergraduate course in transportation engineering. 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 1971-72 and alternate years.

EnE 315. ANALYSIS OF RECEIVING WATERS. 3 *credits, 2nd sem.* DRESNACK.

Prerequisites: EnE 214, EnE 217, and mathematics acceptable to the Department. The deozygenation and reaeration of receiving waters are considered in detail. Mathematical models for water quality are developed.

Offered 1971-72 and alternate years.

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

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 1971-72 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 1971-72 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 1971-72 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 1971-72 and alternate years.

EnE 364. TRANSPORTATION PROJECTS. 3 *credits, 2nd sem.* DEUTSCHMAN.

Prerequisite: EnE 361. Individual and group projects are undertaken, integrating methodology obtained in land use, transportation planning, and traffic engineering. Emphasis is on practical techniques.

COURSES OF INSTRUCTION IN MECHANICS

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 and limitations of the derivations and on applications to actual problems.

Offered 1972-73 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 1972-73 and alternate years.

Mech 256. HYDRODYNAMICS. *3 credits, 2nd sem.* GRANIK.

Prerequisite: Vector analysis or Math 151. Dynamics of ideal fluids are treated by methods of singularities and separation of variables. Two dimensional flows are analyzed by the methods of complex variables. Blasius' theorem is used to compute pressure distribution, forces, and moments on submerged bodies.

Offered 1972-73 and alternate years.

Mech 304. THEORY OF ELASTIC STABILITY. *3 credits, 2nd sem.* GOLUB.

Prerequisites: Mech 206. A study is made of the critical load and buckling configuration of bars with axial and lateral loads, non-uniform cross-sections, thin plates, and shells. Both strain-energy and differential equation methods are discussed. The methods developed are applied to numerical problems.

Offered 1972-73 and alternate years.

DEPARTMENT OF COMPUTER SCIENCE

MASTER OF SCIENCE PROGRAMS
IN ENGINEERING SCIENCE

As part of the College's offerings in Engineering Science, advanced work in computer science is available to:

(A) The graduate who has an extensive background in computer science and desires to further his formal education by specializing in advanced topics in the discipline, or

(B The graduate with a nominal background in computer science who wishes to pursue an interdisciplinary graduate program while broadening his background in computer science.

Two programs reflecting these objectives are described below. CS 110 may not be used to satisfy any of these requirements. A program of more than the minimum number of credits will be necessary for a candidate requiring this course.

MASTER OF SCIENCE

PROGRAM A

Students electing Program A must have graduated from a program in engineering science with the computer science option or must have an equivalent background in computer science. Students in this program must include:

1. Eighteen credits of specialization in computer science, including ESc 300, Master's Project, or ESc 301, Master's Thesis, and CS 235, Computer Programming Languages. The remaining credits are limited to no more than two areas of specialization (see below).

2. Six credits in mathematics.

3. Six credits in related elective courses.

PROGRAM B

Students electing Program B must have graduated from a program in engineering, mathematics, or science and must have an extensive knowledge of at least one procedure oriented language such as FORTRAN. Students in this program must include:

1. Fifteen credits of specialization in computer science, including ESc 300, Master's Project, or ESc 301, Master's Thesis, and CS 235. The remaining credits are limited to no more than two areas of specialization (see below).

2. Fifteen credits of elective courses approved by the student's adviser.

AREAS OF SPECIALIZATION

I. Systems Programming: CS 230, CS 231, CS 251

II. Language Systems: CS 235, CS 236

III. Numerical Programming: CS 221, CS 222

IV. Formal Theory: CS 140, CS 240, CS 241

COURSES OF INSTRUCTION

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 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.

Prerequisites: Undergraduate differential equations, and computer programming. 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.

Prerequisites: Calculus and some matrix theory. 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.* Department Faculty.

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 1971-72 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.

ESc 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, concurrently, 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.

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. 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.

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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.

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 System Engineering:

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
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 Computers:

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 Theory:

EE 222—Wave Propagation
EE 242—Modulation Theory I
EE 273—Random Processes in Electrical Communication I

EE 342—Modulation Theory II
EE 344—Communications System Design
EE 373—Random Processes in Electrical Communication 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 Engineering:

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.

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.

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 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 technical reading of one or more appropriate foreign languages.

4. Demonstration of proficiency in both analog and digital computer programming.

5. 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 vacuum-tube and transistor amplifiers, with linear and nonlinear circuits. Feedback amplifiers and oscillators. Amplitude modulation. Rectifiers and filters.

EE 150. CIRCUIT ANALYSIS. *3 credits, 1st sem.*

Prerequisite: Math 173 or equivalent. Transient and steady-state analysis of linear, lumped-parameter electric circuits, using the pole-zero approach. Mesh and nodal analysis, network theorems, analogues, Laplace transform method applied to systems with non-zero initial conditions.

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 1972-73 and 1975-76.

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 1971-72 and 1974-75.

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

Prerequisite: EE 210 or 216. Topics of the course include fundamental principles of protective relaying, relay operating characteristics, relay response and problems of protection with over-current, voltage, directional and differential relays; distance relays and wire pilot relays; and transformer, bus and line protection.

Offered 1971-72 and 1974-75.

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

Prerequisites: EE 120 and Math 174 or equivalent. Electromagnetic field theory; rectangular waveguides; the differential antenna; linear antennas; and antenna arrays are covered.

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

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 1971-72 and alternate years.

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

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 1972-73 and alternate years.

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

Prerequisite: Bachelor's degree in science or engineering. 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. MODULATION THEORY I. 3 credits, 1st sem.

Prerequisite: EE 140 or equivalent. 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.

Prerequisite: EE 222 or equivalent. This course is concerned with the foundations of microwave engineering. The topics covered include passive microwave devices, electromagnetic resonators, periodic structures and filters, microwave tubes, microwave masers and parametric amplifiers.

Offered 1972-73 and alternate years.

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

Prerequisite: EE 250 or equivalent. 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, 2nd sem.

