1-1-1967

Newark College of Engineering Catalog of Graduate Programs 1967-1968

New Jersey Institute of Technology

NEWARK COLLEGE OF ENGINEERING

1881

NCE

NEW JERSEY

CATALOG OF GRADUATE PROGRAMS

1967-1968

January, 1967

DIRECTORY FOR CORRESPONDENCE

MAILING ADDRESS: 323 High Street, Newark, N.J. 07102

TELEPHONE: Area Code 201, 645-5321

MATTERS OF GENERAL COLLEGE INTEREST:
Address the President.

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

REGISTRATION:
Address the Registrar. Telephone: 645-5150.

ALUMNI ACTIVITIES:
Address Alumni Secretary. Telephone: 645-5442.

CONTINUING ENGINEERING STUDIES OR CERTIFICATE PROGRAMS IN TECHNOLOGY:
For information concerning non-credit courses, address the Director of the Division. Telephone: 645-5231 or 645-5235.

FINANCIAL MATTERS:
Address the Business Manager. Telephone: 645-5170.

PLACEMENT OF SENIORS AND ALUMNI:
Address the Director of Placement. Telephone: 645-5200.

COUNSELING:
Address the Counseling Center. Telephone: 645-5190.

TRANSCRIPTS:
For transcripts and student grades, address the Records Supervisor. Telephone: 645-5139.

VETERANS:
For information on veteran status, address the Veterans' Coordinator. Telephone: 645-5148.

FOUNDATION FOR THE ADVANCEMENT OF GRADUATE STUDY IN ENGINEERING:
Address the Administrator. Telephone: 645-5210.

PLANT, EQUIPMENT, AND UTILITIES:
Address the Plant Engineer. Telephone: 645-5151.

The business and administrative offices of the College are open between the hours of 9:00 A.M. and 5:00 P.M. Monday through Friday during the school year. The Registrar's Office and the Finance Office are also open evenings between the hours of 5:30 P.M. and 8:30 P.M. daily except Saturdays. During the summer program, the business and administrative offices remain open until 4:00 P.M., Monday through Friday, while the Registrar's Office and the Finance Office are open between the hours of 5:30 P.M. and 8:30 P.M., Monday through Thursday.

CATALOG OF GRADUATE PROGRAMS

1967-1968

PUBLISHED BY
THE BOARD OF TRUSTEES
OF SCHOOLS FOR INDUSTRIAL EDUCATION
OF NEWARK, N. J.

CONTENTS

GRADUATE DIVISION CALENDAR: 1967-68

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

1967

Registration — Fall Semester	In accordance with instructions to be issued.
Fall Semester Begins	September 13
Thanksgiving Holidays	November 22 to 25 inclusive
Christmas Holidays	December 20 to January 2 inclusive

1968

Fall Semester Ends	January 13
Registration — Spring Semester	In accordance with instructions to be issued
Spring Semester Begins	January 31
Washington's Birthday Holiday	February 22
Spring Vacation	April 1 to 5 inclusive
Good Friday	April 12
Spring Semester Ends	May 21
Commencement (tentative)	June 6
Registration — Summer Session*	June 7
Summer Session Begins	June 10
Independence Day Holiday	July 4
Summer Session Ends	August 1

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

THE BOARD OF TRUSTEES

Appointed by the Governor

HON. RICHARD J. HUGHES, *Ex Officio*
Governor of the State of New Jersey

HON. HUGH J. ADDONIZIO, *Ex Officio*
Mayor of the City of Newark

EDWARD F. WESTON, *Honorary Chairman*
Chairman of the Board, retired
Weston Electrical Instrument Corporation

DONALD C. LUCE, *Chairman*
Director, The Public Service Electric and Gas Co.

ROBERT G. COWAN, *Vice-Chairman and Treasurer*
Chairman of the Board,
National Newark and Essex Bank

ROBERT D. LILLY, *Assistant Treasurer*
President, New Jersey Bell Telephone Co.

EDWARD F. BATAILLE
Chief Editorial Writer, The Newark News

FREDERICK W. BIRKENHAUER
Director, National Newark and Essex Bank

FRANCIS X. KEEGAN
President, Newark Testing Laboratories

JOHN H. YAUCH
Partner, Yauch and Fagan

ROBERT W. VAN HOUTEN, *Secretary*
President of the College

WILLIAM HAZELL, *Assistant Secretary*
Dean and Vice-President

ADVISORY COMMITTEES TO THE BOARD OF TRUSTEES

CHEMICAL ENGINEERING

AUSTIN S. BRUNJES
Lummus Corporation

THOMAS P. FORBATH
American Cyanamid Company

HOMER Z. MARTIN
Esso Research & Engineering Co.

FRED P. PETERS
Reinhold Publishing Corporation

FRANK VAN ANTWERPEN
American Institute of Chemical Engineers

J. CRAIG YACOE
E. I. du Pont de Nemours & Co.

CIVIL ENGINEERING

ELLIS L. ARMSTRONG
Porter, Armstrong & Ripa

CHARLES H. CAPEN
Consultant

ROGER H. GILMAN
The Port of New York Authority

DONALD R. GOODKIND
Goodkind & O'Dea

PETER HOMACK
Elston T. Killam Assoc., Inc.

GEORGE LELAND
Edwards & Kelcey

ELECTRICAL ENGINEERING

JEAN H. FELKER
New Jersey Bell Telephone Co.

MORRIS D. HOOVEN
The Public Service Electric & Gas Co.

ARMIG G. KANDOIAN
Communication Systems, Inc.

JOHN E. LOGAN
Jersey Central Power & Light Company

JERRY B. MINTER
Components Corp. of America

JAN A. RAJCHMAN
RCA Laboratories

INDUSTRIAL AND MANAGEMENT ENGINEERING

WILLIAM H. BALENTINE
McGraw Edison

PHIL CARROLL
Professional Engineer, Maplewood, N. J.

LILLIAN M. GILBRETH
Gilbreth, Inc.

GEORGE W. JERNSTEDT
Westinghouse Electric Corp.

CHANNING C. NELSON
Esso Mathematics & Systems Corp.

JOHN R. SHELTON
The Port of New York Authority

MECHANICAL ENGINEERING

ARTHUR J. BURKE
Howe Richardson Scale Co.

GEORGE F. HABACH
Worthington Corp.

JULES KOVACS
Westfield, N. J.

LEE W. LEMON
The Public Service Electric & Gas Co.

C. ROBERT ODERMANN
The Singer Manufacturing Company

ARTHUR M. PERRIN
National Conveyers Company, Inc.

OFFICERS OF ADMINISTRATION

GRADUATE DIVISION

ROBERT W. VAN HOUTEN, B.S., C.E., Sc.D., D.Eng., D.Sc., Litt.D., LL.D.
President of the College

WILLIAM HAZELL, B.S., M.Eng.Ed., Litt.D.
Dean and Vice-President

L. BRYCE ANDERSEN, B.S., M.S., M.A., Ph.D.
Dean of Engineering

IRVING P. ORENS, B.S., M.A., Ph.D.
Dean, Graduate Division

EUGENE H. SMITHBERG, B.M.E., M.M.E., D.Eng.Sc.
Associate Dean, Graduate Division

JOSEPH JOFFE, A.B., B.S., M.A., Ph.D.
Chairman, Department of Chemical Engineering

JAMES M. ROBBINS, S.B., S.M.
Chairman, Department of Civil Engineering

FREDERICK A. RUSSELL, B.S., E.E., M.S., Engr.Sc.D.
Chairman, Department of Electrical Engineering

OLIVER J. SIZELOVE, B.S., M.Ad.Eng.
Chairman, Department of Industrial and Management Engineering

GEORGE B. THOM, M.E., M.S., M.A.
Chairman, Department of Mechanical Engineering

FACULTY OF THE GRADUATE DIVISION

January 1, 1967

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

ARNOLD ALLENTUCH, B.S., M.S., Ph.D.
Associate Professor of Mechanical Engineering.

STANLEY B. ALTERMAN, B.S., M.S.
Adjunct Professor of Electrical Engineering.

L. BRYCE ANDERSEN, B.S., M.S., M.A., Ph.D.*
Professor of Chemical Engineering.

RICHARD ANDERSON, B.S.
Adjunct Professor of Civil Engineering.

ROBERT E. ANDERSON, B.S., M.S.*
Professor of Electrical Engineering.

FRED ASSADOURIAN, B.S., M.S., Ph.D.
Adjunct Professor of Electrical Engineering.

JOHN AXELSON, B.S., Ph.D.
Adjunct Professor of Chemical Engineering.

W. H. WARREN BALL, B.E., M.A.Sc., Ph.D.
Adjunct Professor of Electrical Engineering.

ROBERT E. BANNON, B.S., S.M.
Associate Professor of Metallurgy.

HERBERT BARKAN, B.A., M.A.
Professor of Mathematics.

FREDERICK W. BAUDER, B.S., M.S.*
Professor Emeritus of Chemistry.

STEPHEN BENCZE, B.Sc., M.Sc.
Adjunct Professor of Mechanical Engineering.

HAROLD BERNSTEIN, M.D.
Visiting Research Professor.

FREDERICK J. BISHOP, Dip. Kauf.
Adjunct Professor of Management Engineering.

JOHN L. BLACKBURN, B.S.*
Adjunct Professor of Electrical Engineering.

RUSSELL W. BRANCATO, M.D.
Visiting Research Professor.

WILLIAM D. BROWER, B.S., M.A.
Associate Professor of Mathematics.

JAMES J. BROWNE, B.A., M.A.
Adjunct Professor of Management Engineering.

LEON J. BUTEAU, B.S., M.S., Ph.D.
Associate Professor of Mechanical Engineering.

VINCENT N. CAGNATI, B.A., M.S.
Assistant Professor of Chemistry.

SALVATORE R. CALABRO, B.E.E.*
Adjunct Professor of Management Engineering.

BENEDICT CARLAT, B.S., M.A.
Adjunct Professor of Electrical Engineering.
Professor of Chemistry.
Professor in Chemical Engineering.

ROBERT CASCIANO, B.S., M.S., Ph.D.
Assistant Professor of Chemical Engineering.

**Licensed Professional Engineer.*

RALPH CECCHETI, B.S., Ph.D.
Adjunct Professor of Chemical Engineering.

RONG-YAW CHEN, B.S., M.S., Ph.D.
Assistant Professor of Mechanical Engineering.

SU-LING CHENG, B.S., M.S., Ph.D.
Assistant Professor of Civil Engineering.

GARLAND E. CHING, B.E., B.S., B.S., Ph.D.
Associate Professor of Electrical Engineering.

CHUNG-WEI CHOW, B.S., M.S.
Assistant Professor of Electrical Engineering.

MATTHEW CIESLA, B.S., M.S.*
Assistant Professor of Applied Mechanics.

IRA COCHIN, B.M.E., M.M.E.
Assistant Professor of Mechanical Engineering.

BARRY COHEN, Sc.B., D.Eng.
Adjunct Professor of Electrical Engineering.

ALFRED L. COPLEY, M.D., F.R.S.M.
Adjunct Research Professor.

GEORGE DANCO, B.S.
Adjunct Professor of Management Engineering.

E. DOUGLAS DEAN, B.Sc., M.Sc.
Adjunct Professor of Management Engineering.

HERBERT DENGLER, B.E., M.S., Ph.D.
Adjunct Professor of Chemical Engineering.

AARON DEUTSCHMAN, B.M.E., M.M.E.*
Assistant Professor of Mechanical Engineering.

VITO DI PALO, B.S., M.S.*
Adjunct Professor of Management Engineering.

DONALD W. DICKEY, B.S., M.S.*
Professor of Electrical Engineering.

MICHAEL D. DISKO, B.S., M.S.*
Assistant Professor of Civil Engineering.

LAWRENCE EISENBERG, B.S., M.S., D.Eng.Sc.
Assistant Professor of Electrical Engineering.

HERMAN A. ESTRIN, A.B., M.A., Ed.D.
Professor of English.

JOSEPH M. FITZGERALD, B.S., M.A.
Professor of Chemistry.

PAUL FLATOW, B.S.
Associate Professor of Mathematics.

