

1-1-1970

Newark College of Engineering Graduate Programs 1970-71 Academic Year

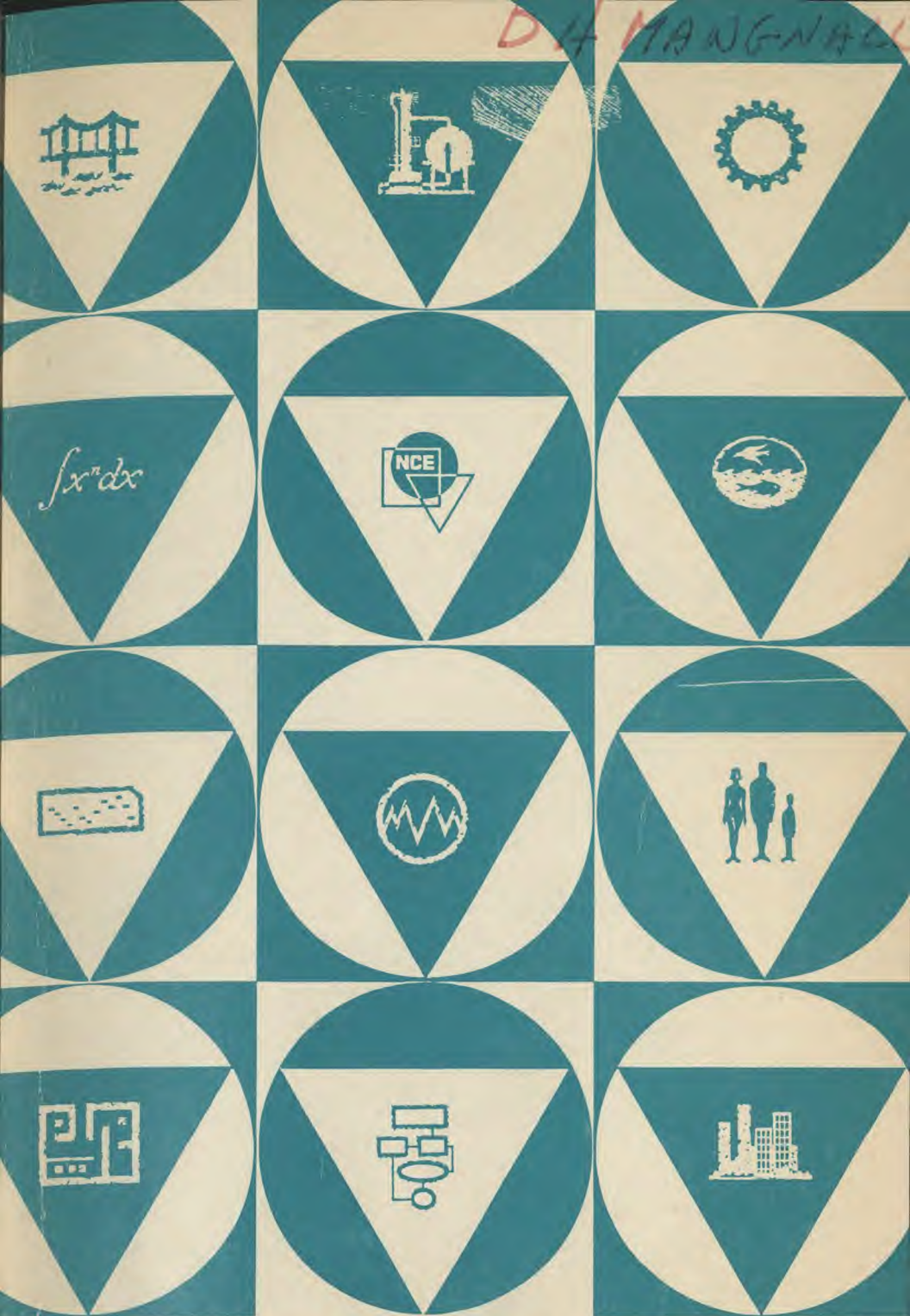
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GRADUATE PROGRAMS
1970-71 ACADEMIC YEAR

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TELEPHONE: Area Code 201, 645-5321

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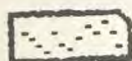
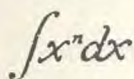
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CATALOG
OF
GRADUATE
PROGRAMS



1970-1971
ACADEMIC
YEAR

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GRADUATE DIVISION CALENDAR: 1970-71

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

1970

Registration — Fall Semester	In accordance with instructions to be issued.
Fall Semester Begins	September 16
Thanksgiving Holidays	November 25 to 28, inclusive
Christmas Holidays	December 21 to January 2, inclusive

1971

Fall Semester Ends	January 16
Registration — Spring Semester	In accordance with instructions to be issued.
Spring Semester Begins	February 3
Washington's Birthday Holiday	February 15
Spring Vacation	March 29 to April 3, inclusive
Good Friday	April 9
Spring Semester Ends	May 25
Commencement	To be announced.
Registration — Summer Session*	June 11
Summer Session Begins	June 14
Summer Session Ends	August 5