Prerequisite: EE 140 or equivalent. 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, 2nd 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.

Prerequisite: EE 150. Corequisite: Math 258. After a brief review of Fourier and Laplace transform theory, this course presents the discrete and fast Fourier transforms, sampling theory, and the Laplace inversion integral. State-variable representation of systems, matrix methods, the z-transform, concepts of feedback and stability, and the relationships between the real and imaginary parts of two-port-transfer functions are studied. Where feasible, the digital computer is used to solve problems that illustrate applications of the methods considered.

Offered 1971-72 and alternate years.

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

Prerequisite: EE 256. Topics covered include physics and characteristics of integrated circuit devices such as surface field-effect transistors and capacitors, junction field-effect transistors, Shottky-barrier diodes, and bipolar transistors. Processing technologies used in their fabrication (epitaxy, diffusion, photolithography, sputtering, thermal and electron

beam evaporation) are discussed, followed by an introduction to the implementation and performance of integrated circuits using the studied devices.

Offered 1971-72 and alternate years.

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

Prerequisite: Undergraduate courses in electrical 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 1971-72 and 1974-75.

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

Prerequisite: EE 263. 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 1971-72 and alternate years.

EE 264. DISCRETE SYSTEMS. 3 *credits, 1st sem.*

Prerequisite: EE 263 or 256. 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 1972-73 and alternate years.

EE 266. CONTROL SYSTEM LABORATORY. 3 *credits, 2nd sem.* PADALINO.

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 1972-73 and alternate years.

EE 270. ADVANCED ELECTROMECHANICAL ENERGY CONVERSION I. 3 *credits, 1st sem.*

Prerequisite: EE 260. The course deals with advanced topics in induction and synchronous machines, effects of space and time harmonics, speed-torque-current control, modes of vibration and mechanical resonance, dynamic stability, and effects of pulsating torque. The course is supplemented by laboratory experiments.

Offered 1972-73 and 1975-76.

EE 273. RANDOM PROCESSES IN ELECTRICAL COMMUNICATIONS I. 3 *credits, 1st sem.*

Prerequisite: EE 150 or equivalent. 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 1972-73 and alternate years.

EE 274. NOISE IN ELECTRICAL CIRCUITS. 3 *credits, 2nd sem.* MISRA.

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 1972-73 and alternate years.

EE 275. SYNTHESIS OF DIGITAL CONTROL CIRCUITS. 3 *credits, 2nd sem.*

Prerequisites: EE 140 or 175 and 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 1972-73 and alternate years.

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

Prerequisites: EE 263, 160, 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 1972-73 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.* Department Faculty.

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. The paper must be initiated in an EE course, with the knowledge and approval of the instructor in such course, at the start of the course. Students must make substantial progress toward completion of the project while taking the designated course. They will then be required to register the succeeding semester for EE 300, during which semester the paper must be completed, usually with the original instructor as the student's adviser. A student who has submitted a report in EE 300 deemed by the adviser to be of exceptional quality may, upon the initiative of the adviser, be allowed to extend the Master's Project, EE 300, into a Master's Thesis, EE 301.

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.* Department Faculty.

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.*

Prerequisites: EE 210 or 216 and EE 212. Theoretical developments and computer methods in determining economic operation within the boundaries of a given steam-electric operating area. Energy accounting control, and economic theories for interconnected steam and hydro-electric power systems with emphasis on digital computers.
Offered 1971-72 and 1974-75.

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 1972-73 and alternate years.

EE 339. FEEDBACK AMPLIFIERS II. 3 *credits,* 2nd *sem.* ZAMBUTO.

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 1972-73 and alternate years.

EE 342. MODULATION THEORY II. 3 *credits, 2nd sem.* KLAPPER.

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 1971-72 and 1974-75.

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 1971-72 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 1971-72 and alternate years.

EE 352. NETWORK THEORY II. 3 *credits, 1st sem.*

Prerequisite: EE 252. Included are general methods of driving-point impedance synthesis, ladder networks and two terminal pairs, and approximation methods. Offered 1971-72 and alternate years.

EE 353. ELECTRIC FILTER DESIGN. 3 *credits, 1st sem.* PADALINO.

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 1972-73 and alternate years.

EE 358. INTEGRATED CIRCUITS II. 3 *credits, 2nd sem.*

Prerequisite: EE 258. The course covers design and analysis of microelectric logic and memory circuits; reliability; pulse propagation using thin film transmission lines; linear integrated circuits; and topics of current interest. Offered 1971-72 and alternate years.

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

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 1971-72 and alternate years.

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

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 1971-72 and alternate years.

EE 373. Random Processes in Electrical Communication II. 3 *credits, 1st sem.* Rosenstark.

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 1972-73 and 1975-76.

EE 375. Digital Communication. 3 *credits, 2nd sem.* Klapper and Kurland.

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 1972-73 and 1975-76.

EE 376. Information Theory. 3 *credits, 2nd sem.* Dobrow and Klapper.

Prerequisite: EE 273. 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 1977-72 and 1974-75.

EE 377. Statistical Decision Theory in Communications. 3 *credits, 1st sem.* Weisbecker.

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.* DOBROW.

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 1971-72 and 1974-75.

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

Prerequisite: EE 242 or equivalent. 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 1972-73 and 1975-76.

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

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 1971-72 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 or 216, EE 212. This course covers the elements of the stability problem, the principal factors affecting stability, the ordinary simplied 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 1972-73 and 1975-76.

EE 395. MAGNETOHYDRODYNAMIC POWER GENERATION. *3 credits, 2nd sem.*

Prerequisites: EE 260 and 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.* Department Faculty.

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 also 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.* Department Faculty.

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.* Department Faculty.

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 also for EE 401 unless requirement is waived, in writing, by thesis adviser.

EE 403. PROFESSIONAL PROJECT. *Credits as designated, 1st or 2nd sem.* Department Faculty.