ACHILLES E. FOSTER, B.S., M.A., Ph.D.
Professor of Mathematics.

PHYLLIS FOX, B.A., B.S., M.S., Ph.D.
Associate Director, Computing Center.

ALBERT G. FRANCO, B.S., M.S., E.E.
Adjunct Professor of Electrical Engineering.

RICHARD A. GAAL, B.S., M.S.M.E., M.S. (Aero)
Assistant Professor of Mechanical Engineering.

JOHN GALANDAK, B.S., M.S., M.B.A.*
Adjunct Professor of Civil Engineering.

IRVING R. GOLDSTEIN, B.S., M.S.
Associate Professor of Management Engineering.

ROBERT GORDAN, B.I.E., M.S.
Assistant Professor of Industrial Engineering.

**Licensed Professional Engineer.*
† *On Leave of Absence.*

GERALD GRANIK, B.S., M.S., M.S.M.E., Sc.D.
Associate Professor of Applied Mechanics.

DERAN HANESIAN, B.ChE., Ph.D.
Associate Professor of Chemical Engineering.

HARRY HERMAN, B.M.E., M.S.C.E., Ph.D.
Associate Professor of Mechanical Engineering.

PAUL O. HOFFMANN, B S., A.M., Ph.D.
Professor of Physics.

PETER HRYCAK, B.S., M.S., Ph.D.
Associate Professor of Mechanical Engineering.

JUI SHENG HSIEH, B.E., M.S., Ph.D.
Professor of Mechanical Engineering.

CHING-RONG HUANG, B.S., M.S., M.S. (Math), Ph.D.
Assistant Professor of Chemical Engineering.

ROBERT M. JACOBS, B.S., M.S.*
Associate Professor of Mechanical Engineering.

JOSEPH JOFFE, A.B., B.S., M.A., Ph.D.*
Distinguished Professor of Chemical Engineering.

WILLIAM JORDAN, III, B.S., M.S.*
Professor of Electrical Engineering.

ANTHONY R. KATORSKI, B.S., Ph.D.
Assistant Professor of Chemistry.

MARTIN KATZEN, B.S.
Assistant Professor of Mathematics.

GEORGE C. KEEFFE, B.S., Ch.E., M.S.*
Professor of Chemical Engineering.

HOWARD S. KIMMEL, B.S.,M.S.,Ph.D.
Assistant Professor of Chemistry.

CARL KONOVE, B.S., M.A.
Professor of Mathematics.

JOSEPH E. KOPF, B.S., M.S.
Adjunct Professor of Management Engineering.

CHARLES KOREN, B.S., M.A., Ed.D.
Professor of Mathematics.

WALTER H. KRAFT, B.S., M.S.
Adjunct Professor of Civil Engineering

SAUL I. KREPS, B.S., B.Ch.E., M.S., Ph.D.
Professor of Chemical Engineering.

BORIS KUHARETZ, B.S., M.S.
Assistant Professor of Physics.

FRANKLIN F. KUO, B.S., M.S., Ph.D.
Adjunct Professor of Electrical Engineering.

MARSHALL C. KUO, B.S., M.S., Ph.D.
Associate Professor of Electrical Engineering.

MICHAEL J. LAVERDA, B.B.A., M.B.A.
Associate Professor of Management Engineering.

FREDERICK M. LAW, B.S., M.S., Ph.D.*
Associate Professor of Civil Engineering.

FREDERICK G. LEHMAN, B.C.E., S.M., Sc.D.*
Professor of Civil Engineering.

MARTIN J. LEVY, B.S., M.S , D.Sc.*
Professor of Mechanical Engineering.

†*Member, New Jersey Bar.*
**Licensed Professional Engineer.*

CHARLES E. LEYES, B.S., M.Ch.E., D.Ch.E.
Adjunct Professor of Management Engineering.

MURRAY LIEB, B.S., M.S.
Instructor in Mathematics.

MICHAEL LIONE, A.B., M.S.
Associate Professor of Mathematics.

YASHWANT R. LOONKAR, B.Chem.E., M.Chem.E., Ph.D.
Adjunct Professor of Chemical Engineering.

WILLIAM H. LOUISELL, B.S., M.S., Ph.D.
Adjunct Professor of Electrical Engineering.

CHARLES L. MANTELL, B.A., B.S., M.A., Ph.D.*
Professor Emeritus of Chemical Engineering.

JAMES L. MARTIN, B.S.C.E., M.S., Ph.D.*
Associate Professor of Mechanical Engineering.

EMIL J. MATAS, B.S., LL.B.***
Adjunct Professor of Management Engineering.

LOWELL I. MAZIE, B.M.E., M.S.
Adjunct Professor of Management Engineering.

JOHN E. MCCORMICK, B.Sc., Ph.D.
Associate Professor of Chemical Engineering.

ROBERT R. MEOLA, B.S., M.S.*
Associate Professor of Electrical Engineering.

IVAN METZGER, B.S., S.M., M.S., Ph.D.*
Professor of Civil Engineering.

ANDREW U. MEYER, M.S., Ph.D.
Associate Professor of Electrical Engineering.

FREDERICK J. MEYSTRE, JR., M.E., M.B.A.
Adjunct Professor of Management Engineering.

WALTER J. MICHELS, B.S., M.S.*
Associate Professor of Mechanical Engineering.

JOHN MIHALASKY, B.S., M.S., M.B.A., M.I.E.
Associate Professor of Industrial Engineering.

EDWARD MILLER, B.S., M.M.E., M.A., M.S., M.Aero.E.*
Professor of Mechanical Engineering.

RAJ P. MISRA, B.S., M.E.E., Ph.D.
Professor of Electrical Engineering.

WALTER J. NEIDHARDT, M.E., M.S., Ph.D.
Assistant Professor of Physics.

GEORGE V. NEWMAN, D.D.S.
Adjunct Research Professor.

PAUL E. NIELSEN, B.S., M.S.*
Professor of Applied Mechanics.

IRVING P. ORENS, B.S., M.A., Ph.D.
Professor of Physics.

JOSEPH J. PADALINO, B.S., M.S., Ph.D.*
Professor of Electrical Engineering.

RICHARD C. PARKER, B.S., Ph.D.
Assistant Professor of Chemistry.

DAVID C. PEARCE, B.S., M.S.†
Assistant Professor of Mechanical Engineering.

JOSEPH PEKARSKY, B.B.A., M.B.A.
Adjunct Professor of Management Engineering.

* *Licensed Professional Engineer.*
*** *Licensed Attorney.*
† *On Leave of Absence.*

HOWARD D. PERLMUTTER, B.A., M.S., Ph.D.
Assistant Professor of Chemistry.

JEROME L. POLANER, B.S., M.S.*
Professor of Mechanical Engineering.

JOHN O. PREDALE, B.S., M.S.
Professor of Mechanical Engineering.

MARTIN PRESS, B.E.E., M.S.*
Adjunct Professor of Electrical Engineering.

TONIS RAAMOT, A.B., B.S., M.S., Ph.D.*
Professor of Civil Engineering.

GERSON L. RAM, B.A., M.Sc., ScD., M.R.S.H.**
Professor of Chemistry.

EIVIND G. F. RAMBERG, B.C.E., M.C.E.*
Professor of Applied Mechanics.

JOHN RAUSEN, B.ChE., A.M., Ph.D.
Assistant Professor of Mathematics.

ISRAEL REFF, B.S., A.M., Ph.D.
Professor of Physics.

JAMES L. RIGASSIO, B.S., M.Engrg.
Professor of Industrial Engineering.

ERVINE M. RIPS, B.S., M.S.*
Associate Professor of Electrical Engineering.

JAMES M. ROBBINS, S.B., S.M.*
Professor of Civil Engineering.

J. JAY ROMMER, Ph.G., B.A., M.D., F.A.P.A.
Adjunct Research Professor of Bio-Medical Engineering.

ROBERT H. ROSE, B.S., M.S.
Associate Professor of Electrical Engineering.

MAURICE RUCKER, B.A., M.A.†
Assistant Professor of Personnel Relations.

FREDERICK A. RUSSELL, B.S., E.E., M.S., Engr.Sc.D.*
Distinguished Professor of Electrical Engineering.

JAMES SAGURTON, B.S., M.S., Ph.D.
Professor of Physics.

JEROME J. SALAMONE, B.Ch.E., Engr.Sc.D.*
Professor of Chemical Engineering.

GERT G. SCHLESSINGER, B.S., M.S., Ph.D.
Assistant Professor of Chemistry.

THEODORE A. SCHNEIDER, B.S., M.S.*
Associate Professor of Mechanical Engineering.

LIONEL S. SENHOUSE, B.M.E., M.S., Ph.D.
Adjunct Professor of Electrical Engineeering.

AVNER SHILMAN, M.S., M.A., Ph.D.
Associate Professor of Chemistry.

ARTHUR A. SHUKUR, B.S., M.S.
Assistant Professor of Physics.

OLIVER J. SIZELOVE, B.S., M.Ad. Eng.*
Distinguished Professor of Management Engineering.

JOHN P. SMITH, A.B., M.A., Ph.D.
Adjunct Professor of Management Engineering.

EUGENE H. SMITHBERG, B.M.E., M.M.E., D.Eng.Sc.*
Professor of Mechanical Engineering.

* *Licensed Professional Engineer.*

** *Licensed Health Officer, State of New Jersey.*

WILLIAM H. SNYDER, A.B., Ph.D.
Associate Professor of Chemistry.

EUGENE STAMPER, B.M.E., M.S.*
Associate Professor of Mechanical Engineering.

PHYLLIS R. STRAUSS, A.B., M.A., Ph.D.
Assistant Professor of Mathematics.

LAWRENCE SUCHOW, B.S., Ph.D.
Associate Professor of Chemistry.

ROBERT L. TAETZSCH, B.S., M.S., M.S.
Adjunct Professor of Management Engineering.

GEORGE B. THOM, M.E., M.S., M.A.*
Professor of Mechanical Engineering.

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

ROMAN W. VORONKA, B.S., M.S.
Instructor in Mathematics.

NORMAN J. WEINSTEIN, B.Ch.E., M.Ch.E., Ph.D.
Adjunct Professor of Chemical Engineering.

HENRY B. WEISBECKER, B.E.E., M.E.E., Dr. Ing.
Associate Professor of Electrical Engineering.

SIDNEY WEISMAN, B.S., M.S.
Adjunct Professor of Mechanical Engineering.

STEPHEN M. WEISS, B.A., M.S.
Instructor in Mathematics.

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

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

CHARLES E. WILSON, JR., B.S., M.S.M.E., M.S.E.M.*
Assistant Professor of Mechanical Engineering.

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

CARL WOLF, B.B.A., M.S.I.E.
Assistant Professor of Management Engineering.

MELVIN WOLKSTEIN, B.S., M.Ch.E.
Adjunct Professor of Chemical Engineering.

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

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

STEVEN M. ZIMMERMAN, B.S., M.S.
Assistant Professor of Industrial Engineering.

* *Licensed Professional Engineer.*

GENERAL INFORMATION

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

Graduate work in science and engineering is becoming increasingly necessary, not only from an individual but, equally important, from an industrial and technical point of view. The rapid growth and formulation of scientific theories, too intricate to be studied in undergraduate courses which are of necessity devoted to basic elements and operations, require additional study for the individual seriously interested in a thorough knowledge and understanding of his field. Industrial and technical uses, instrumentation and operation resulting from these theories make it mandatory that there be personnel capable not only of understanding the theory but also of intelligently and creatively initiating and maintaining its application. 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 on basic engineering 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, Electrical, and Mechanical Engineering. 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.

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 89-90 of this catalog.

PROFESSIONAL CONDUCT

The College feels that the development of a sensitivity in the students on the importance of dress and good grooming is a part of the social, technical and professional diciplines which constitute engineering education. The College therefore requires that all male students shall, in addition to the customary items of dress, wear a shirt, tie and coat to all formal classes and that women students shall also be suitably attired. Recognizing that time and employment may make complete compliance by some evening students difficult, the College expects conformance to the maximum possible extent. Certain concessions can be made during continuous warm weather and in laboratories, drafting rooms, and field trips.