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

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- ONOFRIO L. RUSSO, B.E.E., M.S.*
Assistant Professor of Physics.
- JAMES SAGURTON, B.S., M.A., Ph.D.
Professor of Physics.
- JEROME J. SALAMONE, B.Ch.E., M.Ch.E.,
Engr.Sc.D.*
Professor of Chemical Engineering.
- LEONARD M. SALZARULO, B.S., M.S., Ph.D.*
Professor of Physics.
- BERNARD M. SCHEINTHAL, B.Sc., M.A., Ph.D.
Adjunct Research Associate.
- MICHAEL SCHILDER, M.S., Ph.D.
Assistant Professor of Mathematics.
- THEODORE A. SCHNEIDER, B.S., M.S.*
Associate Professor of Mech. Engrg.
- DALE A. SEILER, B.S., M.A., Ph.D.
Adjunct Professor of Mgt. Engrg.
- LIONEL S. SENHOUSE, B.M.E., M.S., Ph.D.
Adjunct Professor of Electrical Engrg.
- JOHN R. SHELTON, B.A.
Adjunct Professor of Mgt. Engrg.
- AVNER SHILMAN, M.S., M.A., Ph.D.
Professor of Chemistry.
- ARTHUR A. SHUKUR, B.S., M.S.
Associate Professor of Physics.
- OLIVER J. SIZELOVE, B.S., M.Ad.Eng.*
Distinguished Professor of Mgt. Engrg.
- JOHN P. SMITH, A.B., M.A., Ph.D.
Adjunct Professor of Mgt. Engrg.
- EUGENE H. SMITHBERG, B.M.E., M.M.E.,
D.Eng.Sc.*
Professor of Mechanical Engineering.
- WILLIAM H. SNYDER, A.B., Ph.D.
Associate Professor of Chemistry.
- KENNETH S. SOHN, B.S., M.S., Sc.D.
Associate Professor of Electrical Engrg.
- DOMINICK SOMMA, M.S.*
Adjunct Professor of Civil Engineering.
- OLUWOLE O. SONGONUGA, B.S., M.Eng.,
Ph.D.
Assistant Professor of Civil Engrg.
- FRANKLIN M. SPOONER, B.S., M.S.
Adjunct Professor of Chemical Engrg.
- WILLIAM S. STACK, B.S., B.C.E., M.S.*
Assistant Professor of Civil Engineering.
- EUGENE STAMPER, B.M.E., M.S.*
Professor of Mechanical Engineering.
- BENJAMIN H. STEVENSON, JR., B.S., M.S.
Assistant Professor of Physics.
- GERALD P. STONE, B.C.N.E., M.Ad.Eng.,
D.Eng.Sc.*
Associate Professor of Industrial Engrg.
- LAWRENCE SUCHOW, B.S., Ph.D.
Associate Professor of Chemistry.
- BENEDICT SUN, B.S., M.S., Ph.D.*
Assistant Professor of Mechanical Engrg.
- DIMITRIOS P. TASSIOS, M.S., Ph.D.
Assistant Professor of Chemical Engrg.
- GEORGE B. THOM, M.E., M.S., M.A.*
Professor of Mechanical Engineering.
- NORA S. THORNER, A.B., Ph.D.
Assistant Professor of Mathematics.
- JAMES THRONE, B.S., M.Ch.E., Ph.D.
Adjunct Professor of Chemical Engrg.
- NISSIM M. TOWFIK, B.S., A.M.
Associate Professor of Physics.
- ARE TSIRK, B.C.E., M.C.E., Ph.D.
Associate Professor of Civil Engrg.
- NORMAN J. WEINSTEIN, B.Ch.E., M.Ch.E.,
Ph.D.
Adjunct Professor of Chemical Engrg.
- HENRY B. WEISBECKER, B.E.E., M.E.E.,
Dr. Ing.
Associate Professor of Electrical Engrg.
- SIDNEY WEISMAN, B.S., M.S.
Adjunct Professor of Mechanical Engrg.
- WERNER J. WENISCH, B.S., M.S., Ph.D.
Associate Professor of Chemistry.
- GEORGE L. WILLIAMS, B.S., M.S.
Associate Professor of Applied Mech.
- WILLIAM E. WILLIAMS, B.A., M.S., Ph.D.
Adjunct Professor of Mgt. Engrg.
- CHARLES E. WILSON, JR., B.S., M.S.M.E.,
M.S.E.M., Ph.D.*
Associate Professor of Mechanical Engrg.
- JOSEPH WINSTON, B.S., M.S.
Associate Professor of Electrical Engrg.
- JAMES N. WISE, B.A., M.A.
Associate Professor of English.
- CARL WOLF, B.B.A., M.S.I.E.
Associate Professor of Mgt. Engrg.
- MELVIN WOLKSTEIN, B.S., M.Ch.E.
Adjunct Professor of Chemical Engrg.
- RALPH W. WYNDRUM, JR., B.S., M.S.,
Eng. Sc.D.
Adjunct Professor of Electrical Engrg.
- MAURO H. ZAMBUTO, Ph.D.
Professor of Electrical Engineering
- THEODORE ZANER, B.S., M.A., Ed.D.
Professor of Industrial Relations.
- HENRY ZATZKIS, B.S., M.S., Ph.D.
Professor of Mathematics.
- JOHN L. ZOZZARO, B.S., M.S.
Adjunct Professor of Industrial Engrg.

* Licensed Professional Engineer.

† On Leave of Absence.

GENERAL INFORMATION

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

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

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, and Electrical 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 91-92 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 College Library, centrally located on the campus, provides facilities for study, research, and browsing. A collection of more than 63,000 volumes is available for student use. Subscriptions to over 1,100 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 21.)

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 \$25.00 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
- Newark College of Engineering Alumni Association Doctoral Fellowships
- Esso Education Foundation Fellowships
- Food Machinery and Chemical Corporation Fellowships
- E. I. Du Pont de Nemours and Company, Inc. 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 Westinghouse publication "Continued Education—Announcement of Courses—1969-1970," 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 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 in which this may now be done include polymer engineering, systems engineering, urban studies and transportation engineering.

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 101.)

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 *undergraduate* 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.), and Electrical Engineer (E.E.).

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

ADMISSION REQUIREMENTS

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

ADMISSIONS APPLICATION

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

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

DEGREE REQUIREMENTS

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

COURSE WORK

The program of course work will be planned by the candidate and his candidacy committee. This committee will be appointed when the candidate has passed a written departmental candidacy examination. Permission to take the candidacy examination must be requested by filing a candidacy application form

with the Graduate Division. This should be done shortly after the completion of twelve credits of course work, but in any event prior to the completion of eighteen credits. The program will be planned on the basis of the candidate's academic and professional background with particular weight given to the subject matter of the proposed professional project. At least twelve credits of the course work must be at the 300 or 400 level. Course work at the 100 level is not acceptable in fulfillment of the minimum requirements. An average grade of B or better will be required in meeting the degree requirements.

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

PROFESSIONAL PROJECT

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

APPLICATION FOR THE DEGREE OF ENGINEER

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

TIME LIMITATION

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

DOCTOR OF ENGINEERING SCIENCE PROGRAMS

The impact of recent advances in science and engineering and the acceleration of research demands, not only for industry and defense but to an equal degree for education, have made doctoral programs mandatory. There is a growing and insistent need for qualified scholars to move into the frontiers of scientific and engineering knowledge and to transmit the consequent advances to the classrooms and laboratories of our institutions of higher learning. Responsive to such requirements, Newark College of Engineering has formulated programs leading to the degree of *Doctor of Engineering Science*. At the present time these programs are restricted to the Departments of Chemical Engineering, 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 6:30 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.