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 424. ADVANCED ANTENNA THEORY. *3 credits, 2nd sem.*

Prerequisite: EE 222, Math 258, Math 174 or approximate equivalents, and permission of the department. Selected topics in advanced electromagnetic field theory, such as radiation over a conducting earth, aperture type antennas, antenna pattern synthesis methods, supergain antennas, and others as determined by interests of the students.

Offered 1972-73 and alternate years.

EE 432. SEMINAR IN COMMUNICATION SYSTEMS. 3 *credits, 1st sem.* KLAPPER.

Prerequisites: EE 242 and 273 or equivalents. 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 1971-72 and alternate years.

EE 446. LASERS AND MASERS. 3 *credits, 2nd sem.* ZAMBUTO.

Prerequisites: EE 348 and Phys 230. This course covers selected topics in maser design, modulation, and applications. Included are population inversion 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 1971-72 and alternate years.

EE 451. SEMINAR ON RELIABILITY PROBLEMS AND RESEARCH. 3 *credits, 2nd sem.* MISRA.

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 1971-72 and alternate years.

EE 466. OPTIMAL CONTROL THEORY. 3 *credits, 1st sem.* KUO.

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 1972-73 and alternate years.

EE 467. STOCHASTIC CONTROL THEORY. 3 *credits, 2nd sem.* PERLIS.

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 1972-73 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 1972-73 and 1975-76.

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, ergonomics, 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 industrial or management engineering.

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

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 and Programming of Digital
            Computers (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 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—Introduction to Systems
EM 255—Intro. to Systems Engrg.
          & Electronic Data
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

SYSTEMS ENGINEERING

CS 110—Computer Programming
CS 221—Numerical Analysis I
CS 222—Numerical Analysis II
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—Intro. to Systems Engrg.
          & Electronic Data
EnE 266—Mass Transportation
          Systems
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

ERGONOMICS

EnE 267—Traffic Engineering
IE 203—Behavioral Science

IE 207—Seminar in Contemporary
          Management Problems

IE 261—Man-Machine Systems
IE 269—Human Design Factors in
Engineering
Math 261—Mathematical Statistics
Math 262—Statistical Inference

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

OS 223—Psychology in Engineering
OS 224—Methods of Research in the
Behavioral Sciences
OS 277—Techniques of Executive
Control

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 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 leading to the Master of Science degree, the following specializations are available:

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 Manage-
ment Science
EM 203—Analytical Engineering Sta-
tistics
EM 207—Product Liability
Control
EM 234—Planning & Management of
Industrial Research
EM 235—Management of Design &
Development

IE 203—Behavioral Science
IE 207—Seminar in Contemporary
Mgt. Problems
IE 221—Applications & Programg. of
Digital Computers
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 Sta-
 tistics
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 & Pub-
 lic Planning
SS 171—Urban Social Structure
SS 262—Economic Analysis of Urban
 Areas

Plus fifteen credits of electives.

COURSES OF INSTRUCTION
IN INDUSTRIAL ENGINEERING

IE 201. MEASUREMENT METHODS FOR MANAGEMENT SYSTEMS. 3 *credits, 2nd sem.* NARCAVAGE.

Prerequisite: Undergraduate course in mathematics for management science. 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.

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

Prerequisite: Undergraduate course in probability and statistics. 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, 2nd sem.* BAUMGARTNER.

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.

IE 205. MATHEMATICAL PROGRAMMING IN MANAGEMENT SCIENCE. 3 *credits*, 1*st sem.* MAXIM.

Prerequisite: EM 250. 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.

IE 207. SEMINAR IN CONTEMPORARY MANAGEMENT PROBLEMS. 3 *credits*, 1st *or 2nd sem.* MIHALASKY.

Prerequisites: Undergraduate courses in economics and management science. 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.

IE 221. APPLICATIONS AND PROGRAMMING OF DIGITAL COMPUTERS. 3 *credits*, 1*st 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*, 1*st sem.* BAUMGARTNER.

Prerequisite: Introductory course in management science. 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 or equivalent, 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.

IE 261. MAN-MACHINE SYSTEMS. 3 *credits, 2nd sem.* FICKS.

Prerequisite: EM 203 or equivalent. 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*, 1*st sem.* FICKS.

Prerequisite: Undergraduate course in probability and statistics. A study of the methods and findings of human factors research related to product and equipment design and development. Capabilities and limitations of the human sensory-motor system, design of displays and controls, ar-

rangements of groups of men and machines, effects of environment on human performance, and designing for ease of operation and maintenance are discussed.

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.* MLADINEO.
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.* BASSOFF.
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.*
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. INTRODUCTION TO MANAGEMENT SCIENCE. *3 credits, 1st or 2nd sem.* BURBRIDGE and 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: EM 203. 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 1972-73 and alternate years.

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

Prerequisite: EM 203. 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.

EM 207. PRODUCT LIABILITY CONTROL. *3 credits, 1st sem.* JACOBS.

Prerequisite: EM 202. 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 EM 102. 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 234. PLANNING AND MANAGEMENT OF INDUSTRIAL RESEARCH. *3 credits, 1st sem.* KREBS.

An objective study of industrial research and development, covering management problems in the organization, planning and operation of industrial research and development. Topics include R&D as a corporate function, the interrelationship of the business and technology plans, the

R&D organization, its direction, support, and programming, the evaluation and application of research projects, technical service, financing, patents, licensing, and the relations of R&D to the technical community. This course is designed for the R&D worker and his supervisor, or to complement training in general industrial management.

EM 235. MANAGEMENT OF DESIGN AND DEVELOPMENT. *3 credits, 2nd sem.* SHELTON.

This course analyzes the basic techniques and current practices employed for effective management of engineering. Included among the topics covered are: engineering organization, project evaluation, selection, scheduling, manpower analysis, work load planning, engineering personnel practices, and the function of the engineering administrator. Attention is given to the liaison function of engineering and relationships with research, manufacturing, accounting, and purchasing departments.

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

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.

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

Prerequisite: Introductory course in management science. 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. INTRODUCTION TO SYSTEMS ENGINEERING AND ELECTRONIC DATA PROCESSING. *3 credits, 2nd sem.* GOLDSTEIN.