The College requires that every student shall conduct himself with decorum and shall constantly adhere to ethical and professional behavior. No student may use or give any unauthorized aid in any test, report, or assigned paper. All work offered as the student's own must be the work of the individual student. Instances of alleged unethical or unprofessional conduct will be brought to the attention of the appropriate College authorities for investigation and action.

FACILITIES

COLLEGE LIBRARY

The College Library presently occupies the third floor of Weston Hall. The reading room has chairs for two hundred students and provides a suitable environment for serious study. A new Library-Humanities building is now under construction and scheduled for completion in Spring, 1967, which will allow expansion of library holdings and facilities.

The book collection consists of approximately 50,000 volumes, including bound back files of the more important engineering and physical science periodical publications. Numerous unbound runs of essential journals, government bulletins, and booklets add to the library's informational resources. The current periodical subscription list numbers some five hundred fifty titles and includes the periodical indexes and abstract journals required to locate specific data quickly. Books and magazines are selected with emphasis on the fields of study offered by the College.

The resources of the College Library are supplemented by easy access to other libraries in the community; by means of interlibrary loan relationships with other libraries across the nation; and by the availability of printed material in photocopy and microfilm form.

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)	$24.00 per credit
Tuition (Non-residents of New Jersey)	$35.00 per credit
Registration Fee	$7.00 per semester
Student Facilities Fee	$5.00 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 or dissertation 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.

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 24.)

FINANCIAL SUPPORT

FELLOWSHIPS

Through the College and its Foundation for the Advancement of Graduate Study in Engineering, fellowships are available to graduate students to enable them to pursue a combined program of research, teaching and study leading to the master's degree.

Holders of fellowships who are engaged in part-time teaching under the program of the Foundation are required to register and attend the seminar, G 200, Seminar on Engineering Education, which is directed toward analyzing and discussing the fundamentals of college teaching in the field of Engineering. The seminar is also open to all assistants and instructors not directly connected with the Foundation program. For a description of the course see page 89.

Fellowships and assistantships for students engaged in full time M.S. or doctoral studies are available through various programs supported by the Federal government, by industry, and by the NCE Alumni Association. Inquiries concerning these fellowships and the Foundation fellowships should be directed to the Graduate Division.

HOWARD B. BEGG FELLOWSHIP

This fund provides financial assistance for students pursuing the Master's degree in the Industrial and Management Engineering Department. Grants may be used by the recipients for tuition and fees, or research and publication costs in connection with the Master's thesis.

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—1966-1967," 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; e.g., M.S. in Chemical 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.

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." 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. A student whose major field of interest is in an area of Engineering Science must follow a course of study approved by the Engineering Science Group Committee.

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.

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, Management, 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. 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 six credits of courses numbered from 100 to 199 may be included but only with the approval of the department of specialization.

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. 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 as part of the degree requirement but only with the approval of the department of specialization or the Engineering Science Group Committee, as appropriate.

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. Requests for extension of transfer credits 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.

APPLICATION FOR CANDIDACY

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 Candidacy 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.

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.

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

An applicant for admission to the doctoral program must submit, in a letter addressed to the Dean of the Graduate Division, an outline of his personal and academic background and his reasons for wishing to undertake doctoral studies. The applicant must also submit two transcripts of all previous academic work beyond the secondary school.

The application fee of $10.00 must accompany the letter, in 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.

When all letters, transcripts, and credentials have been received, the applicant will be notified to make an appointment for an interview with an advisor in his department of major study.

Admission will be predicated on satisfactory evidence of probable success as demonstrated from the information obtained from the applicant's academic background, recommendations, and 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. Students who fail to comply with these instructions must make appointments to see their advisers during registration week, and present, *in person,* their approved registration forms to the registration staff for payment of tuition and fees.

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

It is anticipated that many students may wish to do their graduate work in the evenings. Accordingly, classes in all courses may be scheduled for day or evening hours, or both, in accordance with the numbers enrolled.

The College reserves the right to require students registered in the Day Session to complete courses in the Evening Session.

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 week.

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 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:

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

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

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.

SEQUENCE OF COURSES IN NUCLEAR ENGINEERING

The increasing use of nuclear processes in industrial research and technology has motivated the introduction of a group of courses in nuclear engineering. In addition a fully equipped radioisotopes laboratory and a modern nuclear laboratory built around a water-moderated sub-critical reactor are available for laboratory instruction and research.

Specialization in the nuclear field is designed to proceed from an extension of basic engineering principles into this new area. Accordingly, a student, depending on his area of major interest, may pursue courses related to the nuclear field, under the direction of any of the engineering departments or of the Engineering Science Group.

The following courses are suggested as forming a group from among which may be chosen a sequence of courses appropriate for one with an interest in nuclear engineering:

Phys 120, Modern Physics
Phys 221, Nuclear Physics
Phys 222, Elements of Nuclear Engineering
Phys 224, Nuclear Engineering Laboratory

Chem 110, Radioisotope Theory and Application
Chem 111, Radioisotopes Laboratory
ME 201, Heat Transfer
ME 314, Advanced Heat Transfer.

Detailed descriptions of each of these courses may be found on the pages of this catalog in which the administering department lists its courses.

DEPARTMENT OF CHEMICAL ENGINEERING AND CHEMISTRY

MASTER OF SCIENCE PROGRAMS

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 in order to satisfy requirements in the area of specialization:

1. ChE 301, Thesis (6).
2. ChE 226, Mathematical Methods in Chemical Engineering (3).
3. Two courses (totaling 6 credits) from among the following:

   ChE 223, Heat Transfer.
   ChE 224, Transport Phenomena I.
   ChE 211, Thermodynamics.
   ChE 229, Chemical Engineering Laboratory.

4. Three additional credits selected from among courses in Chemical Engineering.

MASTER OF SCIENCE

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

1. ChE 301, Thesis (6).
2. Nine credits from among courses in Chemical Engineering and forming a related group.

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 mathe-

matics, 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.

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.

Students who have passed the first part of the qualifying examination are 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 additional dissertation credit or, if this registration be waived, at the discretion of the department and the Committee on Doctoral Studies, the student will be required to maintain his candidacy status by payment of the registration fee for each semester

intervening between such submission and acceptance, with a maximum extension to not more than is indicated in the section "Time Limitation" on page 27. The oral dissertation examination will be given only after the acceptance of the completed dissertation.

COURSES OF INSTRUCTION IN CHEMICAL ENGINEERING

ChE 125. INTRODUCTORY PROCESS CONTROL. 3 *credits, 1st sem.*

Prerequisite: B.S. in ChE. or M.E. or E.E. or engineering training satisfactory to the department. An introduction to chemical process dynamics and control with emphasis on the mathematical description and analysis of systems.

ChE 207. ELECTROCHEMICAL ENGINEERING. 3 *credits, 1st sem.*

Prerequisite: B.S. in ChE., or E.E., or Physics, or Chemistry, or previous training satisfactory to the instructor. This course deals with electrochemical theories, processes, and operations; the furnishing and utilization of electrical power to the industries; and the design, construction and operation of electrochemical plants.

Offered 1968-69 and alternate years.

ChE 211. THERMODYNAMICS. 3 *credits, 1st sem.* Dr. JOFFE.

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.* Dr. HANESIAN.

Prerequisite: Undergraduate reaction kinetics and ChE 211. 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 217. ADSORPTION. 3 *credits, 1st sem.*

Prerequisite: Previous training satisfactory to the department. Adsorption as a unit operation, theory and development; the solid adsorbents and ion exchangers; manufacture; applications for odor, taste, color and poison removal; dehydration and dehumidification; preservation of naval and military equipment; gas hydrates in pipe lines; fractionation of gases, liquids, ions, precious and rare metals, fission products, ions and molelcules by fixed and moving beds; adsorption catalysts; replacement of other unit operations.

Offered 1968-69 and alternate years.

ChE 220. PETROLEUM REFINING. 3 *credits, 1st sem.* Dr. WEINSTEIN.

Prerequisite: Previous training satisfactory to the department. A study of petroleum fractionation, cracking, reforming, treating, equipment design, operation, and economics of the various processes.

Offered 1967-68 and alternate years.

ChE 222. TECHNOLOGY OF MATERIALS. 3 *credits, 2nd sem.*

Prerequisite: Bachelor's degree in science, engineering, or closely allied field. A course coordinating the materials entering into engineering structures, machinery, and equipment from the viewpoints of service as a function of variation of chemical composition, mechanical processing and fabrication, thermal processing, protection against deterioration and corrosion, and adaptation to special services.

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

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

ChE 226. MATHEMATICAL METHODS IN CHEMICAL ENGINEERING. 3 *credits, 1st or 2nd sem.* Dr. 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 229. CHEMICAL ENGINEERING LABORATORY. 3 *credits per year, 1st* and *2nd sem.* Prof. KEEFFE.

Prerequisite: ChE 223 or ChE 224. The experimental program is developed by the individual student and may be chosen from an area of interest in chemical engineering science or technology. The experimental program may consist of a study, in depth, of a particular problem or a study of a number of different problems.

Laboratory fee: $5.00 per semester. Laboratory deposit: $25.00.

ChE 231. EQUILIBRIUM STAGE PROCESSES. 3 *credits, 1st sem.* Dr. CECCHETTI.

Prerequisite: Undergraduate transport operations. This course draws together the important basis 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.*

Prerequisite: Undergraduate process dynamics or process control or ChE 125; 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, 2nd sem.* Prof. 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 ten 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 sem.*

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 ten students each semester.

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

ChE 255. Plastics. 3 *credits, 2nd sem.* Dr. Geacintov.

Prerequisite: B.S. in ChE or M.E. or training satisfactory to the department. A course concerned with the effect of molecular and morphological structure on high polymer properties; molecular interpretation of mechanical properties of plastic materials, including kinetic theory of rubber elasticity, phenomenological viscoelasticity, the glassy state, glass transitions and crystallization and morphological behavior of semi-crystalline polymers; engineering analysis of industrial applications, including stress-cracking, creep, thermal and electrical properties of plastics, as well as processing methods and variables; and the economic utilization of plastics.

ChE 256. Catalysis. 3 *credits, 1st sem.* Dr. 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 1967-68 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 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. Tuition fee: $24.00 per credit. 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.* Dr. 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.

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

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

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

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 1967-68 and alternate years.

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

Prerequisites: ChE 226 and ChE 234 or equivalents. Mathematical development of optimization techniques with applications to problems in chemical process design and control. Methods of calculus of variations and dynamic programming are compared; the discrete maximum principle is developed and applied to problems in the design of multistage chemical processes such as cross-current extraction and a stirred tank reactor sequence.

ChE 357. Catalytic Reactor Design. 3 *credits, 2nd sem.* Dr. 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 1967-68 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. Tuition fee: $24.00 per credit per semester. 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: $24.00 per semester.

COURSES OF INSTRUCTION IN CHEMISTRY

Chem 102. Advanced Organic Chemistry I. 3 *credits, 1st sem.* Dr. Snyder.

Prerequisites: Undergraduate organic chemistry and physical chemistry. Organic reactions are treated from a mechanistic point of view. Some of the topics covered include chemical bonding, nucleophilic aliphatic substitution, additions to multiple bonds, elimination reactions, electrophilic and nucleophilic aromatic substitution.

Chem 110. Radioisotopes Theory and Application. 3 *credits, 1st sem.* Prof. Fitzgerald.

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 1968-69 and alternate years.

Chem 111. Radioisotopes Laboratory. 3 *credits, 2nd sem.* Prof. Fitzgerald.

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 1968-69 and alternate years.
Laboratory fee: $25.00.

Chem 120. Advanced Inorganic Chemistry. 3 *credits, 1st sem.* Prof. Cagnati and Dr. 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 130. Advanced Analytical Chemistry. 3 *credits, 2nd sem.* Dr. Shilman and Prof. 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 200. Sanitary Microbiology. 3 *credits, 1st sem.* Dr. Ram.

Prerequisites: An undergraduate course in chemistry and some knowledge of the subject matter of Chem 201. A lecture and laboratory course providing an introduction to the biological aspects of water, sewage, and food. Basic principles of microbiology, characteristics and control of bacteria and disease, are included with applications to public health problems. Bacteriological examinations of water, sewage, and milk are made.