If the dropping of a course, or courses, causes the change to be classified as a withdrawal from College, the student should follow the procedures stipulated in the section "Interruption of Studies," below.

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. However, it is recognized that in exceptional cases withdrawal by a student may be necessary. 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). The date of receipt of the notice by the Graduate Division will be considered to be the date of withdrawal.

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:

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

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

REGULATIONS

The 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.

Each prospective candidate for any degree 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. Forms may be obtained from the office of the Graduate Division.

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 Faculty.

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.

Courses listed are normally offered each year except where otherwise indicated.

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, including inorganic, analytic, organic, and physical; 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 120, 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 101. INTRODUCTION TO SOLID WASTE PROBLEMS. 3 credits, 1st sem. PERNA.

Prerequisite: Senior or graduate standing in engineering. This course serves as an introductory course in solid waste disposal. It covers industrial and urban sources of solid waste and the conventional methods for disposal of these wastes. Application of engineering principles as related to this area is stressed.

Offered 1971-72 and alternate years.

ChE 121. PROPERTIES OF GASES, SOLIDS AND LIQUIDS. 3 credits, 2nd sem. GRISKEY.

Prerequisite: B.S. in ChE or Chemistry. This course presents methods for estimating and/or correlating the physical and chemical properties of gases, solids and liquids. These properties include transport properties, compressibility behavior, thermodynamic properties, chemical reaction rate constants, and phase equilibrium. Emphasis is placed on the bases from which the methods and correlation have been developed as well as on the precision of estimated data.

Offered 1970-71 and alternate years.

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 advanced treatment of molecular and turbulent momentum, energy, and mass transport. Emphasis is on the mathematical description of physical mechanisms in momentum and energy transport.

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.

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.

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 properties. 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 1970-71 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 1970-71 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 1971-72 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 multi-stage 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 mechanistic, viewpoint. Topics covered include atomic and molecular structure, stereochemistry, reactive intermediates (cations, anions, radicals and carbenes), and spectroscopy.

Chem 120. ADVANCED INORGANIC CHEMISTRY. 3 credits, 2nd sem. CAGNATI and SUCHOW.

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 140. INTRODUCTION TO POLYMERS. 3 credits, 1st sem. WENISCH.

Prerequisites: Undergraduate physical chemistry or thermodynamics. Synthesis of typical polymers of commercial importance is presented from a descriptive viewpoint. Determination of the size and shape of polymer molecules and the morphology of crystalline polymers is considered. Mechanical properties of polymers in the crystalline, glassy and elastomeric states are related to structure. Properties of available polymers are examined in relation to specific applications.

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

Prerequisites: Undergraduate organic and physical chemistry or suitable background in these subjects. This is an introductory course in biochemistry. It includes fundamentals from the viewpoint of physical and organic chemistry and the industrial applications in the field. It is directed particularly to those students who have an interest in biophysics and bioengineering.

Chem 202. ADVANCED ORGANIC CHEMISTRY II. 3 credits, 2nd sem. PERLMUTTER and TRATTNER.

Prerequisite: Chem 102 or equivalent. Organic chemistry is treated from a point of view of reaction mechanisms. Reactions covered include nucleophilic and electrophilic aliphatic and aromatic substitution, addition, elimination, thermal and photochemical rearrangements, and oxidation and reduction reactions.

Offered 1970-71 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 1970-71 and alternate years.

Chem 208. INSTRUMENTAL ANALYSIS. 3 credits, 2nd sem. DAUERMAN.

Prerequisite: Undergraduate physical chemistry or modern physics. The principles of instrumental techniques of current significance are presented. The interpretation and application of the information obtained are discussed. Emphasis is placed upon those methods which are of significance in air pollution, catalysis, combustion, and separation procedures.

Lab fee? \$30.00

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 1971-72 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.

Offered 1971-72 and alternate years.

Laboratory fee: \$30.00.

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 1970-71 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 I. 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.

Chem 241. POLYMER PROPERTIES. 3 credits, 1st sem. WENISCH.

Prerequisite: Chem 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.

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 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 1970-71 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/or thesis 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* 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/or thesis 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.

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 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 125, Introductory Process Control.
- ChE 234, Chemical Process Dynamics and Control.

INDUSTRIAL AND MANAGEMENT ENGINEERING:

- IE 204, Advanced Analytical Engineering Statistics.
- IE 205, Mathematical Programming in Management Science.
- IE 233, Linear Programming.
- IE 269, Human Factors in Engineering.
- EM 202, Introduction to Management Science.
- EM 203, Analytical Engineering Statistics.
- EM 250, Introductory Operations Research.

SOCIAL SCIENCE AND ORGANIZATIONAL SCIENCE:

- SS 102, Methods of Research in the Behavioral Sciences.
- SS 203, Econometrics.
- SS 250, Cost-Benefit Analysis and Economic Decisions.
- SS 262, Economic Analysis of Urban Areas.
- OS 171, Urban Social Structure.

MECHANICAL ENGINEERING:

- ME 223, Experimental Stress Analysis.

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.

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.

Laboratory fee: \$20.00.

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 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. A review of basic soil properties and applied mineralogy. 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.

Laboratory fee: \$20.00

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

Prerequisites: Undergraduate course in soil mechanics and the design of structures. Fundamentals of applied soil mechanics, criteria for the design of foundations and selection of foundation types.

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

Prerequisite: CE 253. Problems in the design of foundations and earth structures, including structural foundation elements.

CE 271. STRUCTURAL THEORY I. 3 credits, 1st sem. STACK.

Prerequisite: Undergraduate course in structures. This course reviews basic structural analysis and introduces practical techniques for rigid frame, trussed, and cabled structures. Topics include energy methods, matrix analysis, and relaxation techniques.

CE 272. STRUCTURAL THEORY II. 3 credits, 2nd sem. STACK.

Prerequisite: Undergraduate course in structures. This course includes numerical and network analysis techniques suitable to large space frameworks and continuous structures and critical studies of new advances from current literature.

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 1970-71 and alternate years.

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

Prerequisite: B.S. degree in C.E., Architecture, or related field. A study of the management aspects of contracting. Topics include bonds, insurance, contracts and specifications, financing, estimating, personnel administration, and labor relations.

Offered 1970-71 and alternate years.