Prerequisite: Computer programming experience. Treating information flow in a company as an integrated system, the course discusses the engineering of electronic data processing systems which will optimize managerial requirements. Consideration is given to feasibility studies, systems studies, the selection, installation, staffing and controlling of electronic data processing equipment. Particular attention is given to the characteristics and programming techniques of typical large and small scale computers.

EM 260. FINANCING AN INDUSTRIAL ENTERPRISE. *3 credits, 1st 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.

Offered 1971-72 and alternate years.

EM 272. INDUSTRIAL QUALITY CONTROL. *3 credits, 2nd sem.* JACOBS.

Prerequisite: EM 203. 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 1971-72 and alternate years.

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

Prerequisites: Undergraduate economics and accounting. 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 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 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. *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 sem.* DANCO and ZOZZARO.

Prerequisites: Undergraduate economics, enterprise 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, 2nd sem.* DANCO and ZOZZARO.

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. INDUSTRIAL COSTING AND MANAGEMENT CONTROL. 3 *credits, 2nd sem.* WOLF.

Prerequisite: Six credits of EM courses of level 200 or above. The analysis and control of costs and other aspects of industrial enterprises. Included are managerial controls, manufacturing and distribution controls, analytical financial statements, budgeting controls, and reports for executive direction.

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 and differential equations. 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.* CHASE.

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

Math 174. DIFFERENTIAL EQUATIONS II. *3 credits, 1st or 2nd sem.* KOREN.

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.

Math 177. STOCHASTIC PROCESSES. *3 credits, 1st sem.* MULLAN.

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. *Formerly* EE 177.

Math 220. MATRIX THEORY. *3 credits, 1st or 2nd sem.* FOSTER.

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: Math 220 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 1971-72 and alternate years.

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

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 or 2nd 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. *Formerly* Math 356.

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.* MAGRIEL.

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.* M. MILLER.

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.

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

Prerequisites: Strength of materials, vector analysis, Math 174, 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 1971-72 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.

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 1971-72 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 offered by the Department of Mathematics.

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 non-mechanical engineering graduate who wishes to specialize in some advanced mechanical engineering work or for the mechanical engineering graduate who wishes to broaden his field and to take a relatively large number of courses in some other field of study.

AREAS OF SPECIALIZATION

It is the intention of the department that areas of extension and specialization be selected in terms of individual need, and it is essential that the final selection of courses encompass sufficient depth and breadth to develop some mastery of the areas of major interest. To facilitate the selection of courses for an integrated Master's degree, the offerings of the department and of other departments whose courses are applicable have been divided into the following areas of specialization:

A. Behavior of Fluids.

B. Stress Analysis and Machine Design.

Area A. Those students interested in the Behavior of Fluids must satisfy the specialization requirements by choosing courses as follows:

Two courses must be selected from the following group:

ME 113—Dynamics of Compressible Fluids
ME 201—Heat Transfer
ME 203—Gas Turbines
ME 207—Advanced Thermodynamics
ME 216—Refrigeration & Air Conditioning Design
ME 227—Power Plant Design
ME 237—Control of Electro-Mechanical Networks
ME 242—Radiation Heat Transfer
ME 244—Energetics

Two courses must be selected from the following group:

ChE 224—Transport Phenomena
ME 218—Instrumentation
ME 221—Matrix-Tensor Methods in
Mechanical Engineering
ME 222—Dynamics of Incompressible
Flow
ME 238—Gas Dynamics
ME 246—Analysis & Synthesis for
Design
ME 307—Non-Equilibrium
Thermodynamics

ME 311—Conduction Heat Transfer
ME 314—Convection Heat Transfer
ME 317—Special Problems in
Mechanical Engineering
ME 319—Mechanics of Viscous Fluids
ME 322—Case Studies in Engineering
Design
ME 332—Statistical Thermodynamics
ME 337—Aerodynamics

If, in the opinion of the adviser, the student's interests are such that an integrated course of study would include courses offered by the Department of Physics and the Department of Civil and Environmental Engineering, one or more of the following courses may be substituted for those in the above groupings:

Mech 256—Hydrodynamics
Phys 120—Modern Physics
Phys 210—Theoretical Physics
Phys 221—Nuclear Physics

Phys 222—Elements of Nuclear
Engineering
Phys 224—Nuclear Engineering
Laboratory
Phys 230—Quantum Mechanics

Area B. Those students interested in Stress Analysis and Machine Design must satisfy the specialization requirements by choosing courses as follows:

Two courses must be chosen from the following group:

ME 205—Analytical Methods in
Machine Design
ME 210—Engineering Metallurgy
ME 217—Bearings & Bearing
Lubrication
ME 223—Experimental Stress
Analysis

ME 224—Photoelasticity
ME 226—Corrosion
ME 237—Control of Electro-
Mechanical Networks
ME 248—Design of Automatic
Machinery

Two courses must be chosen from the following group:

ME 220—Advanced Mechanical
Vibrations
ME 221—Matrix-Tensor Methods in
Mechanical Engineering
ME 230—Dynamics of Machinery
ME 234—Design of Plates and Shells
ME 235—Random Vibrations
ME 246—Analysis and Synthesis for
Design
ME 313—Viscoelasticity
ME 316—Thermal Stresses

ME 317—Selected Problems in Me-
chanical Engineering I
ME 318—Selected Problems in Me-
chanical Engineering II
ME 321—Kinematic Synthesis of
Mechanisms
ME 322—Case Studies in Engineering
Design
ME 331—Adv. Control of Electro-
Mechanical Networks

If, in the opinion of the adviser, the student's interests are such that an integrated course of study would include courses offered by the Department of Physics and the Department of Civil and Environmental Engineering, one or more the following courses may be substituted for those in the above groupings:

Mech 206—Theory of Elasticity
Mech 304—Theory of Elastic Stability
Phys 212—Dynamics of a Particle

Phys 213—Dynamics of Rigid Bodies
Phys 330—Theory of Metals

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 differential equations, vector analysis, probability and statistics, transform methods, and modern physics, as well as in engineering science. 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

The examination will be given in two parts. The first part will be taken in February, following admission, and will require demonstration of competence in the following fields:

1. Mathematics: Differential equations; Laplace transforms; vector analysis; probability and statistics; and complex variables.
2. Physics: Undergraduate physics, including modern physics; electricity and magnetism; and light and sound.
3. Mechanical Engineering: Undergraduate thermodynamics; heat transfer; fluid mechanics; mechanics; kinematics; vibrations; and strength of materials.