Chem 201. Sanitary Chemistry. 3 *credits, 2nd sem.* Dr. Ram.

Prerequisite: An undergraduate course in chemistry. A lecture and laboratory course providing an introduction to the chemistry of water, sewage, and food. Principles of physical, organic, quantitative, and colloid chemistry applicable to the treatment processes in sanitary engineering are included. Laboratory determinations are made for data used in the design, operation, and analysis of treatment processes.

Chem 202. Advanced Organic Chemistry II. 3 *credits, 2nd sem.* Dr. Snyder.

Prerequisite: Chem 102 or equivalent. The approach will be similar to that used in Chem 102. Topics covered include the formation and reactions of carbanions, homolytic, aliphatic, and aromatic substitution, molecular rearrangements, and polymerization reactions.

Offered 1967-68 and alternate years.

Chem 203. Advanced Organic Chemistry Laboratory I. 3 *credits, 1st sem.* Drs. 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: $5.00. Laboratory deposit: $25.00.

Chem 206. Physical Organic Chemistry. 3 *credits, 2nd sem.* Dr. 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 1968-69 and alternate years.

Chem 208. PHYSICO-CHEMICAL INSTRUMENTATION METHODS I. 3 *credits, 1st sem.* Prof. BISHOP, Dr. SHILMAN.

Prerequisite: Undergraduate physical chemistry. Industrial and theoretical applications of such methods as ultra-violet, visible and infrared spectrometry, flame photometry, dielectric measurements, polarography, coulometry, gas, paper and thin layer chromatography and electrophoresis separations.

Chem 209. PHYSICO-CHEMICAL INSTRUMENTATION METHODS II. 3 *credits, 2nd sem.* Prof. BISHOP, Dr. SHILMAN.

Prerequisite: Chem 208. A continuation of Chem 208.

Chem 221. SOLID STATE INORGANIC CHEMISTRY. 3 *credits, 2nd sem.* Dr. SUCHOW.

Prerequisite: Undergraduate physical chemistry. A course dealing with relationships among structure, and physical and chemical properties of solid-state materials and with the formation of such materials.

Offered 1967-68 and alternate years.

Chem 240. POLYMER CHEMISTRY I. 3 *credits, 1st sem.* Drs. 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, 2nd sem.* Dr. 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.* Drs. SNYDER and WENISCH.

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

Chem 247. COLLOIDS. 3 *credits, 2nd sem.* Dr. CARLSON.

Prerequisite: Undergraduate course in physical chemistry or equivalent. Such subjects in colloidal chemistry as adsorption of gases by solids, contact catalysis, wetting of surfaces, sols, gels, aerosols, and electrophoresis are included among those studied.

Offered 1967-68 and alternate years.

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

Prerequisite: Undergraduate physical chemistry. A course concerned with atomic and molecular structure and properties, and the relationships between structure and physical properties.

Offered 1968-69 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 investiga-

tion 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 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. Tuition fee: $24.00 per credit. If the use of laboratory facilities or equipment is necessary, a $25.00 deposit must be maintained.

DEPARTMENT OF CIVIL 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 course work in mathematics, chemistry, physics, or mechanics; and (3) six credits of related elective course work.

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 mathematics, 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 one of the four fields of sanitation, soil mechanics, structural engineering or transportation, and all shall include a minimum of six credits of 300 level courses and/or 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.

COURSES OF INSTRUCTION

CE 201. CIVIL ENGINEERING PROJECTS I. 3 *credits,* 1*st* or 2*nd 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,* 1*st* or 2*nd sem.* Department Faculty.

A continuation of CE 201.

CE 215. WATER SUPPLY I. 3 *credits,* 1*st sem.* Dr. METZGER.

Prerequisite: Undergraduate courses in water supply and public health. The physical and chemical principles involved in the evaluation and treatment of water are presented. Consideration is given to the composition and impurities of natural waters, the interpretation of water analysis and to the water quality criteria used to evaluate supplies. Topics selected are those basic to treatment processes and include gas transfer, corrosion control, water softening, disinfection, coagulation, control of tastes and odors, and the removal of certain impurities.

Offered 1968-69 and alternate years.

CE 216. WATER SUPPLY II. 3 *credits,* 2*nd sem.* Dr. METZGER.

Prerequisite: CE 215. This course is a continuation of CE 215, with emphasis given to physical principles involved in water treatment such as mixing, flocculation, sedimentation and filtration. Hydraulic considerations in water treatment plant design are included. Emphasis is placed on process design considerations for municipal and industrial supplies. Special topics and recent developments are included according to the interests of the students.

Offered 1968-69 and alternate years.

CE 217. WATER POLLUTION CONTROL I. 3 *credits,* 1*st sem.* Dr. METZGER.

Prerequisite: Undergraduate courses in sanitary engineering and public health. The physical, chemical and biological principles necessary for an evaluation of water pollution are presented. These principles are applied to the deoxygenation and reaeration analysis of streams and other bodies of water. The results of such analysis are considered in light of water quality criteria established by regulatory agencies and are used to emphasize required levels of waste treatment. Techniques of systems engineering are applied to pollution problems in natural waters for planning and management of the overall water systems.

Offered 1967-68 and alternate years.

CE 218. WATER POLLUTION CONTROL II. 3 *credits,* 2*nd sem.* Dr. METZGER.

Prerequisite: CE 217. The principles presented in CE 217 are extended to describe aerobic treatment processes which include oxidation ponds, trickling filters, and activated sludge. The fundamentals of solid-liquid separation, anaerobic digestion and sludge handling and disposal are presented. Emphasis is on the application of fundamentals to the design and operation of waste-water treatment facilities. Recent developments in waste-water treatment are included according to the interests of the students.

Offered 1967-68 and alternate years.

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

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.

Offered 1968-69 and alternate years.

CE 245. HYDRAULIC ENGINEERING I. 3 *credits,* 1*st sem.* Dr. DRESNACK.

Prerequisite: Undergraduate course in fluid mechanics. A study of selected hydraulic topics which are of importance to the civil engineer and which are often not presented in depth in undergraduate courses.

The particular topics selected will vary with the needs and interests of the class. Typical topics may include open channel flow, pipe flow, fluid machinery, pumps, and hydraulic control devices. Emphasis is placed on practical application of the selected material.

Offered 1968-69 and alternate years.

CE 246. HYDRAULIC ENGINEERING II. 3 *credits, 2nd sem.* Dr. DRESNACK.

Prerequisites: Undergraduate courses in hydraulics, hydrology, and statistics. An analytical study concerning the part of the hydrologic cycle which deals with the occurrence and distribution of water on the surface of the earth. Emphasis is placed on the evaluation of extremes such as floods and droughts. Presented are statistical techniques which are employed to describe the nature of precipitation data and resulting runoff. A mathematical description of groundwater is presented for various types of aquifers and flow conditions. Flood routing and drainage problems are considered. The digital computer is utilized for certain problems such as the generation of synthetic data and the simulation of the flow of surface and ground waters.

Offered 1968-69 and alternate years.

CE 251. SOIL MECHANICS I. 3 *credits, 1st sem.* Dr. RAAMOT.

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: $5.00.
Offered 1968-69 and alternate years.

CE 252. SOIL MECHANICS II. 3 *credits, 2nd sem.* Dr. RAAMOT.

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: $5.00.
Offered 1968-69 and alternate years.

CE 253. FOUNDATION ENGINEERING I. 3 *credits, 1st sem.* Prof. MONAHAN.

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.

Offered 1967-68 and alternate years.

CE 254. FOUNDATION ENGINEERING II. 3 *credits, 2nd sem.* Dr. RAAMOT.

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

Offered 1967-68 and alternate years.

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

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 1968-69 and alternate years.

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

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 1968-69 and alternate years.

CE 267. TRAFFIC ENGINEERING. 3 *credits, 1st sem.* Adj. Prof. 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.

Offered 1968-69 and alternate years.

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

Prerequisite: Undergraduate course in structures as given to civil engineering students. 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.

Offered 1968-69 and alternate years.

CE 272. STRUCTURAL THEORY II. 3 *credits, 1st sem.*

Prerequisite: Undergraduate course in structures as given to civil engineering students. 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.

Offered 1967-68 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. *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. Tuition fee: $24.00 per credit. If the use of laboratory facilities or equipment is necessary, a $25.00 deposit must be maintained.

CE 311. WATER TREATMENT PLANT DESIGN. 3 *credits, 1st or 2nd sem.* Adj. Prof. GALANDAK and Dr. DRESNACK.

Prerequisite: CE 215. The study, design and reports for a municipal or industrial water treatment plant are prepared. Emphasis is on the practical aspects of design. The work is accomplished under the supervision and guidance of an adviser who establishes the metes and bounds of the project based on individual student interest.

CE 313. WASTE-WATER TREATMENT PLANT DESIGN. 3 *credits, 1st or 2nd sem.* Adj. Prof. GALANDAK and Dr. DRESNACK.

Prerequisite: CE 217. The study, design and reports for a municipal or industrial waste-water treatment facility are prepared. Emphasis is on the practical aspects of design. The work is accomplished under the supervision and guidance of an adviser who establishes the metes and bounds of the project based on individual student interest.

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

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 1967-68 and alternate years.

CE 336. Design of Lightweight Roof and Floor Systems. 3 *credits, 1st sem.* Dr. Law.

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 1967-68 and alternate years.

CE 337. Reinforced Concrete Design II. 3 *credits, 2nd sem.* Dr. Law.

Prerequisite: CE 237. This course covers the analysis and design of alternate structural building systems consisting of reinforced and prestressed concrete elements. Included is a study of the design of prestressed concrete members, reinforced concrete members, shear walls, and composite members both precast and cast in place.

Offered 1968-69 and alternate years.

CE 351. Earth Structures. 3 *credits, 1st sem.* Dr. Raamot.

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 1967-68 and alternate years.

CE 352. Seepage and Well Analysis. 3 *credits, 2nd sem.* Prof. 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 1967-68 and alternate years.

CE 361. Urban Transportation Planning. 3 *credits, 1st sem.* Adj. Prof. Kraft.

Prerequisite: CE 265, 266. This course deals with urban travel patterns and trends, community and land activity related to transportation planning; transportation study techniques including survey methods, network analysis, assignment and distribution techniques. Case studies of statewide and urban area studies are examined.

Offered 1967-68 and alternate years.

CE 362. Transportation Design. 3 *credits, 2nd sem.* Adj. Prof. Kraft.

Prerequisite: CE 361. Design problems include airports, terminals, and highway intersections and interchanges.

Offered 1967-68 and alternate years.

CE 364. Transportation Projects. 3 *credits, 2nd sem.*

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

CE 371. Structural Design I. 3 *credits, 2nd sem.*

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 1968-69 and alternate years.

CE 372. Structural Design II. 3 *credits, 2nd sem.*

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 1967-68 and alternate years.

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 100, Vector and Tensor Analysis.
Math 273, 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 256, Functions of a Complex Variable.

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 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 256, Functions of a Complex Variable.
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 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 248, Wave Shape and Pulse Form Control.
EE 252, Network Theory I.
EE 273, Random Processes in Electrical Communication.
EE 352, Network Theory II.
EE 353, Electric Filter Design.
EE 376, Information Theory.
Math 258, Operational Mathematics.

Area II. Automatic Control and Industrial Electronics:

EE 245, Industrial Electronics.
EE 261, Servomechanism Components.
EE 262, Magnetic Amplifiers.
EE 263, Servomechanisms.
EE 266, Servomechanisms Laboratory.
EE 364, Sampled-Data and A-C Servomechanisms.
EE 365, Introduction to Nonlinear Systems.
EE 366, Stability Theory of Nonlinear Systems.
EE 466, Modern Control Theory.
EE 467, Statistical Design of Servomechanisms.
ME 236, Inertial Guidance Systems.

Area III. Electronic Computers:

EE 250, Transistor Circuits.
EE 262, Magnetic Amplifiers.
EE 275, Design of Digital Control Circuits.
EE 280, Analog Computers.
EE 281, Techniques of Digital Computers.
Math 290, Computer Programming Language.