CE 282. CONCRETE CONSTRUCTION. 3 credits, 2nd sem. OLSEN.

Prerequisite: Undergraduate course in strength of materials. This course deals primarily with a study of concrete and methods used in the concrete construction industry. Particular emphasis is placed on the design of concrete formwork, including new methods used in complicated forming operations. Designs will include engineering cost analysis and the use of computers.

Offered 1970-71 and alternate years.

CE 283. CONSTRUCTION ENGINEERING I. 3 credits, 1st sem. OLSEN.

Prerequisites: Undergraduate courses in construction management and computers. This course deals with project planning and scheduling. New methods used in controlling construction costs and the application of engineering fundamentals to construction methods are studied.

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. DESIGN OF LIGHTWEIGHT ROOF AND FLOOR SYSTEMS. 3 credits, 1st sem. SALEK.

Prerequisite: CE 237 and CE 271. Analysis and design of two and three dimensional load carrying structural systems and their supporting elements. Included is a study of reinforced concrete and steel flat and folded plates, cylindrical shells, and domes.

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 1970-71 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 1970-71 and alternate years.

CE 371. STRUCTURAL DESIGN I. 3 credits, 2nd sem. MONASA.

Prerequisite: CE 271. This course includes design methodology using the systems engineering approach and applies this technique to a wide range of structural components and structural systems. Examples are drawn from building frame applications. Some work will be done in computer program development.

Offered 1970-71 and alternate years.

CE 372. STRUCTURAL DESIGN II. 3 credits, 2nd sem. TSIRK.

Prerequisite: CE 272. This course includes applications to the design of tall buildings, space frame works, and other problems of similar scope tailored to the students' interests.

Offered 1971-72 and alternate years.

CE 381. CONSTRUCTION ENGINEERING II. 3 credits, 2nd sem. OLSEN.

Prerequisite: CE 283 or equivalent. A study of construction operations in both the heavy and building construction fields with particular emphasis on scientific and computer evaluation. This includes techniques of statistical analysis applied to direct costs, indirect costs, and profits.

Offered 1971-72 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 1970-71 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 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 1970-71 and alternate years.

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

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 1970-71 and alternate years.

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

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. METZGER.

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 1970-71 and alternate years.

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

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 1970-71 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 1970-71 and alternate years.

EnE 246. HYDROLOGY. 3 credits, 2nd sem. METZGER.

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 1970-71 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 1970-71 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 1970-71 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 315. ANALYSIS OF RECEIVING WATERS. 3 credits, 2nd sem. DRESNACK.

Prerequisites: EnE 214, EnE 217, and mathematics acceptable to the Department. The deoxygenation and reoxygenation 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. METZGER.

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 1970-71 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 1970-71 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 1970-71 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 1970-71 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.

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.
4. CS 110 may not be used to satisfy any of the above requirements.

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). CS 110 may not be used to satisfy this requirement.
2. Fifteen credits of elective courses approved by the student's adviser.

AREAS OF SPECIALIZATION

- I. Systems Programming: CS 110, CS 230, CS 231
- 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.
Offered 1970-71 and alternate years.
- 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.
Offered 1970-71 and alternate years.
- CS 235. COMPUTER PROGRAMMING LANGUAGES. 3 credits, 1st sem. MOSHOS.
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. *Formerly Math 290.*
Offered 1971-72 and alternate years.

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.

Offered 1971-72 and alternate years.

CS 240. RECURSIVE FUNCTION THEORY. 3 credits, 2nd sem. V. MILLER.

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. *Formerly Math 291.*

Offered 1970-71 and alternate years.

CS 241. FORMAL LANGUAGES. 3 credits, 2nd sem. V. MILLER.

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.

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.

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:

- Math 173, Differential Equations I.
- EE 120, Electromagnetic Field Analysis.
- EE 140, Electronic Circuits.
- EE 150, Circuit Analysis.
- EE 160, A-C Machinery.

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 include:

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 includes EE 300 or EE 301 and EE 256, must be limited to no more than two related areas.
5. At least 6 credits in a correlated (non-electrical) field as a minor.

MASTER OF SCIENCE

B. For the *Master of Science*, candidates must include:

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 includes 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 Amplifier 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. Automatic Control Systems:

- EE 261, Control System Components.
- EE 263, Introduction to Automatic Control Systems.
- EE 266, Automatic Control Systems Laboratory.
- EE 273, Random Processes in Electrical Communication I.
- EE 291, Large Power Control Systems.
- EE 364, Discrete Systems.
- EE 365, Introduction to Nonlinear Systems.
- EE 466, Modern Control Theory.
- EE 467, Stochastic Control Theory.
- EM 250, Introductory Operation Research.
- ME 331, Advanced Control of Electro-Mechanical Networks.

Area III. Electronic Computers:

- CS 235, Computer Programming Language.
- EE 250, Transistor Circuits.

- EE 275, Design of Digital Control Circuits.
- EE 280, Analog Computers.
- EE 281, Techniques of Digital Computers.

Area IV. Communication Theory:

- 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 Machines and Power Systems:

- EE 215, Power Transmission.
- EE 216, Power Distribution.

- EE 218, Symmetrical Components.
- EE 261, Control System Components.
- EE 271, Electric Power Systems.
- EE 290, Advanced A-C Machines I.
- EE 390, Advanced A-C Machines II.
- Phys 222, Elements of Nuclear Engineering.

The department may require a program of more than the minimum number of 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 42 credits of courses on the 300 and 400 levels as approved by the adviser.

QUALIFYING EXAMINATION

The qualifying examination will require competence in the following fields:

1. Mathematics: Differential equations and vector analysis; transformation or operational calculus; advanced calculus; complex variables; elements of probability; and stochastic processes.
2. Engineering Physics: Undergraduate physics, including kinetics, kinematics and thermodynamics. Advanced topics in classical and modern physics. Also included are engineering applications to branches of engineering other than electrical.
3. General Electrical Engineering: Undergraduate electrical engineering and elementary graduate study in circuits, fields, and electronics.

4. A specialized area of Electrical Engineering: This field must be indicated to the department chairman within two months before the date of the qualifying examination. This section of the examination will entail a critical evaluation of the area specified in order to determine ability to conduct research requiring such knowledge and to apply this knowledge to broader and more general problems.