The second part of the doctoral examination will be written and oral, and must be taken within three years of the first part. This portion of the examination will test the student's mastery in his major field and his general knowledge of advanced engineering.

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

COURSES OF INSTRUCTION

ME 113. DYNAMICS OF COMPRESSIBLE FLUIDS. *3 credits, 1st sem.* CHEN.

Prerequisites: Undergraduate differential equations, fluid mechanics, and thermodynamics. Topics include one dimensional reversible and irreversible compressible fluid flow, normal shock; two dimensional flow including oblique shock, introduction to method of characteristics, rarified gas flow, magnetohydrodynamics, and measurements in compressible flow.

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

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, 1st sem.* JACOBS.

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 1971-72 and alternate years.

ME 205. ANALYTICAL METHODS IN MACHINE DESIGN. *3 credits, 1st sem.* DEUTSCHMAN and HERMAN.

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 207. ADVANCED THERMODYNAMICS. *3 credits, 1st sem.* HSIEH.

Prerequisites: Undergraduate differential equations, fluid mechanics, and one year of thermodynamics. Course material is directed to a consideration of topics which are hastily treated or intentionally omitted in an undergraduate course in thermodynamics. Topics include thermodynamic relations for the pure substance, equations of state, gaseous mixtures and liquid solutions, low temperature thermodynamics, and thermodynamics of reactive systems.

ME 210. ENGINEERING METALLURGY OF ALLOY STEELS. *3 credits, 2nd sem.*
Prerequisites: Undergraduate metallurgy and mechanics of deformable
bodies. The course consists of a study of the effects of alloy additions
on the constitution and properties of the iron-carbon system, with
special emphasis on transformation products and tempering results.
Offered 1972-73 and alternate years.

ME 216. REFRIGERATION AND AIR CONDITIONING. *3 credits, 2nd sem.* STAMPER.
Prerequisites: Undergraduate differential equations, fluid mechanics, and
1 year of 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.

ME 217. BEARINGS AND BEARING LUBRICATION. *3 credits, 1st sem.* MICHELS.
Prerequisites: Undergraduate differential equations and senior machine
design. A lecture course on the theoretical and physical aspects of lubri-
cation. 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.

ME 218. INSTRUMENTATION. *3 credits, 2nd sem.* JACOBS.
Prerequisites: Undergraduate differential equations, fluid mechanics, and
1 year of thermodynamics. The course is directed to the theory and
design of the primary elements of instrumention such as pressure, tem-
perature, 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.

ME 220. ADVANCED MECHANICAL VIBRATIONS. *3 credits, 2nd sem.* MICHELS.
Prerequisite: Undergraduate vibrations. Included in the course are a
consideration of the more advanced principles of vibration. La Grange's
equation of motion, field balancing, matrix notation and iteration pro-
cedure, influence coefficients, and Fourier series representation are applied
to the solution of vibration problems.

ME 221. MATRIX-TENSOR METHODS IN MECHANICAL ENGINEERING. *3 credits,
1st sem.* LEVY.
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, 2nd sem.* SMITHBERG.
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. Boun-
dary layer theory and dimensional analysis are introduced.

ME 223. EXPERIMENTAL STRESS ANALYSIS. *3 credits, 1st sem.* MILLER.

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.

ME 224. PHOTOELASTICITY. *3 credits, 2nd sem.* MILLER.

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 1971-72 and alternate years.

ME 226. CORROSION. *3 credits, 1st sem.*

Prerequisite: B.S. in science, engineering, or closely allied field. The course covers the general nature and theories of corrosion; influence of manufacturing methods and composition of metals; laboratory test methods; and protection against various forms of corrosion. Lecture material is supplemented by selected laboratory tests.

Laboratory fee: $15.00.
Offered 1972-73 and alternate years.

ME 227. POWER PLANT DESIGN. *3 credits, 1st sem.* POLANER.

Prerequisites: Undergraduate fluid mechanics and one year of thermodynamics. An analysis of modern steam power plant cycles including heater arrangements and heat balances using an analytical approach. Methods of predicting performance of steam turbine generators by short cut methods are considered. Economic considerations in the selection and arrangement of auxiliaries are presented along with the theory and practical application of incremental loading and rates.

Offered 1971-72 and alternate years.

ME 230. DYNAMICS OF MACHINERY. *3 credits, 2nd sem.* MILLER.

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 1972-73 and alternate years.

ME 234. DESIGN OF PLATES AND SHELLS. *3 credits, 2nd sem.* ALLENTUCH and WILSON.

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.

Offered 1971-72 and alternate years.

ME 235. RANDOM VIBRATIONS. 3 *credits, 1st sem.* ALLENTUCH and WILSON.

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 1971-72 and alternate years.

ME 237. CONTROL OF ELECTRO-MECHANICAL NETWORKS. 3 *credits, 1st sem.* COCHIN.

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 1972-73 and alternate years.

ME 238. GAS DYNAMICS. 3 *credits, 2nd sem.* GAAL.

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 1972-73 and alternate years.

ME 242. RADIATION HEAT TRANSFER. 3 *credits, 2nd Sem.* HRYCAK.

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 1971-72 and alternate years.

ME 244. ENERGETICS. 3 *credits, 1st sem.* SCHMERZLER.