Area IV. Communication Theory

EE 239, Feedback Amplifiers I.
EE 242, Modulation Theory I.
EE 274, Noise in Electric Circuits.
EE 339, Feedback Amplifiers II.
EE 342, Modulation Theory II.
EE 344, Communications System Design.
EE 376, Information Theory.

Area V. Communication Devices:

EE 222, Wave Propagation.
EE 246, Microwave Systems.
EE 250, Transistor Circuits.
EE 268, Transducers and Acoustics.
EE 270, Transducers and Acoustics Laboratory.
EE 323, Microwave Transmission.
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:

Phys 211, Transistor Physics.
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.

Area VIII. Electric Machines and Power Systems:

Phys 222, Elements of Nuclear Engineering.
EE 215, Power Transmission.
EE 216, Power Distribution.
EE 218, Symmetrical Components.
EE 261, Servomechanism Components.
EE 271, Electric Power Systems.
EE 290, Advanced A-C Machines I.
EE 291, Large Power Control Systems.
EE 390, Advanced A-C Machines II.

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 12 credits of courses on the 300 and 400 levels as approved by the adviser.

QUALIFYING EXAMINATION

The qualifying examination will require competence in the following fields:

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

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 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 additional dissertation credit, or, if this registration be waived, at the discretion of the department and the Committee on Doctoral Studies, the student will be required to maintain his candidacy status by payment of the registration fee for each semester intervening between such submission and acceptance, with a maximum extension to not more than is indicated in the section "Time Limitation" on page 27. The oral examination will be given only after the acceptance of the completed dissertation.

COURSES OF INSTRUCTION

EE 120. ELECTROMAGNETIC FIELD ANALYSIS. 3 *credits,* 1*st* or 2*nd sem.* Department Faculty.

Prerequisite: Math 100 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,* 2*nd sem.* Department Faculty.

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,* 1*st* or 2*nd sem.* Department Faculty.

Prerequisite: Math 273 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,* 1*st sem.* Department Faculty.

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.

EE 177. STOCHASTIC PROCESSES. 3 *credits,* 1*st sem.* Department Faculty.

Prerequisites: Undergraduate differential equations and circuit theory. 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.

EE 215. Power Transmission. 3 *credits, 2nd sem.* Prof. Jordan.

Prerequisite: EE 256. The fundamentals of mechanical and electrical design of transmission lines, power line operation, problems of system performance.

Offered 1968-69 and alternate years.

EE 216. Power Distribution. 3 *credits, 1st sem.* Prof. Jordan.

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. Modern practice in urban and rural distribution, overhead and under-ground lines, networks, lightning protection, and voltage regulation are included.

Offered 1968-69 and alternate years.

EE 218. Symmetrical Components. 3 *credits. 1st sem.* Adj. Prof. 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 1967-68 and alternate years.

EE 222. Wave Propagation. 3 *credits, 2nd sem.*

Prerequisites: EE 120 and Math 274 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.* Dr. Zambuto.

Prerequisites: EE 140, EE 150, and Math 256 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 1967-68 and alternate years.

EE 241. Reliability Problems in Electronics. 3 *credits, 1st sem.* Dr. Misra.

Prerequisites: EE 120, EE 140 or equivalents. The course deals with study of factors causing instability and reliability failure in electronic equipment and components. Particularly, study will be made of problems in dielectrics, including distribution of potentials and electric fields. Transistors will be studied from the point of view of beta stability and leakage current problems including conditions prevailing under different reverse bias conditions. For electron tubes cathodic failure mechanism will be 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 will be placed on engineering approach but basic statistics required for sampling will also be covered. Different types of accelerated life testing problems and physical principles underlying these will be critically studied.

EE 242. Modulation Theory I. 3 *credits, 1st sem.* Dr. Assadourian.

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 245. INDUSTRIAL ELECTRONICS. 3 *credits, 1st sem.* Prof. ANDERSON.

Prerequisite: EE 140 or equivalent. Fundamental principles including thermistors, varistors, switching circuits; R. F. heating, electronic control (motor, welding and photoelectric); power rectifiers and inverters; X-ray applications; and electrostatic precipitation are covered.

Offered 1968-69 and alternate years.

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 1968-69 and alternate years.

EE 248. WAVE SHAPE AND PULSE FORM CONTROL. 3 *credits, 2nd sem.* Department Faculty.

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* or *2nd sem.* Prof. MEOLA.

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, 1st sem.* Department Faculty.

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.* Department Faculty.

Prerequisite: EE 150 or equivalent. Corequisite: Math 256. The following topics are included in the course: Gain-phase and frequency-time relationships, concepts of feedback and stability, matrix methods, and state-variable representation.

EE 261. SERVOMECHANISM COMPONENTS. 3 *credits, 1st sem.* Prof. WINSTON.

Prerequisite: EE 263. The steady-state and transient characteristics of commonly used magnetic components such as servomotors, rate generators, synchros, eddy-current and inertia dampers, polarized torquemotors, hysteresis clutches and particle clutches are covered. Emphasis is placed on problems affecting the performance of the complete system of which the component is a part.

Offered 1968-69 and alternate years.

EE 262. MAGNETIC AMPLIFIERS. 3 *credits, 1st sem.* Prof. ANDERSON.

Prerequisites: Undergraduate magnetic circuits, EE 140, EE 150. A study of the theory, application, and uses of the magnetic amplifier including loading, load characteristics, harmonics, frequency characteristics, output

power, maximum power transfer, efficiency, gain, and feedback. Both steady-state and transient conditions are investigated.

Offered 1967-68 and alternate years.

EE 263. SERVOMECHANISMS. 3 *credits, 1st or 2nd sem.* Department Faculty.

Prerequisite: EE 256 or mechanical engineering course in vibration theory. Analysis and design of linear servomechanisms. Transient, steady-state frequency response and root locus methods with stress on the latter for design purposes. The principal emphasis is on electromechanical systems.

EE 266. SERVOMECHANISMS LABORATORY. 3 *credits, 2nd sem.* Dr. PADALINO.

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 268. TRANSDUCERS AND ACOUSTICS. 3 *credits, 1st sem.* Prof. ROSE.

Prerequisite: EE 150 or equivalent. Generation, propagation, and detection of sound and sonic waves in gaseous and fluid media. Transducers for generation and detection of these waves are studied through analogues which reduce the mechanical properties to electric circuitry.

Offered 1967-68 and alternate years.

EE 270. TRANSDUCERS AND ACOUSTICS LABORATORY. 3 *credits, 2nd sem.* Prof. ROSE.

Prerequisite: EE 268 and electronics laboratory experience. Lecture and laboratory study of transducers for the generation and detection of sound, with emphasis on gaseous media. Sensitivity, amplitude-frequency response, and directional characteristics are examined.

Offered 1967-68 and alternate years.

EE 271. ELECTRIC POWER SYSTEMS. 3 *credits, 1st sem.* Prof. JORDAN.

Prerequisite: Undergraduate courses in alternating current circuits and machines. Selected topics dealing with power generation, transmission and distribution. Among these topics are hydro and steam operation, economic and reliability factors involved in power system interconnections, load-frequency control, power factor economics, system protection, steady state, and transient stability problems.

Offered 1967-68 and alternate years.

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

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 1967-68 and alternate years.

EE 274. Noise in Electrical Circuits. 3 *credits, 1st sem.* Dr. 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 1968-69 and alternate years.

EE 275. Design of Digital Control Circuits. 3 *credits, 2nd sem.* Prof. 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.* Prof. 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.* Prof. 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.* Dr. Lawrence.

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 1967-68 and alternate years.

EE 291. Large Power Control Systems. 3 *credits, 2nd sem.* Prof. 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 1967-68 and alternate years.

EE 300. Master's Project. 3 *credits, 1st* or *2nd sem.* Department Faculty.

Prerequisite: Matriculation for a M.S. degree and substantial progress in writing an extensive paper in the designated EE course. 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: Matriculation for the M.S. degree. 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. Tuition fee: $24.00 per credit. If the use of laboratory facilities or equipment is necessary, a $25.00 deposit must be maintained.

EE 318. THEORY OF CONTROL IN POWER SYSTEMS. 3 *credits, 2nd sem.* Prof. YEH.

Prerequisite: EE 218. This course includes general theory of control in power systems; high-speed protection of overhead lines, protection of underground systems, and relay applications; control of generators, motors and other electromagnetic devices, the magnetic amplifiers; low-frequency coordination of power and communications systems; and supervisory-control circuits.

Offered 1967-68 and alternate years.

EE 323. THEORY OF GUIDED WAVES. 3 *credits, 1st sem.* Dr. CHING.

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 1968-69 and alternate years.

EE 339. FEEDBACK AMPLIFIERS II. 3 *credits, 2nd sem.* Dr. 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 1967-68 and alternate years.

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

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 1967-68 and alternate years.

EE 344. COMMUNICATIONS SYSTEMS DESIGN. 3 *credits, 2nd sem.* Dr. ASSADOURIAN.

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

Offered 1968-69 and alternate years.

EE 348. QUANTUM ELECTRONICS. 3 *credits, 1st sem.* Dr. 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 Heinsenberg 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 1968-69 and alternate years.

EE 349. INTRODUCTION TO QUANTUM FIELD THEORY. 3 *credits, 2nd sem.* Dr. CHING.

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 1968-69 and alternate years.

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

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.* Dr. 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.

Offered 1967-68 and alternate years.

EE 364. SAMPLED-DATA AND A-C SERVOMECHANISMS. 3 *credits, 1st sem.* Dr. MEYER.

Prerequisite: EE 263 or equivalent. The course deals with sampled-data servomechanisms including modulation, sampling, z-transform theory, predictors, and servos with digital computers; and a-c servomechanisms including analysis of modulators and demodulators, a-c motors, and a-c compensation.

Offered 1967-68 and alternate years.

EE 365. Introduction to Nonlinear Systems. 3 *credits, 2nd sem.* Dr. 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 1967-68 and alternate years.

EE 366. Stability Theory of Nonlinear Systems. 3 *credits, 1st sem.* Dr. 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 1968-69 and alternate years.

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

Prerequisite: EE 273 or EE 274. An introductory course in the modern communication theory of discrete and continuous random signals. Basic probability theory, communication in binary units through binary systems, statistical properties of continuous signals in time and frequency domains, and communication through a channel with noise are covered. Applications include binary systems, filters, PAM and PCM systems, potentiometer noise, and servomechanism error functions.

Offered 1967-68 and alternate years.

EE 390. Advanced A-C Machines II. 3 *credits, 2nd sem.* Dr. Lawrence.

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 1967-68 and alternate years.

EE 391. Selected Topics in Electrical Engineering. 3 *credits.*

Prerequisites: EE 256, Math 256, 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.*

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. Tuition fee: $24.00 per credit per semester. 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 students registered for EE 301.*

Seminar fee: $24.00 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 424. ADVANCED ANTENNA THEORY. *3 credits, 2nd sem.*

Prerequisite: EE 222, Math 256, Math 274 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 1968-69 and alternate years.

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

Prerequisite: Phys 230. This course covers selected topics in master design, modulation, and applications. Included are population inversion methods, maser states in ammonia and the ammonia maser, maser levels in paramagnets, three level solid and gas masers, noise, and degrees of coherence.

Offered 1968-69 and alternate years.

EE 449. RADIATION AND NOISE IN QUANTUM ELECTRONICS. *3 credits, 2nd sem.*

Prerequisite: Phys 230 or equivalent. The course includes a review of quantum mechanics using the Dirac nonrelativistic formulation. The harmonic oscillator is treated by means of operator techniques. The electromagnetic radiation field is quantized and examples are given of the quantized field interacting with matter. Quantum statistics are presented using the density operator. Applications include quantum noise in masers, attenuators and parametric amplifiers.

Offered 1968-69 and alternate years.

EE 451. SEMINAR ON RELIABILITY. 3 *credits, 2nd sem.* Dr. MISRA.

Prerequisite: EE 241 or equivalent. A more detailed study of active elements will be 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 will be 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 1967-68 and alternate years.

EE 466. MODERN CONTROL THEORY. 3 *credits, 1st sem.* Dr. PADALINO.

Prerequisites: EE 263 and permission of the department. Selected topics in modern control theory, adaptive control systems, and optimal control theory using state representation are covered.

Offered 1968-69 and alternate years.

