Polytechnic
UNIVERSITY

CATALOG
1988 — 1990

Brooklyn: 333 Jay Street, Brooklyn, N.Y. 11201   718/260-3600
Long Island: Route 110, Farmingdale, N.Y. 11735   516/755-4400
Westchester: 36 Saw Mill River Road, Hawthorne, N.Y. 10532   914/347-6940

GENERAL INFORMATION

The **Polytechnic University Catalog** is an official publication of the University and is intended to provide a helpful summary of college policies and procedures, and selected activities and services. The catalog provides information about academic programs to students and prospective students as well as to the faculty and staff of Polytechnic. Information concerning admissions, academic regulations and requirements, student services, academic offerings and a list of the administrative officers and faculty are included. Every effort has been made to publish a catalog that is as complete and as accurate as possible, but requirements, deadlines, fees, curricula, courses and staffing are subject to change at any time, without advance notice or obligation.

This catalog was prepared well in advance of its effective date; therefore some course descriptions may vary from actual course content due to advancements in discipline, interests of individual professors or decisions to change the scope of a course. Supplements to this catalog in the form of schedules of classes are issued for each semester and for summer sessions. Those schedules include updated information about course offerings, fees, registration and academic procedures.

Westchester Campus

Brooklyn Campus

Long Island Campus

CONTENTS

ACADEMIC CALENDAR
1988-1989

FALL
Wednesday, Thursday, August 31. September 1, 1988 — Registration
Wednesday, September 7, 1988 — CLASSES BEGIN
Monday, September 12, 1988 — No classes (Rosh Hashanah)
Tuesday, September 20, 1988 — No evening classes after 6 pm.
Wednesday, September 21, 1988 — No classes (Yom Kippur)
Thursday, Friday, November 24, 25 — Thanksgiving recess
Tuesday, December 13, 1988 — Evening classes only meet. CLASSES END
Wednesday, December 14, 1988 — Reading Day
Thursday, December 15 — Friday, December 23, 1988 Final Exams.

RECESS
Monday, December 26 — Friday, December 30, 1988

INTERSESSION
Monday, January 2 — Friday, January 20, 1989

SPRING
Monday, Tuesday, Wednesday, January 23, 24, 25, 1989 — Registration
Monday, January 30, 1989 — CLASSES BEGIN
Monday, April 17 — Friday, April 21, 1989 — Spring Recess
Friday, May 5, 1989 — CLASSES END
Monday, Tuesday, May 8, 9, 1989 — Reading Days
Wednesday, May 10 — Thursday, May 18 — Final Exams
Commencement: To be announced

INTERSESSION
Friday, May 19 — Tuesday, May 30, 1989

SUMMER
Wednesday, Thursday, May 31, June 1, 1989 — Registration
Monday, June 5, 1989 — CLASSES BEGIN
Tuesday, July 4, 1989 — No classes
Monday, July 17, 1989 — Tuesday classes meet
Monday, August 28, 1989 — CLASSES END

1989-1990

FALL
Tuesday, Aug. 29 — Friday. Sept. 1, 1989 — Registration
Monday, September 4, 1989 — Labor Day
Thursday, September 7, 1989 — CLASSES BEGIN
Monday, October 9, 1989 — No classes (Yom Kippur)
Thursday, Friday, Nov. 23, 24, 1989 — No classes (Thanksgiving Recess)
Monday, December 11, 1989 — CLASSES END
Tuesday, Wednesday, Dec. 12, 13, 1989 — Reading and Make-up days
Thursday, Dec. 14 — Friday. Dec. 22, 1989 — Final Exams

RECESS
Monday, December 25, 1989 — Monday, January 1, 1990

INTERSESSION
Tuesday, Jan. 2 — Monday, Jan. 15, 1990 — Intersession

SPRING
Tuesday, Jan. 16 — Friday, Jan. 19, 1990 — Registration
Tuesday, January 23, 1990 — CLASSES BEGIN
Monday, April 9 — Friday, April 13, 1990 — Spring Recess
Monday, April 30, 1990 — CLASSES END
Tuesday, Wednesday, May 1, 2, 1990 — Reading and Make-up days
Thursday, May 3 — Friday, May 11, 1990 — Final Exams

INTERSESSION
Monday, May 14, 1990 — Friday, May 25, 1990 — Intersession

SUMMER
Monday, Tuesday, May 28, 29, 1990 — Registration
Thursday, May 31, 1990 — CLASSES BEGIN
Wednesday, July 4, 1990 — No Classes (Independence Day)
Friday, July 6, 1990 — Make-up day for July 4, 1990
Wednesday, August 22, 1990 — CLASSES END