Prerequisites: One year of undergraduate thermodynamics and undergraduate differential equations. A study of the theory and application of energy conversion systems and their energy sources. Among the subjects to be developed are electrogasdynamics, fuel cells, magnetofluidynamics, photovoltaics, thermoelectrics, and modern developments in the classical energy conversion systems.

Offered 1972-73 and alternate years.

ME 246. ANALYSIS AND SYNTHESIS FOR DESIGN. 3 *credits, 2nd sem.* NAHAVANDI.

Prerequisites: Bachelors degree in mechanical engineering and Math 151 or equivalent. 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.* A. DEUTSCHMAN.

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.

ME 300. MECHANICAL ENGINEERING DESIGN. 3 *credits,* 1st or 2nd *sem.* Department Faculty.

Prerequisites: Matriculation for M.S. degree and substantial progress in writing an extensive paper in a designated ME course. For credit an extensive paper involving design, construction and analysis, or theoretical investigation is required of all candidates for the Master's degree who do not take ME 301, Thesis. The paper must be initiated in an ME course, with the knowledge and approval of the instructor early in the course. Students must make substantial progress toward completion of the project while taking the designated course. They will then be required to register in the succeeding semester for ME 300, during which semester the paper must be completed, usually with the original instructor as the student's adviser. A student who has submitted a report in ME 300 deemed by the adviser to be of exceptional quality may, upon the initiative of the adviser, be allowed to extend the Master's Project, ME 300, into a Master's Thesis, ME 301.

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: Department approval. A written report involving experimental research, original analysis, design or development in the field of Mechanical Engineering. Discussions of the analytical and experimental solution of the assigned projects and a review of current literature will be held in the form of a seminar. *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 307. NON-EQUILIBRIUM THERMODYNAMICS. 3 *credits, 2nd sem.* BUTEAU.

Prerequisites: Undergraduate vector analysis and ME 207 or equivalent. The concepts of thermodynamic forces and fluxes are considered along with the Onsager reciprocal relations. Applications include chemical reactions, heat conduction, diffusion, viscous flow, and electrical effects.

Offered 1971-72 and alternate years.

ME 311. CONDUCTION HEAT TRANSFER. 3 *credits,* 1st *sem.* FLORIO.

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 1971-72 and alternate years.

ME 313. VISCOELASTICITY. *3 credits, 2nd sem.* MARTIN.

Prerequisite: Mech 206 or equivalent. 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 1971-72 and alternate years.

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

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 1972-73 and alternate years.

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

Prerequisites: Vector analysis or Math 151 and Mech 206. 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 1971-72 and alternate years.

ME 317. SELECTED TOPICS IN MECHANICAL ENGINEERING I. *3 credits, 1st sem.*

Prerequisites: Math 252 or equivalent, and departmental approval. This special area course will be given when suitable interest develops. Advance notice of forthcoming topics will be given.

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

Prerequisites: Math 252 or equivalent, and departmental approval. See course description for ME 317, above.

ME 319. MECHANICS OF VISCOUS FLUIDS. *3 credits, 1st sem.* HRYCAK.

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 1972-73 and alternate years.

ME 321. KINEMATIC SYNTHESIS OF MECHANISMS. *3 credits, 1st sem.* SUN.

Prerequisites: Undergraduate course in kinematics of mechanism, Math 151, 252. Modern methods for synthesizing plane and three dimensional linkages. Graphical and analytical techniques are employed and compared from the viewpoint of obtaining optimal linkage configuration.

Offered 1972-73 and alternate years.

ME 322. CASE STUDIES IN ENGINEERING DESIGN. *3 credits, 2nd sem.*

Prerequisites: ME 237, 246. A series of weekly lectures relating the complete historical background and development of a design problem from its inception to its completion. Cases are selected from industry, files on case studies, and the experience of the staff.

Offered 1971-72 and alternate years.

ME 331. ADVANCED CONTROL OF ELECTRO-MECHANICAL NETWORKS. *3 credits,* *2nd sem.* COCHIN.

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 1972-73 and alternate years.

ME 332. STATISTICAL THERMODYNAMICS. *3 credits, 2nd sem.* HSIEH.

Prerequisite: ME 207 or equivalent. This course constitutes an introduction to kinetic theory of gases and statistical mechanics. Topics include Maxwellian distribution; transport phenomena; elements of quantum mechanics; Maxwell-Boltzmann, Bose-Einstein, and Fermi-Dirac statistics; partition functions and their relations to thermodynamic functions in gaseous, liquid, and solid states.

Offered 1972-73 and alternate years.

ME 337. AERODYNAMICS. *3 credits, 1st sem.* DEUTSCHMAN and GAAL.

Prerequisite: ME 222 or Mech 256. A study of the fundamental physical principles of flow past wings and airfoil sections. The principles developed are used to establish the phenomena of lift and drag. The thin airfoil and finite wing are of primary interest. In addition, the fundamental concept of the boundary layer and its effects upon flow characteristics about airfoils are introduced.

Offered 1971-72 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.* HERMAN.

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.

Offered 1972-73 and alternate years.

ME 406. THEORY OF DEFORMABLE SOLIDS IN MECHANICAL ENGINEERING II. *3 credits, 2nd sem.* HERMAN.

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.

Offered 1972-73 and alternate years.

ME 407. INELASTIC BEHAVIOR OF CONTINUOUS MEDIA. *3 credits, 1st sem.* MARTIN.

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.

Offered 1972-73 and alternate years.

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 43-44.

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 75-76.

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 1971-72 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 1972-73 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 1971-72 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.*

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 princi-

pal 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 1972-73 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.* TALMADGE.

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 1971-72 and alternate years.

OS 277. TECHNIQUES OF EXECUTIVE CONTROL. 3 *credits, 1st sem.* TALMADGE.

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 1971-72 and alternate years.

COURSES OF INSTRUCTION IN SOCIAL SCIENCE

SS 171. URBAN SOCIAL STRUCTURE. 3 *credits, 2nd sem.* TALMADGE.

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 1972-73 and alternate years.

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

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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 1971-72 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 1972-73 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 1972-73 and alternate years.