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

REGISTRATION FOR DISSERTATION

Registration for dissertation and research will require as prerequisites:

1. Such courses as may be specified by the department.
2. Satisfactory completion of the qualifying examination.
3. Demonstration of proficiency in 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 ANALYSIS. 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 160. A-C MACHINERY. 3 credits, 1st sem.

Prerequisite: Undergraduate circuit theory. This course includes a review of induction and synchronous machine fundamentals; the balanced and unbalanced polyphase induction machine; the single-phase machine; the synchronous machine in steady-state; and a review of winding and skew factors.

Offered 1970-71 and alternate years.

EE 215. POWER TRANSMISSION. 3 credits, 2nd sem. CHOW.

Prerequisite: EE 256. The course covers the calculation of generalized transmission line circuit constants, power circle diagram, load flow studies, digital solutions of symmetrical and asymmetrical fault studies, digital calculation of network impedance matrices, development of transmission loss formula, and economic operation of power systems. Emphasis is placed on current technical articles and recent developments.

Offered 1970-71 and alternate years.

EE 216. POWER DISTRIBUTION. 3 credits, 1st sem.

Prerequisites: Undergraduate courses in electric circuits and machines. The operation, maintenance, and expansion of power distribution systems from the transmission substation to the customer's outlet are considered. Modern practice in urban and rural distribution overhead and underground lines, networks, lightning protection, and voltage regulation are included.

Offered 1970-71 and alternate years.

EE 218. SYMMETRICAL COMPONENTS. 3 credits, 1st sem. BLACKBURN.

Prerequisite: EE 256. The course includes principles of the method of symmetrical components; use of the method in the calculation of faults in power systems; and behavior and characteristics of machines, lines and transformers under unbalanced conditions.

Offered 1970-71 and alternate years.

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 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 1970-71 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 deals with microwave diodes and triodes; klystrons and magnetrons; pulse modulation; radar components; and radar transmitters and receivers.

Offered 1970-71 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, 1st sem.

Prerequisites: EE 140 and EE 150 or equivalent. A study of semi-conductor principles including the theory of the p-n junction and the mechanism of transistor action. The physical analysis is followed by a study of the transistor as a circuit element. Emphasis is placed on the specific circuit requirements of the transistor rather than on the specific circuit type. Topics include equivalent circuits, bias considerations, low frequency applications, high frequency applications, switch applications, and oscillators.

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, 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 or equivalent. Fourier and Laplace transforms, Laplace inversion integral, application of Fourier integral to the determination of impulse response of a system, concepts of feedback and stability, relationships between gain-frequency and phase-frequency characteristics, matrix methods, and state-variable representation are topics covered. Computer-oriented techniques, such as the fast Fourier transform, convolution integral, trapezoidal approximation of impulse response, and iterative procedures using the state-transition matrix are included where feasible.

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

Prerequisite: EE 256. After a brief review of fundamental network

analysis, this course covers the following topics: passive RC networks; non-reciprocal and active two port networks for active synthesis; distributed RC networks; properties of RC networks with positive and negative resistance; synthesis of active RC one- and two-port networks; and sensitivity and minimization.

EE 261. CONTROL SYSTEM COMPONENTS. 3 credits, 1st 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 torque motors, 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 1970-71 and alternate years.

EE 263. INTRODUCTION TO AUTOMATIC CONTROL SYSTEMS. 3 credits, 2nd sem.

Prerequisite: EE 256. Review of linear system fundamentals. Linear feedback control systems, treated in both state variable and transfer function representation. Stability and transient performance of linear system. Nyquist criterion, root locus and parameters plane methods are introduced and applied to both analysis and design of linear time-invariant control systems. Though this course deals primarily with linear systems, effects of nonlinearities and power constraints are considered. A survey of various topics is given, such as a-c carrier control systems and some selected nonlinear and stochastic control problems.

EE 266. AUTOMATIC CONTROL SYSTEMS LABORATORY. 3 credits, 2nd sem.

Prerequisite: EE 263 or equivalent, and undergraduate laboratory courses in electric machines and electronics. A laboratory course in the practice of the principles developed in EE 263. Use of components, techniques of testing and synthesis of complete servosystems. Nonlinearities are emphasized.

Laboratory fee: \$15.00.

EE 271. TRANSIENT ANALYSIS AND PROTECTIVE RELAYING OF POWER SYSTEMS. 3 credits, 1st sem.

The course will cover the fundamentals of transient stability including definition of the problem, solution of associated networks, swing equation and swing curves, equal area criterion, two machine and multi-machine analysis of stability, typical stability studies, clearing times for faults, etc. In addition, fundamental principles of protective relaying, relay operating characteristics, relay response and problems of protection with overcurrent distance and pilot relays will be discussed. Emphasis is placed on current technical publication articles and recent developments. Students are assumed to be familiar with symmetrical components fault and short circuit calculations, normal network techniques and the per unit system. These are reviewed briefly at the beginning of the course.

Offered 1971-72 and alternate years.

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 1971-72 and alternate years.

EE 274. NOISE IN ELECTRICAL CIRCUITS. 3 credits, 1st 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 1970-71 and alternate years.

EE 275. DESIGN OF DIGITAL CONTROL CIRCUITS. 3 credits, 2nd sem. ANDERSON.

Prerequisite: EE 140 or equivalent. The course deals with switching apparatus; Control paths; switching logic (algebra of switching circuits); combinational circuits; sequential circuits; electronic switching logic and circuits; and applications (counters, coders, translators, selectors, etc.). Emphasis is placed on solid-state switching circuits.

EE 280. ANALOGUE COMPUTERS. 3 credits, 1st sem. DICKEY.

Prerequisite: EE 150 or equivalent. This course considers methods for solving engineering problems by the use of the analogue computer. Topics considered include solution of linear, adjoint, nonlinear, and systems of differential equations; linear equations; Eigen values, functions and vectors; generation of explicit and implicit functions; optimization techniques; simulation of transfer functions, extraneous poles created by the computer, differential equations in matrix form, and concepts of Lyapunov.

EE 281. TECHNIQUES OF DIGITAL COMPUTERS. 3 credits, 2nd sem. DICKEY.

Prerequisite: EE 150 or equivalent. EE 275 or EE 280 are desirable but not required. This course considers numerical methods for solving engineering problems applicable to digital computer usage. It starts with number representation and progresses to include concepts of Dahlquist, roots of polynomials, characteristic values and vectors and condition number. It is intended to assist the engineering student to evaluate the result of using formalized procedures to solve engineering problems.