1990-1991

FALL
Tuesday, Aug. 28 — Friday, Aug. 31, 1990 — Registration
Monday, September 3, 1990 — Labor Day
Thursday, September 6, 1990 — CLASSES BEGIN
Wednesday, September 19, 1990 — No Classes after 4:00 PM
Thursday, September 20, 1990 — No Classes (Rosh Hashana)
Thursday, Friday, Nov. 20, 21, 1990 — No Classes (Thanksgiving Recess)
Tuesday, December 11, 1990 — Wednesday evening classes (Make-up)
Tuesday, December 11, 1990 — CLASSES END
Wednesday, December 12, 1990 — Reeding and Make-up Day
Thursday, Dec. 13 — Friday, Dec. 21, 1990 — Final Exams

RECESS
Monday, December 24, 1990 — Tuesday, January 1, 1991

INTERSESSION
Wednesday, Jan. 2 — Tuesday, Jan. 15, 1991 — Intersession

SPRING
Wednesday, Jan. 16. — Friday, Jan. 18, and Monday, Jan. 21, 1991 — Registration
Wednesday, January 23, 1991 — CLASSES BEGIN
Friday, March 29 — Friday, April 5, 1991 — Spring Recess
Wednesday, May 1, 1991 — Friday classes meet; CLASSES END
Thursday, Friday. May 2, 3, 1991 — Reading and Make-up days
Monday, May 6 — Tuesday. May 14, 1991 — Final Exams

INTERSESSION
Wednesday, May 15, 1991 — Tuesday. May 28, 1991 — Intersession

SUMMER
Tuesday, Wednesday, May 28, 29, 1991 — Registration
Monday, June 4, 1991 — CLASSES BEGIN
Thursday, July 4, 1991 — No Classes (Independence Day)
Friday, July 5, 1991 — Make-up day for July 4, 1991
Friday, August 23, 1991 — CLASSES END

1991-1992

FALL
Tuesday, Aug. 27 — Friday, Aug. 30, 1991 — Registration
Monday, September 2, 1991 — Labor Day
Wednesday, September 4, 1991 — CLASSES BEGIN
Monday, September 9, 1991 — No Classes (Rosh Hashana)
Tuesday, September 17, 1991 — No Classes after 4:00 PM
Wednesday, September 18, 1991 — No Classes (Yom Kippur)
Thursday, Friday, Nov. 28, 29, 1991 — No Classes (Thanksgiving Recess)
Tuesday, December 10, 1991 — Wednesday evening classes (Make-up)
Tuesday, December 10, 1991 — CLASSES END
Wednesday, December 11, 1991 — Reading Day
Thursday, Dec. 12 — Friday, Dec. 20, 1991 — Final Exams

RECESS
Wednesday, Dec. 25, 1991 — Wednesday, January 1, 1992

INTERSESSION
Thursday, Jan. 2 — Wednesday, Jan. 15, 1992 — Intersession

SPRING
Thurs., Fri., Jan. 16, 17; Mon., Tues., Jan. 20, 21, 1992 — Registration
Thursday, January 23, 1992 — CLASSES BEGIN
Friday, April 17 — Friday, April 24, 1992 — Spring Recess
Thursday, April 30, 1992 — Friday classes meet; CLASSES END
Friday, Monday, May 1, 4, 1992 — Reading and Make-up days
Tuesday, May 5, — Wednesday, May 13, 1992 — Final Exams

INTERSESSION
Thursday, May 14, 1992 — Wednesday, May 27, 1992 — Intersession

SUMMER
Thursday, Friday, May 28, 29, 1992 — Registration
Tuesday, June 2, 1992 — CLASSES BEGIN
Monday, August 24, 1992 — CLASSES END

1992-1993

FALL
Thurs., Fri., Mon., Tues., Aug. 27, 28, 31. Sept. 1, 1992 — Registration
Thursday, September 3, 1992 — CLASSES BEGIN
Monday, September 7, 1992 — No Classes (Labor Day)
Monday, September 28, 1992 — No Classes (Rosh Hashana)
Tuesday, October 6, 1992 — No Classes after 4:00 PM
Wednesday, October 7, 1992 — No Classes (Yom Kippur)
Thursday, Friday, Nov. 26, 27, 1992 — No Classes (Thanksgiving Recess)
Tuesday, December 8, 1992 — Tuesday evening classes (Make-up)
Thursday, December 10, 1992 — Monday classes meet (Make-up)
Thursday, December 10, 1992 — CLASSES END
Friday, December 11, 1992 — Reading day
Monday, December 14 — Tuesday, December 22, 1992 — Final Exams