DEPARTMENT OF PHYSICS

MASTER OF SCIENCE PROGRAMS
IN ENGINEERING SCIENCE

Advanced work in *Physics* or *Materials Science* is available to qualified students meeting the admissions requirements for the Master's program in Engineering Science. At the discretion of the Department, the applicant may be required to remove any deficiencies in his background by taking related required courses in addition to the requirements for the M.S. degree. Before initiating work toward the degree the candidate is required to consult with a departmental adviser and draw up a complete program of study subject to the approval of the adviser.

The research interests of the members of the Department of Physics cover a wide range, from theoretical physics through experimental physics, neutron physics and material science. In brief, the work being done at the present time includes the following topics: theory of general relativity; quantum mechanics applied to low-temperature physics and superconductivity; electrodynamics; plasma physics, including the study of galactic plasmas; solid state physics involving studies of resistivity of metals, dielectric failures in semiconductors, thin films, the properties of dilute metal alloys, Hall effect, crystallographic studies; biophysics; nuclear reactor physics; high pressure (explosives) physics; structure studies, growth of crystals and strength of materials. In order to aid students in the selection of Master's projects and theses, supplementary literature, including a brochure on research activities of the faculty, is available upon request to the Department.

PROGRAMS IN PHYSICS

The program provides a fundamental background in modern physics with areas of specialization possible in applied physics, solid state physics, nuclear engineering and reactor physics. A student selecting a program in physics must include the following courses:

1. ESc 300—Project or ESc 301—Thesis.
   Phys 120—Modern Physics.
   Phys 230—Quantum Mechanics.

2. One course from among the following:
   Phys 210—Theoretical Physics.
   Phys 212—Dynamics of a Particle.

3. The remaining courses, which must form a coherent physics oriented program, may be selected from physics, mathematics, chemistry, and engineering courses. Normally at least two of these courses, forming a related group, should be chosen from areas other than physics.

Some suggested areas of specialization are listed below. These are listed only to stimulate the student's interest in possible opportunities; they are not intended to be fixed requirements in a particular area of specialization.

SOLID STATE PHYSICS

EE 348—Quantum Electronics
Phys 120—Modern Physics
Phys 210—Theoretical Physics
Phys 211—Transistor Physics
Phys 214—Solid State Physics

Phys 230—Quantum Mechanics
Phys 330—Theory of Metals
Phys 340—Advanced Quantum
 Mechanics

NUCLEAR ENGINEERING

Phys 120—Modern Physics
Phys 210—Theoretical Physics
Phys 221—Nuclear Physics
Phys 222—Flements of Nuclear
 Engineering

Phys 224—Nuclear Engineering
 Laboratory
Phys 230—Quantum Mechanics

MATHEMATICAL PHYSICS

EE 120—Electromagnetic Field
 Analysis
Phys 120—Modern Physics
Phys 210—Theoretical Physics
Phys 212—Dynamics of a Particle
Phys 213—Dynamics of Rigid Bodies
 & Intro. to Cont. Media
Phys 230—Quantum Mechanics

Phys 340—Advanced Quantum
 Mechanics
Phys 211—Transistor Physics
Phys 214—Solid State Physics
Phys 221—Nuclear Physics
Phys 240—Optics
Phys 260—Celestial Mechanics
Phys 330—Theory of Metals

MECHANICS OF DISCRETE AND CONTINUOUS MEDIA

Mech 206—Theory of Elasticity
Phys 120—Modern Physics
Phys 210—Theoretical Physics
Phys 212—Dynamics of a Particle
Phys 213—Dynamics of Rigid Bodies
 & Intro. to Cont. Media
Phys 230—Quantum Mechanics

Phys 260—Celestial Mechanics
Phys 211—Transistor Physics
Phys 214—Solid State Physics
Phys 221—Nuclear Physics
Phys 240—Optics
Phys 330—Theory of Metals

PROGRAMS IN MATERIALS SCIENCE

The student selecting a program in materials science must include the following courses:

1. Chem 221—Solid State Inorganic Chemistry.

2. MatSci 270—Physics of Materials

3. MatSci 271—Advanced Materials Science Library.

4. ESc 301—Thesis.

5. Fifteen hours of electives in, or related to the student's specialization in Materials Science, selected with the adviser's approval from courses offered in this catalog. Not more than 6 hours of 100 level courses may be included.

Some suggested areas of specialization are:

1. Theory of materials.

2. Ceramics.

3. Inorganic crystals.

4. Metallic materials.

5. Polymers.

6. Semi-conductor materials.

7. Nuclear science and technology.

COURSES OF INSTRUCTION IN PHYSICS

Phys 120. MODERN PHYSICS. *3 credits, 1st sem.* FARBER.

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.* NEIDHARDT.

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.

Phys 211. TRANSISTOR PHYSICS. *3 credits, 1st sem* .TOWFIK.

Prerequisites: Differential equations and modern physics. An introduction to modern physical theories with special emphasis on the free electron and band theory of metals, followed by a study of semiconductors, particularly conductivity, Fermi-Dirac statistics, Hall effect, mobility, and crystal imperfections, and concluding with the theory of p-n junctions and p-n-p transistors.

Offered 1971-72 and alternate years.

Phys 212. DYNAMICS OF A PARTICLE. *3 credits, 1st sem.* KUHARETZ.

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 1972-73 and alternate years.

Phys 213. DYNAMICS OF RIGID BODIES AND INTRODUCTION TO CONTINUOUS MEDIA. *3 credits, 2nd sem.* KUHARETZ.

Prerequisite: Undergraduate analytical or engineering mechanics. The kinematics and kinetics of rigid bodies, Euler's equations of motion, inertia tensor, principal axes, transformation theory, Euler's angles, gyroscopic motion, and the symmetric top are covered under rigid body motion. Utilizing some of the mathematical techniques developed in rigid body dynamics, an introduction to the mechanics of continua is also included.

Offered 1971-72 and alternate years.

Phys 214. SOLID STATE PHYSICS. *3 credits, 2nd sem.* TOWFIK.