EE 290. ADVANCED A-C MACHINES I. 3 credits, 1st sem.

Prerequisite: EE 160 or equivalent. Advanced topics investigated in induction machines are harmonics, dips, and cusps in the speed-torque curve, locking torques and noise. The heat developed in induction machines for different duty cycles of starting and plugging is determined both analytically and graphically.

Offered 1970-71 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 1971-72 and alternate years.

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 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 1970-71 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 1971-72 and alternate years.

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

Prerequisite: EE 242. A continuation of EE 242, this course covers the fundamental principles of pulse modulation and pulse modulation systems. The modulation systems are treated on a unified basis consistent with modern information theory. The discussions of information theory are limited to basic concepts with a view to developing quantitative criteria by which the performance of these systems can be measured and compared.

Offered 1971-72 and alternate years.

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 base-band noise in multichannel FM radio systems. Communication systems using earth satellites are covered in great detail, including space communication.

Offered 1970-71 and alternate years.

EE 348. QUANTUM ELECTRONICS. 3 credits, 1st sem. ZAMBUTO.

Prerequisite: Phys 230 or equivalent. This course is designed to acquaint the student with the basic modern physics background needed for an understanding of quantum electronics. Emphasis is placed on fundamentals and devices are used to illustrate the basic theory. The course includes the Schrödinger and Heisenberg formulations of quantum mechanics, atomic structure, quantum statistics, interaction of radiation and matter, theory of the maser and laser, and topics in non-linear optics such as Brillouin scattering in solids.

Offered 1970-71 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 1970-71 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.

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 1971-72 and alternate years.

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

Prerequisites: EE 250 and EE 258. After a brief review of transistors and other semi-conductor devices, this course covers the following topics: monolithic integrated semiconductor technology; thin film hybrid integrated circuit technology; integrated circuit low frequency amplifier design; broadband integrated circuit amplifier design; integrated oscillator design; integrated circuit bandpass amplifier design; and integrated circuit active filters.

EE 364. DISCRETE SYSTEMS. 3 credits, 1st sem. MEYER.

Prerequisite: EE 263 or 256 and approval of instructor. 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 1971-72 and alternate years.

EE 365. INTRODUCTION TO NONLINEAR SYSTEMS. 3 credits, 2nd sem. MEYER.

Prerequisite: EE 263, or EE 256 and approval of instructor. 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, 1st sem. MEYER.

Prerequisite: EE 365 or EE 256 and approval of instructor. Introduction to 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 1970-71 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 1971-72 and alternate years.

EE 375. DIGITAL COMMUNICATION. 3 credits, 1st 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 1970-71 and alternate years.

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 1971-72 and alternate years.

EE 377. STATISTICAL DECISION THEORY IN COMMUNICATIONS. 3 credits, 2nd sem. WEISBECKER.

Prerequisite: EE 273 or equivalent. Review of detection, estimation, and modulation theory; hypothesis testing problem; Bayes decision criteria, minimax and $\text{Pr}(e)$ tests; Neyman-Pearson tests; receiver operat-

ing 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 1971-72 and alternate years.

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 alternate years.

EE 379. PRINCIPLES OF PHASE LOCK AND FREQUENCY FEEDBACK. 3 credits, 2nd 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 1970-71 and alternate years.

EE 390. ADVANCED A-C MACHINES II. 3 credits, 2nd sem.

Prerequisite: EE 290. The direct and quadrature axis transformation of magnetomotive forces are applied to synchronous machines for solution of short-circuit problems and pulling into step of machines. Typical design procedures founded on a thorough understanding of the analytical equations are applied in designing a polyphase induction machine.

Offered 1970-71 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 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, to be 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 or 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 1970-71 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.

Prerequisite: Phys 230. This course covers selected topics in master design, modulation, and applications. Included are population inversion meth-

ods, maser states in ammonia and the ammonia maser, maser levels in paramagnets, three level solid and gas masers, noise, and degrees of coherence.

Offered 1970-71 and alternate years.

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

Prerequisite: EE 241 or equivalent. A course in probability and statistics. 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. MODERN CONTROL THEORY. 3 credits, 1st sem. KUO.

Prerequisite: EE 256 or 263. Topics include calculus of extrema and signal stage decision processes; variational calculus and continuous optimal control; the maximum principle and Hamilton-Jacobi theory; optimum systems control examples; discrete variational calculus and the discrete maximum principle; controllability and observability; and sensitivity in optimum systems control.

Offered 1970-71 and alternate years.

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

Prerequisites: EE 263, and EE 273 or EE 376 (or equivalents) and permission of the department. The course deals with selected topics in advanced servomechanism design; considerations when the reference input is of a random nature and when noise is present in the input and random disturbances occur at the output; the Weiner rms error criterion in terms of transfer functions and noise spectral density; methods of minimizing the rms error; recent advances in statistical design; and specialized topics as determined by the interest of the students.

Offered 1970-71 and alternate years.

DEPARTMENT OF INDUSTRIAL AND MANAGEMENT ENGINEERING

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. Three programs of specialization are available in operations research, systems engineering, and ergonomics.

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 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 will require the student to take undergraduate courses or one or more of the following basic graduate courses:

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.

MASTER OF SCIENCE IN INDUSTRIAL ENGINEERING

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

IE 201, Measurement Methods for Management Systems (3)

IE 203, Behavioral Science (3)

IE 205, Mathematical Programming in Management
Science (3)

IE 207, Seminar in Contemporary Management
Problems (3)

IE 301, 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:

OPERATIONS RESEARCH

- IE 204, Advanced Analytical Engineering Statistics (3)
- IE 221, Applications and Programming of Digital Computers (3)
- IE 233, Linear Programming (3)
- Math 111, Numerical Analysis (3)
- Math 220, Matrix Theory (3)

SYSTEMS ENGINEERING

- CS 240, Logic, Automata and Computers (3)
- EM 205, Engineering Reliability (3)
- IE 221, Applications and Programming of Digital Computers (3)
- IE 241, Operational Analysis of Systems (3)
- Math 220, Matrix Theory (3)

ERGONOMICS

- CE 263, Traffic Engineering (3)
- IE 261, Man-Machine Systems (3)
- IE 269, Human Factors in Engineering (3)
- Math 262, Statistical Inference (3)
- OS 277, Techniques of Executive Control (3)

MASTER OF SCIENCE

For the degree *Master of Science*, candidates must include fifteen course credits as indicated below as part of their programs:

Nine credits as follows as terminal courses:

- EM 315, Design of an Enterprise (3)
- EM 316, Seminar in the Design of an Enterprise (3)
- EM 202, Introduction to Management Science (3)

Six credits from among the following:

- EM 203, Analytical Engineering Statistics (3)
- IE 203, Behavioral Science (3)
- IE 207, Seminar in Contemporary Management Problems (3)
- IE 221, Applications and Programming of Digital Computers (3)
- IE 241, Operational Analysis of Systems (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.