EE 467. STATISTICAL DESIGN OF SERVOMECHANISMS. 3 *credits, 2nd sem.* Dr. RUSSELL.

Prerequisites: EE 263, and EE 274 or EE 376 (or approximate 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 1968-69 and alternate years.

DEPARTMENT OF INDUSTRIAL AND MANAGEMENT ENGINEERING

MASTER OF SCIENCE PROGRAMS

The degree *Master of Science in Management Engineering* is the recommended objective for the graduates of an engineering curriculum whose careers are in, or moving toward, management in an engineering-scientific oriented enterprise. The degree *Master of Science* is the recommended objective for those holders of B.S. degrees who have majored in mathematics, physics, or chemistry, as well as for those graduates of an engineering curriculum whose careers are in, and likely to remain in, technical work but who find need for some background in the management field. 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.

MASTER OF SCIENCE IN MANAGEMENT ENGINEERING

For the degree *Master of Science in Management Engineering* the student must include among the specialization credits:

EM 201, Advanced Management Engineering (3).
EM 202, Introduction to Management Science (3).
EM 203, Analytical Engineering Statistics (3).
EM 301, Thesis (6).

The remaining three of the required eighteen specialization credits (see section "Academic Requirements") must be selected from courses approved by the student's adviser as part of the necessary course preparation for the thesis. Twelve elective credits may be chosen from those offered by the Department of Industrial and Management Engineering or from course offerings of other departments, depending upon the requirements for proper student preparation for the thesis.

MASTER OF SCIENCE

For the degree *Master of Science* the student must include fifteen course credits from the courses below as part of his program. Six credits as follows:

EM 315, Design of an Enterprise (3)
EM 316, Seminar in the Design of an Enterprise (3)

Nine credits from among the following:

EM 201, Advanced Management Engineering (3)
EM 202, Introduction to Management Science (3)
EM 203, Analytical Engineering Statistics (3)
EM 263, Behavioral Science (3)
EM 282, Applications and Programming of Digital Computers (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.

COURSES OF INSTRUCTION

EM 201. ADVANCED MANAGEMENT ENGINEERING. 3 *credits,* 1*st* or 2*nd sem.* Professors SIZELOVE and WOLF.

Prerequisite: Undergraduate economics, accounting, engineering economy, and probability and statistics. A study of the fundaments, principles, and philosophies of management as evidenced in the classical and contemporary literature, toward the formulation of a philosophy of management by the students. Applications in seminar of current management engineering problems.

EM 202. INTRODUCTION TO MANAGEMENT SCIENCE. 3 *credits,* 1*st* or 2*nd sem.* Adj. Profs. 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,* 1*st* or 2*nd sem.* Dr. STONE and Adj. Prof. TAETZSCH.

Prerequisites: Undergraduate calculus and probability and statistics. An introduction of engineering statistics with applications to engineering and management data. The utility of statistical inference as interpretive tool for comprehension of data is stressed.

EM 205. ENGINEERING RELIABILITY. 3 *credits,* 1*st sem.* Dr. 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 1968-69 and alternate years.

EM 213. PRODUCTION ENGINEERING. 3 *credits,* 1*st sem.* Adj. Prof. DANCO.

Prerequisite: Undergraduate production process design. The course is concerned with establishing and maintaining production systems. An analysis of the stages of process and machine tool determination, economic appraisal of process selection and tool engineering.

Offered 1968-69 and alternate years.

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

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 217. Production Engineering Estimating. 3 *credits, 1st sem.* Adj. Prof. Danco.

Prerequisite: Undergraduate production process design and accounting. This course covers the work of the engineer in the field of production cost estimating and its evaluation by management. Special emphasis is placed on the principles and procedures used in cost estimating and its analysis, with specific examples to illustrate the effect on cost of various combinations of plant layout, tooling, product design, and machinery and equipment. Included subjects are manufacturing analysis, material estimating, manpower and machine requirements, distribution of burden, and product cost summaries.

Offered 1967-68 and alternate years.

EM 225. Human Factors in Engineering. 3 *credits, 1st sem.* Dr. J. P. Smith.

A survey of the methods and findings of human factors research related to research, design, and development. Capabilities and limitations of the human sensory-motor system, design of displays and controls, arrangement of groups of men and machines, effects of environment on human performance, and designing for ease of operation and maintenance are discussed.

EM 234. Planning and Management of Industrial Research. 3 *credits. 1st sem.* Dr. Leyes.

An objective study of industrial research, covering management problems in the organization, planning, and operation of an industrial research and development unit. Topics include historical growth of industrial research, interrelations of research and development activities, selection of problems, methods used to solve research problems, treatment of experimental data, reports and budgets, selection and growth of research personnel, laboratory location, and patents. This course is designed for both the individual research worker and for those in various levels of supervisory work.

EM 235. Management of Design and Development. 3 *credits, 2nd sem.* Prof. Rigassio.

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.* Dr. Brosh.

Prerequisite: EM 202. This course treats the foundations, methodology and applications of operations research. Topics included are: statistical techniques, stochastic processes, waiting line theory, linear and non-linear programming, theory of games, cybernetics, information theory, and symbolic logic. Operation research teams and the utility of their findings to guide managerial decision are discussed. The practical limitations and the criteria of effectiveness for the several techniques are stressed.

EM 251. Linear Programming. 3 *credits, 1st sem.* Dr. Brosh.

Prerequisite: EM 202. This course treats the principles, methodology, and practical applications of mathematical programming to complex problems in production and marketing. 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.

EM 255. Introduction to Systems Engineering and Electronic Data Processing. 3 *credits, 2nd sem.* Prof. Gordan.

Prerequisite: Math 190 or equivalent. 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.* Prof. LaVerda.

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 1967-68 and alternate years.

EM 263. Behavioral Science. 3 *credits, 2nd sem.* Dr. J. P. Smith.

Prerequisite: Undergraduate 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.

EM 272. Industrial Quality Control. 3 *credits, 2nd sem.* Adj. Prof. Taetzsch.

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 1967-68 and alternate years.

EM 282. Computer Applications for Managerial Control. 3 *credits, 1st sem.* Prof. Gordan.

Prerequisite: Math 190 or equivalent and EM 202. This course explores some of the applications of digital computers in the 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.

EM 293. Managerial Economics. 3 *credits, 1st sem.* Adj. Prof. Kopf.

Prerequisites: Undergraduate economics and accounting. This course analyzes the internal and external influences on the economic practices of business. It introduces the student to classical and current theories concerning the economic behavior of the firm and to contemporary analytical techniques. The course aims at providing an understanding, from an economic point of view, of the behavior of costs, prices, and profits. Among the topics treated are: demand analysis, competition and monopoly, capital expenditure planning, profit theories, and business

cycles, as well as the econometric models pertaining to the analysis of market strategies, competitive action, and demand behavior.

EM 301. MASTER'S THESIS. 6 *credits, 1st* or *2nd sem.* Department Faculty.

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

Thesis fee: $5.00 per semester. Tuition fee: $24.00 per credit. If the use of laboratory facilities or equipment is necessary, a $25.00 deposit must be maintained.

EM 304. ADVANCED ANALYTICAL ENGINEERING STATISTICS. 3 *credits, 2nd sem.* Dr. STONE.

Prerequisite: EM 203. A continuation of the analytical approach to engineering statistics in the areas of statistical inference, regression analysis, analysis of variance, and design of tests. Industrial applications to engineering tests analysis and designs procedures are stressed.

EM 315. DESIGN OF AN ENTERPRISE. 3 *credits, 1st sem.* Prof. RIGASSIO and Adj. Prof. MAZIE.

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.* Prof. RIGASSIO and Adj. Prof. MAZIE.

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.* Adj. Prof. BISHOP.

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.

EM 380. TECHNIQUES OF EXECUTIVE CONTROL. 3 *credits, 2nd sem.* Prof. WOLF.

Prerequisite: EM 371. 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 firm's objectives and management philosophy.

Offered 1968-69 and alternate years.

DEPARTMENT OF MECHANICAL ENGINEERING

MASTER OF SCIENCE PROGRAMS

Programs leading to the degrees *Master of Science* and *Master of Science in Mechanical Engineering* are offered by the Department and are described below. Candidates for these degrees must include, with the prior approval of the adviser, either ME 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.

C. Behavior of Metals.

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, Steam Power Plant Design.
ME 242, Heat Transfer in Space.

Two courses must be selected from the following group:

ME 218, Instrumentation.
ME 222, Dynamics of Incompressible Flow.
ChE 224, Transport Phenomena.
ME 232, Statistical Thermodynamics.
ME 238, Gas Dynamics.
ME 307, Non-Equilibrium Thermodynamics.
ME 314, Advanced Heat Transfer.
ME 317, Special Problems in Mechanical Engineering.
ME 319, Mechanics of Viscous Fluids.
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 101, Mechanical Vibrations.
ME 205, Advanced Machine Design.
ME 217, Bearings and Bearing Lubrication.
ME 223, Experimental Stress Analysis.
ME 224, Photoelasticity.
ME 231, Gyrodynamics.

Two courses must be chosen from the following group:

ME 220, Advanced Mechanical Vibrations.
ME 208, High Speed Machinery.
ME 230, Dynamics of Machinery.
ME 234, Design of Plates and Shells.
ME 235, Random Vibrations.
ME 236, Inertial Guidance Systems.

ME 313, Viscoelasticity.
ME 316, Thermal Stresses.
ME 317, Selected Problems in Mechanical Engineering I.
ME 318, Selected Problems in Mechanical Engineering II.

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.
Phys 212, Dynamics of a Particle.
Mech 213, Dynamics of a Rigid Body.
Mech 304, Theory of Elastic Stability.

Area C. Those interested in the Behavior of Metals must choose their electives as follows:

Two courses must be selected from the following group:

ME 210, Engineering Metallurgy of Steels.
ME 225, Advanced Metallurgy.
ME 226, Corrosion.
ME 229, Light Alloys.
ME 233, Principles of Physical Metallurgy.

Two courses must be selected from either one of the following groups:

Group I:

ME 201, Heat Transfer.
ME 207, Advanced Thermodynamics.
ME 214, Advanced Heat Transfer.
ME 218, Instrumentation.
ME 222, Dynamics of Incompressible Fluids.
ME 232, Statistical Thermodynamics.

Group II:

ME 101, Mechanical Vibrations.
ME 205, Advanced Machine Design.
ME 220, Advanced Mechanical Vibrations.
ME 223, Experimental Stress Analysis.
ME 224, Photoelasticity.
ME 234, Design of Plates and Shells.

If in the opinion of the adviser the student's interests are such that an integrated course of study would include courses

offered by other departments, one or more of the following courses may be substituted for courses in Groups I or II above:

Chem 111, Radioisotopes Laboratory.
ChE 222, Technology of Materials.
ChE 230, Extractive Metallurgy.
ChE 252, Technology of Nuclear Materials.
Phys 211, Transistor Physics.
Phys 214, Solid State Physics.
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 registration will be required. Depending on the status of the research at the time, this may take the form of registration for additional dissertation credit or, at the discretion of the Department and the Committee on Doctoral Studies, may consist of maintenance of candidacy status by payment of such registration fee semester by semester with a maximum extension not to exceed that indicated in the section "Time Limitation" on page 27.

The oral defense will take place only after submission of the final draft of the dissertation.

COURSES OF INSTRUCTION

ME 101. MECHANICAL VIBRATIONS. 3 *credits,* 1*st sem.* Prof. MICHELS.

Prerequisites: Kinetics and undergraduate differential equations. The course consists of a mathematical analysis of vibrating systems with one or more degrees of freedom, La Place transformations, static and dynamic balancing, harmonic analysis, and numerical analysis.

ME 113. DYNAMICS OF COMPRESSIBLE FLUIDS. 3 *credits,* 1*st sem.* Drs. SMITHBERG and 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,* 1*st sem.* Profs. STAMPER and FLORIO.

Prerequisites: Undergraduate fluid mechanics, heat transfer, and Math 100 or equivalent. A study of heat transfer by conduction, convection, radiation, and during phase change. Analytical and numerical solutions to steady and unsteady state conduction; boundary layer theory and applications to convective heat transfer; analogy between fluid flow and heat transfer; basic laws of radiation and applications; and combined heat transfer mechanisms. ChE 223 may be substituted for ME 201 with departmental approval.