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 1972-73 and alternate years.

Phys 221. NUCLEAR PHYSICS. 3 *credits*, 1*st sem*. REFF.

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 1971-72 and alternate years.

Phys 222. ELEMENTS OF NUCLEAR ENGINEERING. 3 *credits*, 2*nd sem*. STEVENSON.

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 1972-73 and alternate years.

Phys 224. NUCLEAR ENGINEERING LABORATORY. 3 *credits*, 1*st sem*. SHUKUR.

Prerequisite: Course in nuclear engineering. Basic experiments in nuclear physics and experiments with a subcritical assembly are performed to determine and measure neutron flux, slowing down of neutrons, relaxation length, reflector savings factor, buckling, diffusion length, migration area, albedo of water for thermal neutrons, thermal utilization in uranium water lattice, and temperature coefficient of multiplication factor.

Offered 1971-72 and alternate years.

Phys 230. QUANTUM MECHANICS. 3 *credits*, 2*nd sem*. SAVIN.

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.

Phys 240. OPTICS. 3 *credits*, 2*nd sem*. SAGURTON.

Prerequisite: Phys 210 or an introductory graduate course in electricity and magnetism. A basic course in optics emphasizing the electromagnetic basis of the theory with applications in both geometric and physical optics. Topics include geometric optics treated as a special case of wave optics, physical optics and Huygen's principle, interference, diffraction, dispersion, basic optical instruments and their optical resolution, crystal optics, scattering theory, and quantum optics. Optional topics for discussion are electron optics and non-linear optics.

Offered 1972-73 and alternate years.

Phys 260. CELESTIAL MECHANICS. 3 *credits*, 1*st sem*. STEVENSON.

Prerequisites: Undergraduate dynamics and differential equations. A course in the dynamical and mathematical theory describing the motions of planets around the sun, satellites around their parent planets, one member of a double star pair around the other, and similar phenomena. Topics covered include central force motion, the two, three and n-body problems, the computation of orbits, and the theory of perturbations.

Offered 1971-72 and alternate years.

Phys 330. THEORY OF METALS. 3 *credits*, 2*nd sem*. BUTEAU.

Prerequisite: Phys 230. A theoretical course dealing with the one-electron and many-electron approximation, metallic cohesion, the Hartree-Fock method, Bloch functions and Brillouin zones, the method of Wigner and Seitz, and plasma oscillations in metals.

Offered 1971-72 and alternate years.

Phys 340. ADVANCED QUANTUM MECHANICS. 3 *credits, 1st sem.* SAVIN.

Prerequisite: Phys 230. An advanced course in quantum mechanics which discusses dynamical variables as operators, the matrix formulation of quantum mechanics, intrinsic angular momentum, scattering theory, group theory, and selected advanced topics.

Offered 1972-73 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. Approval to register for the thesis must be obtained from the thesis adviser. The work will be carried out under the supervision of a designated member of the faculty. 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 $25.00 deposit must be maintained.

COURSES OF INSTRUCTION IN MATERIALS SCIENCE

MatSc 270. PHYSICS OF MATERIALS. 3 *credits, 2nd sem.* ELLIS.

Prerequisites: Undergraduate solid state or semiconductor physics or quantum electronics or equivalent. This course treats in lectures and recitations the structure of solids, including inperfections in relation to properties; elasticity, plasticity, strength and fracture mechanisms, electrical and thermal properties, magnetism, and the optic and piezo-electric properties of crystals. Included are advanced treatments of the mechanism and kinetics of crystal growth, solid state reactions, diffusion, recrystallization and grain growth as applied to metals and ceramics and the structure and properties of polymers. Topics in the physics and chemistry of surfaces are emphasized.

MatSc 271. ADVANCED MATERIALS SCIENCE LABORATORY. 3 *credits, 1st sem.* BUTEAU.

Prerequisites: Undergraduate solid state or semiconductor physics or quantum electronics or equivalent. This course contains selected experiments illustrating crystal growth, high vacuum deposition and sputtering of thin films, elasticity and plasticity of materials, solid state reactions, diffusion and transformation. Advanced fundamental experiments using x-ray diffraction and electron microscopy and diffraction are included. Typical measurements of electrical and magnetic properties are made.

DEPARTMENT OF HUMANITIES

COURSE OF INSTRUCTION

Eng 101. ENGLISH AS A SECOND LANGUAGE. *No credit, 1st sem.* WISE.

This course is designed to help develop sufficient facility in written and spoken English for the foreign student so that he may proceed successfully with his graduate work at the College. All entering foreign students whose native language is not English will be required to take an English entrance examination. Assignment to Eng 101 will be based on the results of the examination. Satisfactory progress in Eng 101 will be considered in approving continued enrollment in the Graduate Division.

Tuition: $81.00.

COURSES SPONSORED BY THE FOUNDATION FOR THE ADVANCEMENT OF GRADUATE STUDY IN 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, 1st and 2nd 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, 1st and 2nd 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 EXPANDING NCE CAMPUS.

1 ENTWISLE PHYSICAL EDUCATION
BUILDING — 80 LOCK STREET

2 THE CENTER —
150 BLEEKER STREET

3 ALUMNI CENTER FOR CONTINUING
ENGINEERING STUDIES —
150 BLEEKER STREET

4 CULLIMORE HALL (M) —
70 SUMMIT STREET

5 240 HIGH STREET

6 EBERHARDT HALL (E) —
323 HIGH STREET

7 CAMPBELL HALL (C) —
110 SUMMIT STREET

8 WESTON HALL (W) —
367 HIGH STREET

9 SPECHT MAINTENANCE BUILDING —
120 SUMMIT STREET

10 COLTON HALL (L) —
SUMMIT PLACE

11 FACULTY MEMORIAL HALL (F) —
111 SUMMIT STREET

12 TIERNAN HALL (T) —
161 WARREN STREET

13 ROBERT W. VAN HOUTEN LIBRARY
99 SUMMIT STREET