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.

Offered 1971-72 and alternate years.

- IE 203. BEHAVIORAL SCIENCE. 3 credits, 2nd sem. FINCKE, 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, 1st sem. BROSH.

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.

Offered 1971-72 and alternate years.

- 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, 1st sem. HARRIS.

Prerequisites: Computer programming experience and EM 202. This course explores some of the applications of digital computers in the industrial engineering and managerial realm. Areas such as PERT, simulation, random number generation, linear programming, correlation and regression analysis, and decision theory are discussed and problems solved utilizing the digital computer. Other languages (COBOL, ALGOL, etc.) and their application to data processing are covered.

- IE 233. LINEAR PROGRAMMING. 3 credits, 1st sem. BROSH.

Prerequisite: Introductory course in management science. This course treats the principles, methodology, and practical applications of mathematical programming to complex problems in production and market-

ing, 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.

Offered 1970-71 and alternate years.

IE 241. OPERATIONS ANALYSIS OF SYSTEMS. 3 credits, 2nd sem.

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

Offered 1971-72 and alternate years.

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

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.

Offered 1970-71 and alternate years.

IE 269. HUMAN DESIGN FACTORS IN ENGINEERING. 3 credits, 1st sem.

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, arrangements 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 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.

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 de-

sign 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. BASOFF.

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. BROWNE 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.

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 1970-71 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 213. PRODUCTION 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.

Offered 1970-71 and alternate years.

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 250. INTRODUCTORY OPERATIONS RESEARCH. 3 credits, 2nd sem. BROSH.

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. JORDAN.

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 315. DESIGN OF AN ENTERPRISE. 3 credits, 1st sem. DANCO and ZOZZARO.

Prerequisites: Undergraduate economics, accounting, engineering economy, and probability and statistics, plus nine credits of EM courses of level 200 or above. 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 and preparation satisfactory to the department. 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 convergence; classical limit theorems, including weak and strong versions of the law of large numbers, the central limit theorem, and others; and Markov chains. Numerous applications to engineering and reliability theory are considered.

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.

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 and 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:

- ME 218, Instrumentation.
- ME 221, Matrix-Tensor Methods in Mechanical Engineering.
- ME 222, Dynamics of Incompressible Flow.
- ChE 224, Transport Phenomena.
- ME 238, Gas Dynamics.
- ME 246, Analysis and 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 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 Mechanics, one or more of the following courses may be substituted for those in the above groupings:

- 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.
- Mech 256, Hydrodynamics.

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 and Bearing Lubrication.
- ME 223, Experimental Stress Analysis.
- ME 224, Photoelasticity.
- ME 226, Corrosion.
- ME 237, Control of Electro-Mechanical Networks.

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 Mechanical Engineering I.
- ME 318, Selected Problems in Mechanical Engineering II.
- ME 331, Advanced 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 Mechanics, one or more of 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. One dimensional reversible and irreversible compressible fluid flow including effects of variable area, friction, mass addition, heat addition, and normal shock; two dimensional reversible subsonic and supersonic flows with an introduction to the method of characteristics; and two dimensional oblique shock.

ME 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 conduc-

tion, 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. BANNON.

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 1970-71 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 lubrication. Both hydrostatic and hydrodynamic problems are considered. Reynold's differential equation for pressure distribution is applied to the solution of slider bearing and journal bearing problems with and without end leakage.

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 instrumentation such as pressure, temperature, force, and speed measuring elements. Emphasized are response time for dynamic measurement, application of instrumentation in the fields of fluid mechanics, heat transfer, and combustion. Laboratory includes fabrication techniques and testing of various configurations—electrical, mechanical and hydro-pneumatic.

Laboratory fee: \$15.00.

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 procedure, 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 applications of matrix algebra, matrix calculus and introductory tensor methods. Study of matrix methods in the derivation of the fundamental equations in solid and fluid mechanics. Applications to elasticity, plates and shells, viscous fluids and curvilinear coordinates. Matrix-tensor theory is used to show the basic unity in the various applications in engineering analysis.

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. Boundary 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. WEISMAN.

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 1970-71 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 1970-71 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 1970-71 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.

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 artificial satellites and space vehicles. The analogy between heat transfer by radiation and electrical networks is stressed. Also discussed are problems where both conduction and radiation must be considered.

Offered 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 1970-71 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 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 1970-71 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 1970-71 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-stabilized 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 1970-71 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 1970-71 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 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 1970-71 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 1970-71 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 1970-71 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.

COURSES OF INSTRUCTION IN ORGANIZATIONAL SCIENCE

OS 102. METHODS OF RESEARCH IN THE BEHAVIORAL SCIENCES. 3 credits, 2nd sem. ZANER.

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 173. 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 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 1970-71 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 241. LABOR AND THE LAW. 3 credits, 1st sem. KANG.

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 principal non-income objectives of collective bargaining, effective administration of collective agreements, methods of settling disputes, and the impact of public policy on collective bargaining.

OS 243. LABOR-MANAGEMENT RELATIONS IN THE PUBLIC SECTOR. 3 credits, 1st sem. STOCHAJ.

Prerequisites: Undergraduate course in labor relations or its equivalent. An examination and analysis of labor-management relations in the rapidly-growing public sector of the economy. Investigation of federal executive orders and the various state and local laws regulating the right of the employees to organize and bargain collectively with public management. Examination of the similarities and differences between labor-management relations in the public and private sectors with respect to such items as unit determination, the management response, bargainable issues, the bargaining process, types of agreements, and means of dispute settlement.

Offered 1970-71 and alternate years.

OS 276. PERSONNEL SELECTION. 3 credits, 2nd sem. TALMADGE.