ME 203. Gas Turbines. 3 *credits, 1st sem.* Prof. 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.

ME 205. Advanced Machine Design. 3 *credits, 1st sem.* Dr. Herman.

Prerequisites: Undergraduate differential equations, senior machine design, and Math 100 or equivalent. 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; accurate analysis of impact stresses, and stresses beyond the yield point.

ME 207. Advanced Thermodynamics. 3 *credits, 1st sem.* Dr. 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 208. High Speed Machinery. 3 *credits, 2nd sem.* Dr. Herman.

Prerequisites: Senior machine design and Math 100 or equivalent. This advanced course treats of the requirements introduced by the preponderance of centrifugal and dynamic forces in machine parts at high speed.

ME 210. Engineering Metallurgy of Alloy Steels. 3 *credits, 2nd sem.* Prof. Bannon.

Prerequisites: Undergraduate metallurgy, metallography, 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.

ME 216. Refrigeration and Air Conditioning. 3 *credits, 2nd sem.* Prof. 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, steam jet 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.* Prof. 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.* Prof. Jacobs.

Prerequisites: Undergraduate differential equations, fluid mechanics, and 1 year of thermodynamics. The course is directed to the theory and

design of the primary elements of instrumention such as pressure, 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.* Prof. Michels.

Prerequisite: Undergraduate vibrations or ME 101. 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.* Dr. Levy.

Prerequisites: Undergraduate differential equations, fluid mechanics and Math 100 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.* Dr. Smithberg.

Prerequisites: Undergraduate differential equations, fluid mechanics, and Math 100 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.* Prof. 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.* Prof. 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.

ME 225. Advanced Metallurgy. 3 *credits, 1st sem.* Prof. Bannon.

Prerequisites: Undergraduate metallurgy and metallography and mechanics of deformable bodies. A combined lecture and laboratory course dealing with multi-metal systems, both ferrous and non-ferrous; the

deformation of metals; and the principles involved in the thermal response of alloys. Laboratory experiments are designed to illustrate the principal points developed. Some original experimentation will be carried out.

Laboratory fee: $15.00.

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

ME 227. POWER PLANT DESIGN. 3 *credits, 1st sem.* Prof. 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 1967-68 and alternate years.

ME 229. LIGHT ALLOYS. 3 *credits, 1st sem.* Prof. SCHNEIDER.

Prerequisites: Undergraduate courses in metallurgy, metallography, and mechanics of deformable bodies. A combined lecture and laboratory course dealing with the alloys of aluminum, magnesium and titanium. Special laboratory projects are assigned to complement theoretical studies.

Laboratory fee: $15.00.
Offered 1967-68 and alternate years.

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

Prerequisites: Undergraduate differential equations, machine design, and Math 100 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.

ME 231. GYRODYNAMICS. 3 *credits, 1st sem.* Prof. COCHIN.

Prerequisite: Math 100 or equivalent. The object of the course is to bridge the gap between theory and practical design of precision inertial instruments, such as the gyroscope and accelerometer. This is accomplished by creating a physical concept of the tensor and the introduction of matrix-tensor design methods. Starting with fundamentals, these methods are applied to gyro torque, precession, drift, elasticity of support (fluid, electrostatic, magneto-static, superconductive), and rotation of an unsymmetrical elastic body. The course culminates in the design of a complete instrument.

ME 232. STATISTICAL THERMODYNAMICS. 3 *credits, 2nd sem.* Dr. HSIEH.

Prerequisites: Undergraduate courses in differential equations and one year of thermodynamics. This course constitutes an introduction to kinetic theory of gases and statistical mechanics. Topics include Max-

wellian 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. Fluctuations and irreversible processes are also considered.

ME 233. PRINCIPLES OF PHYSICAL METALLURGY. 3 *credits, 1st sem.* Profs. PEARCE and BANNON.

Prerequisites: Undergraduate metallurgy, metallography, thermodynamics, and differential equations. A consideration of advanced concepts of structure-dependent phenomena in metal systems that are only briefly discussed in undergraduate courses in metallurgy. Topics covered include crystal structure and imperfections, phase rule and free energy, solid state diffusion, recovery and recrystalization mechanisms, and X-ray analysis techniques.

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

Prerequisites: Mechanics of deformable bodies and Math 100 or equivalent. A study of plates and shells oriented toward mechanical engineering design which covers solutions for typical loading and boundary conditions by analytical and numerical methods, including digital computer techniques. Sandwich construction, plate and shell interfaces, and thermal stresses are also considered.

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

Prerequisites: Mechanics of deformable bodies, mechanical vibrations, and Math 100 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.

ME 236. INERTIAL GUIDANCE SYSTEMS. 3 *credits, 2nd sem.* Prof. COCHIN.

Prerequisite: Math 100 or equivalent. An introductory course in analysis and synthesis of inertial guidance systems. Use of vector analysis and matrices to illustrate the physical meaning and application of tensors which are used to derive the control loop equations for various coordinate frames. Gyroscopic stabilization, single and multiaxis platform stabilization, the Schuler tuned system, and velocity damped gyrocompassing systems are considered. Applications of random processes and servo analysis to closed loop noise analysis of Schuler and hybrid intertial systems, and guidance of satellite into orbit are included.

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

Prerequisites: Math 100 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. HEAT TRANSFER IN SPACE. 3 *credits, 2nd sem.* Dr. HRYCAK.

Prerequisites: Undergraduate differential equations, thermodynamics, and heat transfer. The objective of this course is to give the student an understanding of the principles of heat transfer and thermodynamics associated with the near space problems, as applicable to the design of

artificial satellites and space vehicles. In particular, the heat transfer by radiation is discussed, between the vehicle and the surroundings and also between the components of a single vehicle. The analogy between the heat transfer by radiation and the electrical networks is stressed. Also, discussed are the problems where both conduction and radiation must be considered.

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. Tuition fee: $24.00 per credit. If the use of laboratory facilities or equipment is necessary, a $25.00 deposit must be maintained.

ME 307. NON-EQUILIBRIUM THERMODYNAMICS. 3 *credits, 1st sem.* Dr. 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.

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

Prerequisite: ME 206 or equivalent. Published papers and classical texts are used to present the first 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.

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

Prerequisite: ME 201. The course deals with the theory of high rate heat transfer, with emphasis on techniques involved in thermal design of complex systems. Analytical, digital, and analog computer methods for transient and steady state high rate heat transfer problems including conduction, convection, radiation, phase change, and heat generation are considered.

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

Prerequisites: Vector analysis and a course in elasticity or its equivalent. Foundations of thermoelasticity, reduction of thermoelastic problems to constant temperature equivalents; fundamentals of heat transfer; and elastic and inelastic stress analysis are topics discussed.

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, 2nd sem.* Dr. 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.

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

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.

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. Tuition fee: $24.00 per credit per semester. Laboratory deposit: $25.00 per semester, or such additional amount as may be necessary to provide laboratory facilities and equipment. Doctoral Dissertation fee: $50.00, payable on submission of an 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: $24.00 per semester.

ENGINEERING SCIENCE GROUP

MASTER OF SCIENCE PROGRAMS

The degree of *Master of Science* in areas of Engineering Science is offered to qualified students with the bachelor's degree in engineering, mathematics, or the physical sciences. The program of study leading to the degree is interdisciplinary in emphasis and is designed to meet the interests of the individual student. Among the areas within the scope of the program are: advanced chemistry; polymer chemistry; theoretical and applied mechanics; theoretical and applied physics; solid state physics; nuclear physics and engineering; computer theory, design, and operation; and advanced engineering mathematics. Other areas may be added as interest indicates. The student in this program must follow a course of study approved by the Engineering Science Group Committee, and an adviser will be appointed by the committee. At least six credits from among courses offered by the Engineering departments must be included in the fifteen elective credits required. The courses chosen in fulfillment of the requirement for fifteen credits of specialization must include ESc 300 or ESc 301.

For course listing in chemistry, see the offerings of the Department of Chemical Engineering and Chemistry.

DEPARTMENT OF MATHEMATICS

COURSES OF INSTRUCTION

Math 100. VECTOR AND TENSOR ANALYSIS. 3 *credits, 1st or 2nd sem.* Dr. ZATZKIS and Prof. LIONE.

Prerequisites: Differential and integral calculus. Introduction to vector and tensor analysis, including a survey of cuvilinear coordinates, with applications to matrix algebra, problems in dynamics, electromagnetic theory, fluid dynamics, and potential theory.

Math 111. INTRODUCTION TO NUMERICAL ANALYSIS. 3 *credits, 1st sem.* Prof. 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 solution of ordinary differential equations.

Math 151. APPLIED MATHEMATICS I. 3 *credits, 1st sem.* Dr. ZATZKIS.

Prerequisites: Elementary differential equations, vector analysis, and introductory physics. Advanced mathematical methods useful in the analysis of engineering problems are considered. The course covers selected topics from the following: infinite series, improper integrals, eliptic integrals, Gamma functions, Beta functions, Fourier series, Fourier integrals, Laplace transforms and related integral transforms, partial differentiation, Green's and Gauss' integral theorems, and matrices.

Math 190. INTRODUCTION TO COMPUTING SCIENCE. 3 *credits, 1st or 2nd sem.* College Faculty.

Prerequisites: Differential and integral calculus. This course is designed for engineers and scientists who have had little or no experience with digital computers. The course considers man-machine communication and emphasizes the reduction of engineering calculations to systematic numerical procedures suitable for computer programming. Machine-language programming is briefly considered and a problem-oriented language is extensively employed. *Formerly* ESc 110.

Math 220. MATRIX THEORY. 3 *credits, 1st or 2nd sem.* Dr. 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 222. ADVANCED NUMERICAL ANALYSIS. 3 *credits, 2nd sem.* Dr. FOX.

Prerequisites: Differential and integral calculus and some matrix theory (or elementary linear algebra). Topics include numerical solution of linear systems, iterative solutions of non-linear equations, approximation theory, calculation of eigenvalues and eigenvectors, and difference methods for partial differential equations.

Math 224. Introduction to Abstract Algebra. 3 *credits, 2nd sem.*

Prerequisites: Differential and integral calculus and permission of the department. This course provides a working knowledge of the basic concepts of abstract algebra. The material introduced will provide an adequate mathematical background for related work in physics and engineering. Specific topics include set theory, rings and ideals, vector spaces, and group theory.

Math 252. Applied Mathematics II. 3 *credits, 2nd sem.* Dr. Zatzkis.

Prerequisites: Math 151, 100 or their equivalents. A continuation of Math 151. Subject matter includes advanced topics in vector analysis, elements of tensor analysis, calculus of variations, integral equations, Green's function, and applications of conformal mapping to boundary value problems.

Math 256. Functions of a Complex Variable I. 3 *credits, 1st* or *2nd sem.* Dr. Foster and Prof. 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.*

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 Mathematics. 3 *credits, 1st sem.* Mr. Voronka.

Prerequisites: Undergraduate ordinary differential equations and Math 256 or equivalent. This course considers applications of operational mathematics to problems in engineering and physics. Boundary value problems in partial differential equations, as well as problems in vibrating mechanical systems, electrical circuits, involving systems of ordinary differential equations are solved using operational techniques. A rigorous development of Laplace transform theory is given. The complex inversion formula and residue theorems are used in solving the inverse problem.

Math 261. Mathematical Statistics. 3 *credits, 1st sem.* Profs. 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.* Prof. Barkan.

Prerequisites: Differential and integral calculus. This course considers inferences about populations based on samples, design of experiments, elementary decision theory, and minimax principle.

Math 273. Differential Equations I. 3 *credits, 1st* or *2nd sem.* Dr. Koren and Prof. Konove.

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

Math 274. DIFFERENTIAL EQUATIONS II. 3 *credits, 1st* or *2nd sem.* Dr. KOREN.

Prerequisite: Math 273 or equivalent. A companion course to Math 273, 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 290. COMPUTER PROGRAMMING LANGUAGE. 3 *credits, 1st sem.* Dr. FOX.

Prerequisite: Math 190 or equivalent programming knowledge. This course includes principles of writing and using various types of computer programming systems; planning of compiler and monitor structure and syntax; techniques of writing compilers; discussion of current computer languages; and use of the computer and appropriate languages for simulation of systems from various fields of engineering. The course development leads from basic machine coding and its symbolic representation through various problem-oriented languages to particular applications of the programming techniques.

Math 291. LOGIC, AUTOMATA, AND COMPUTERS. 3 *credits, 2nd sem.*

Prerequisite: Math 190 or equivalent. Theory of representing effective processes is presented in a way that clarifies the relation between classical logical systems and processes described by computer programs (Metalanguages); discussion of axiomatics and proof procedures from the propositional calculus; theory of computability including decidability procedures, algorithms, and unsolvability; automata theory, turing machines, representability of events, and synchronous-sequential circuits. The course emphasizes computing theory rather than computer programming.

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

Prerequisites: Strength of materials, and Math 100, 220 and 274 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 supplements formal course procedures.

Math 346. INTRODUCTION TO MATHEMATICAL ANALYSIS. 3 *credits, 1st sem.*

Prerequisites: Differential and integral calculus. This course provides the student with a rigorous foundation in mathematical analysis. Topics include a thorough investigation of the real number system, set theory, sequences, differentiation, and a general approach to modern integration theory through the Stieltjes and Lebesgue integrals.

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

Math 374. ADVANCED ORDINARY DIFFERENTIAL EQUATIONS. 3 *credits, 1st sem.* Dr. RAUSEN.

Prerequisite: Math 273 or equivalent. A continuation of Math 273, dealing with the general theory of ordinary differential equations and systems (existence, uniqueness of solutions) and applications to selected advanced topics such as asymptotic solutions, stability theory, and second order boundary value problems.

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. 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. Tuition fee: $24.00 per credit. If the use of laboratory facilities or equipment is necessary, a $25.00 deposit must be maintained.

DEPARTMENT OF PHYSICS AND MECHANICS

COURSES OF INSTRUCTION

Mech 109. ADVANCED STRENGTH OF MATERIALS. 3 *credits, 1st sem.* Prof. RAMBERG.

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.

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

Mech 213. DYNAMICS OF A RIGID BODY. 3 *credits, 2nd sem.* Prof. KUHARETZ.

Prerequisite: Undergraduate analytical or engineering mechanics. The kinematics and kinetics of rigid bodies, Euler equations of motion, inertia tensor, principal axes, transformation theory, Euler's angles, gyroscopic motion, and the symmetric top are covered.

Offered 1967-68 and alternate years.

Mech 252. THEORY OF PLATES AND SHELLS. 3 *credits, 1st sem.* Prof. CIESLA.

Prerequisites: Math 100 or equivalent, and theory of deformable bodies. A study of the differential equations governing the stresses and deformation of plates and shells, strain energy methods, shells with and without bending, and the general theory of cylindrical shells with axially symmetric loads.

Offered 1968-69 and alternate years.

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

Prerequisite: Math 100 or equivalent. 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 1969-70 and alternate years.

Mech 260. CELESTIAL MECHANICS. 3 *credits, 1st sem.* Mr. 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.

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

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 1968-69 and alternate years.

Phys 102. History of the Physical Sciences. 3 *credits, 2nd sem.* Dr. Sagurton.

An outline of the development of science and technology from prehistory to the present. The roles of science and technology in history, their contribution to the evolution of human institutions, and their impact on philosophical inquiry are examined, analyzed, and applied to develop an historical perspective towards a more comprehensive understanding of their meaning and function in the structure of contemporary civilization.

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

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

Phys 123. Radioisotopes Laboratory. 3 *credits, 2nd sem.* Prof. Fitzgerald.

Prerequisite: Modern physics. A series of experiments designed to acquaint the student with the theory and application of radioisotopes. These experiments will afford a study of the instrumentation and nuclear processes involved in this field. Some neutron experiments are included. Area surveying and decontamination methods will be carried out stressing the requirements of radiological safety. Experiments chosen will emphasize the application of physics to this field.

Laboratory fee: $25.00.
Offered 1967-68 and alternate years.

Phys 210. Theoretical Physics. 3 *credits, 1st or 2nd sem.* Dr. 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.* Prof. 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.* Prof. 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 214. Solid State Physics. 3 *credits, 2nd sem.* Prof. 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 1968-69 and alternate years.

Phys 221. NUCLEAR PHYSICS. 3 *credits, 1st sem.* Dr. 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 1967-68 and alternate years.

Phys 222. ELEMENTS OF NUCLEAR ENGINEERING. 3 *credits, 2nd sem.* Mr. 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 1968-69 and alternate years.

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

Prerequisite: Course in nuclear engineering. Corequisite: Phys 222. 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 1969-70 and alternate years.

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

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 310. MICROELECTRIC PHYSICS. 3 *credits, 1st sem.* Prof. RUSSO.

Prerequisite: Phys 211. For the electrical engineer or the applied physicist, this course discusses the basic device theory necessary for the design of integrated circuits. It deals with semiconductor surface physics, conduction through insulating layers and thin film transistors. Emphasis is placed on field effect concepts and the basic monolithic structures. Also considered are the effects of geometry, temperature, and parasitics on both passive and active elements. Practical considerations consisting of the DC and switching characteristics on integrated elements are discussed. The course gives an insight into the technology of integrated circuits so essential for space vehicles and digital computers.

Offered 1968-69 and alternate years.

Phys 330. THEORY OF METALS. 3 *credits, 1st sem.* Dr. 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 1967-68 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. 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. Tuition fee: $24.00 per credit. If the use of laboratory facilities or equipment is necessary, a $25.00 deposit must be maintained.

DEPARTMENT OF ENGLISH AND HUMANISTIC STUDIES

COURSES OF INSTRUCTION

Hu 80. Foreign Language for Engineers. *No credit, 1st or 2nd sem.*

A course directed towards the reading of scientific and technical literature in the original languages. The language offered in any year will depend on student requests and registration. Either German, French, or Russian will be considered. Where necessary and on sufficient registration, two sections will be offered, one for those with some knowledge of the language, another for beginners.

Hu 200. Technical Publication and Editing. *3 credits, 1st sem.* Dr. Estrin.

A seminar dealing with the production and editing of technical writing on the professional level and with problems of publication from both the writer's and the editor's point of view. Students will be assisted individually with their writing—either work already in progress or new work. Students from any department of the Graduate Division will be accepted after consultation with the instructor.

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, engineering and teaching ethics, professional advancement, student research.

IN-SERVICE INSTITUTES FOR HIGH SCHOOL TEACHERS

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

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

G 103. CHEMISTRY INSTITUTE. 6 *credits per year,* 1*st* and 2*nd sem.* Prof. BRADLEY.

Designed to familiarize the participants with some of the newer concepts that have evolved, or have been increasingly emphasized, during recent years, the course stresses the interrelationship of chemistry with physics, astronomy, and biology and emphasize the value of mathematical calculations in physics and chemistry. Attention is given to the texts of the Chemical Bond Approach Committee and other programs in chemical education.

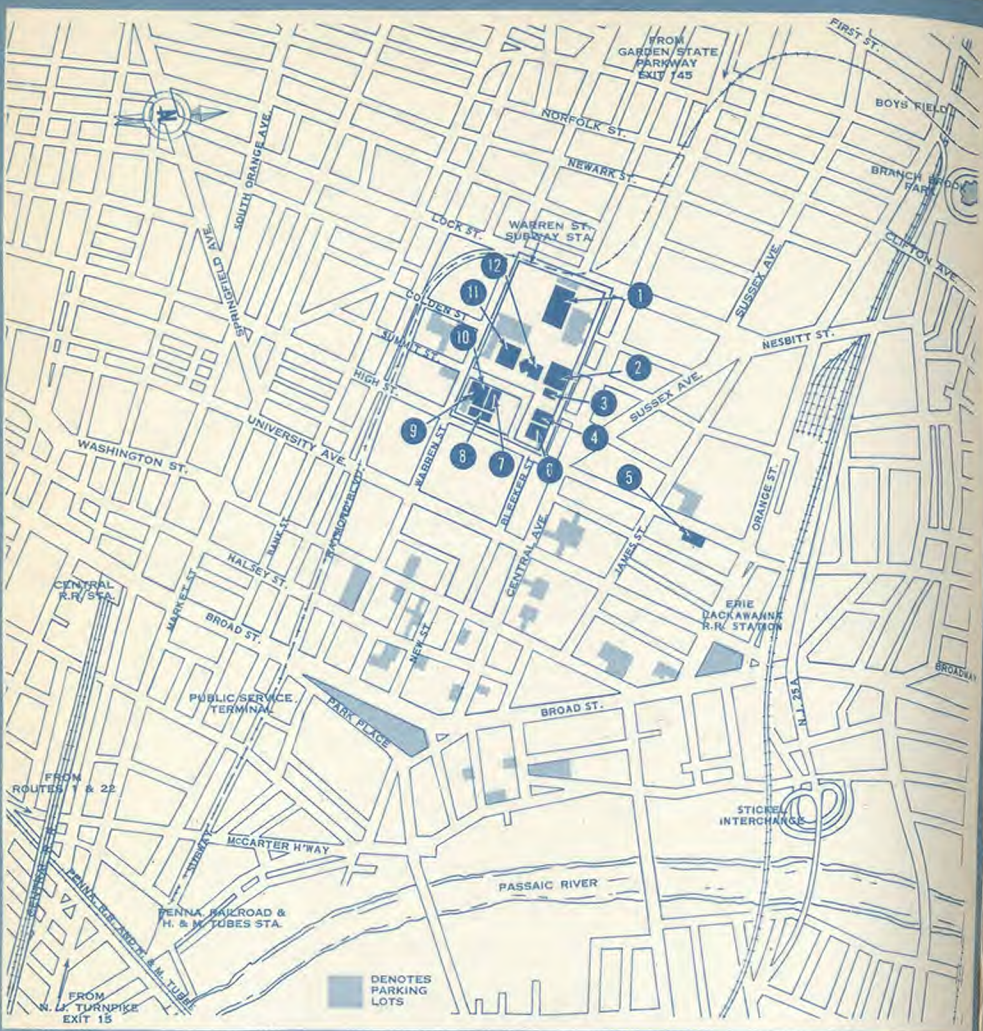
G 104. PHYSICAL SCIENCE STUDY COMMITTEE. 6 *credits per year,* 1*st* and 2*nd sem.* DR. CAPECELATRO.

Designed to stress fundamental principles, the course uses technology to illustrate such principles. It is also designed to train the student to think in physical terms rather than memorize textbook formulas. Selection of topics, development of physical principles, use of the laboratory, and pedagogical methods differ markedly from conventional practices. Class meetings will include a study of printed materials, films, use of laboratory materials, and the philosophy of the Physical Science Study Committee approach to the study of high school physics.

G 108. MATHEMATICS IN PHYSICS. 6 *credits per year,* 1*st* and 2*nd sem.* DR. HOFFMANN.

Designed to present the fundamental principles of physics in mathematical form to indicate the power, elegance, and conciseness of solving physical problems with the proper mathematical techniques, the course stresses the following topics: Newtonian mechanics, the special theory of relativity, principles of electricity and magnetism, Maxwell's equation, modern physics, and a brief introduction to quantum mechanics.

INDEX



1 ENTWISLE PHYSICAL EDUCATION BUILDING — 80 LOCK STREET

2 THE CENTER — 150 BLEEKER STREET

3 ALUMNI CENTER FOR CONTINUING ENGINEERING STUDIES — 150 BLEEKER STREET

4 CULLIMORE HALL — 70 SUMMIT STREET

5 TIERNAN HALL — 240 HIGH STREET

6 EBERHARDT HALL — 323 HIGH STREET

7 CAMPBELL HALL — 110 SUMMIT STREET

8 WESTON HALL — 367 HIGH STREET

9 SPECHT MAINTENANCE BUILDING — 120 SUMMIT STREET

10 COLTON HALL — SUMMIT PLACE

11 FACULTY MEMORIAL HALL — 111 SUMMIT STREET

12 LIBRARY-HUMANITIES BUILDING — 99 SUMMIT STREET