Prerequisite: OS 173. 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 1970-71 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 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 1970-71 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 1970-71 and alternate years.

DEPARTMENT OF PHYSICS

MASTER OF SCIENCE PROGRAMS IN ENGINEERING SCIENCE

Advanced work in physics is available as part of the College's offerings in Engineering Science to qualified students with a bachelor's degree in engineering, mathematics, or the physical sciences. The program provides a fundamental background in modern physics, with areas of specialization possible in applied physics, solid-state physics, materials science, nuclear engineering, and reactor physics.

To qualify for the program, the applicant must have an acceptable undergraduate background in mathematics and physics. At the discretion of the Department of Physics, the applicant may be required to remove any deficiencies in his background by taking certain required courses in addition to the minimum requirements for the M.S. degree.

Before initiating work toward the degree, the candidate is required to consult the departmental adviser and draw up a complete program of study, subject to the adviser's approval. The candidate must include the following courses in his program:

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.

A. Solid State (or Materials Science):

- 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.

Other courses selected from mathematics, physics, chemistry, and engineering.

B. Nuclear Engineering:

- 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.
- Other courses selected from mathematics, physics, chemistry, and engineering.

C. 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 and Introduction to Continuous Media.
- Phys 230, Quantum Mechanics.
- Phys 340, Advanced Quantum Mechanics.
- Select courses from the following:
 - 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
- Other courses selected from mathematics, physics, chemistry, and engineering.

D. 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 and Introduction to Continuous Media.
- Phys 230, Quantum Mechanics.
- Phys 260, Celestial Mechanics.
- Select courses from the following:
 - Phys 211, Transistor Physics
 - Phys 214, Solid State Physics
 - Phys 221, Nuclear Physics
 - Phys 240, Optics.
 - Phys 330, Theory of Metals
- Other courses selected from mathematics, physics, chemistry, and engineering.

The research interests of the members of the Department of Physics cover a wide range, from theoretical physics through experimental physics and neutron physics. In brief, the work

being done at the present time includes the following topics: general theory of 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, the Hall effect, the crystallographic studies; biophysics; nuclear reactor physics; high pressure (explosives) physics; and nuclear emulsion scanning studies. 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.

COURSES OF INSTRUCTION

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

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.

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.

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 1970-71 and alternate years.

Phys 221. NUCLEAR PHYSICS. 3 credits, 1st 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, 2nd 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 1970-71 and alternate years.

Phys 224. NUCLEAR ENGINEERING LABORATORY. 3 credits, 1st 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, 2nd 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, 2nd 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 1970-71 and alternate years.

Phys 260. CELESTIAL MECHANICS. 3 credits, 1st 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, 2nd 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 1970-71 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.

For course listing in Mechanics, see the offerings of the Department of Civil and Environmental Engineering.

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: \$84.00.

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.*

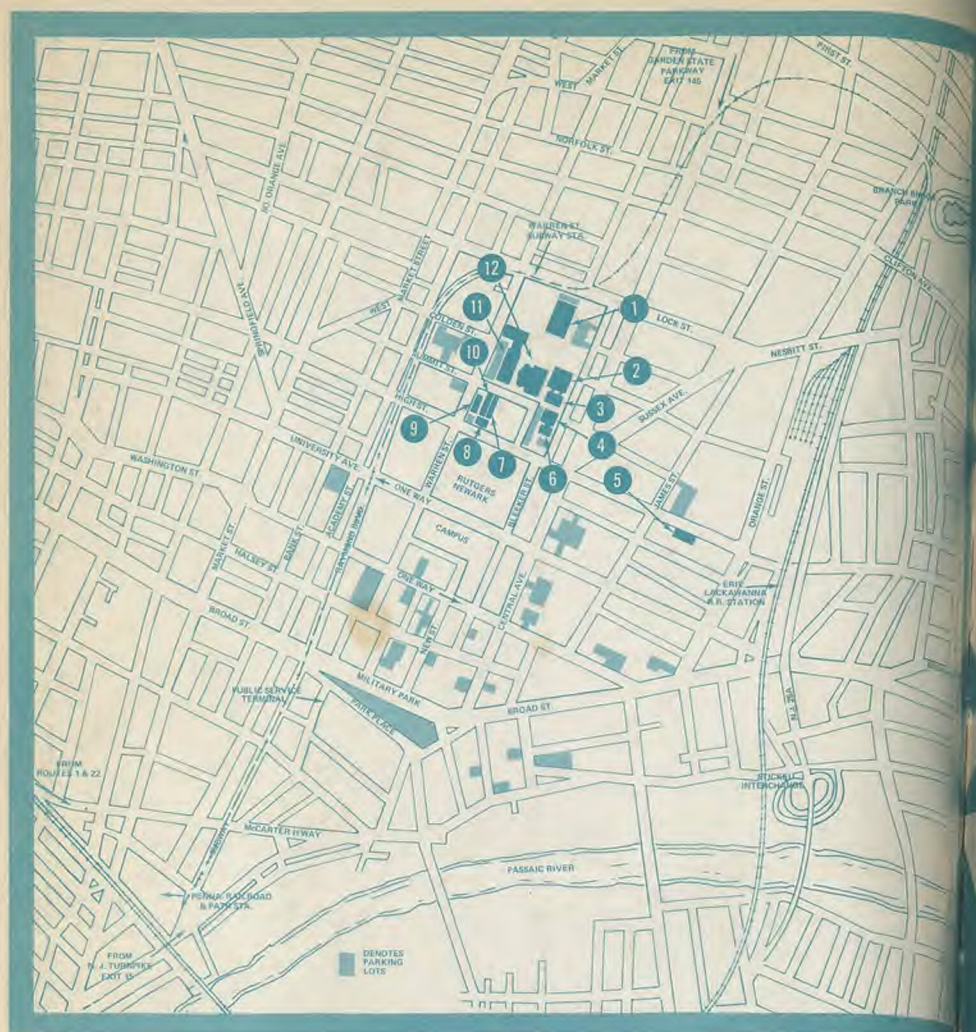
Designed to meet some of the recommendations of the Mathematical Association of America for the training of high school mathematics teachers. Course will include probability, statistics, general ideas of sets, variables, functions, and similarity of structure patterns.



AERIAL VIEW OF THE GOVERNMENT OFFICE BUILDING, NCE CAMPUS.

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