RECESS
Friday, December 25, 1992 — Friday, January 1, 1993

INTERSESSION
Monday, Jan. 4, 1993 — Friday, Jan. 15. 1993 — Intersession/Mini Session

SPRING
Monday, January 18 — Thursday, January 21, 1993 — Registration
Monday, January 25, 1993 — CLASSES BEGIN
Monday, April 4 — Friday, April 9, 1993 — Spring Recess
Friday, April 30, 1993 — CLASSES END
Monday, Tuesday, May 3, 4, 1993 — Reading and Make-up days
Wednesday, May 5 — Thursday, May 13. 1993 — Final Exams

INTERSESSION
Friday, May 14 — Thursday, May 27, 1993 — Intersession

SUMMER
Friday, Monday, May 28, 31, 1993 — Registration
Wednesday, June 2, 1993 — CLASSES BEGIN
Monday, July 5, 1993 — No Classes
Friday, July 9, 1993 — Monday classes meet (Make-up)
Tuesday, August 24, 1993 — CLASSES END

POLYTECHNIC UNIVERSITY

Polytechnic University is the leading technological institution in the New York metropolitan region. Its mission is to provide graduate and undergraduate education and to conduct research in basic scientific theory and applications of technology, management of technology, and relationships between social institutions and technology.

Polytechnic is a coeducational, independent university, accredited by the Middle States Association. Undergraduate programs in aerospace, chemical, civil, electrical, industrial, mechanical, and metallurgical engineering are accredited by the Accreditation Board for Engineering and Technology, and the undergraduate chemistry program is approved by the American Chemical Society.

The student body includes over 2,000 undergraduate students and 2,600 graduate students. Graduate engineering enrollment is among the largest in the nation, and Polytechnic grants more engineering graduate degrees than all but a handful of other universities. Most students live in the New York metropolitan region, but students also come from throughout the country and the world to attend school here. About 13% of Polytechnic's students are women.

Polytechnic's presence is felt throughout the region. Its largest campus is located in New York City, in downtown Brooklyn, across the Brooklyn Bridge from Manhattan's financial district. This campus offers all courses of study at all degree levels, and is the site of major research facilities and projects. A second campus, located in Farmingdale, Long Island, offers most undergraduate programs and selected graduate programs particularly relevant to the aerospace, computer, and electronics industries clustered on Long Island. The University's renowned Weber Research Institute, is located at this campus. A Graduate Center in Hawthorne, Westchester County, offers graduate programs in electrical engineering, computer science, management, and other disciplines.

History

The roots of Polytechnic University reach back to 1854. In that year Brooklyn Collegiate and Polytechnic Institute received its charter from the New York State Board of Regents, and New York University established its School of Civil Engineering and Architecture.

In 1869 the Board of Regents authorized Polytechnic's collegiate department to confer bachelor of science and bachelor of arts degrees; the first were awarded in 1871. Polytechnic Institute of Brooklyn, the name given to the school in 1889, offered master of science degrees as early as 1901. The graduate program was extended to the evening session in the 1920's; the first Ph.D. degrees were given in 1935. Engineer degrees have been awarded since 1970.

In 1961 the Long Island Campus was opened in Farmingdale as a graduate and research center, and was expanded in 1974 to include undergraduate programs.

In 1973 New York University's School of Engineering and Science merged into Polytechnic Institute of Brooklyn. The expanded institution was renamed Polytechnic Institute of New York, and Dr. George Bugliarello was appointed its new president. Under his leadership, Polytechnic has continued to develop.

- New relationships, encompassing research and education, have been developed with major technological corporations throughout the region.
- New research centers have been established in imaging sciences, telecommunications, and philosophy of technology, joining those in polymers, transportation, and electrophysics.
- The world renowned Microwave Research Institute was renamed the Weber Research Institute, in honor of its founder and former president of Polytechnic, Dr. Ernst Weber.
- In 1975 the Westchester Graduate Center opened, and in 1987 the Center moved to larger and better facilities.

In 1985, by action of the New York State Board of Regents, the Institute was renamed Polytechnic University.

Educational Programs

Innovation and breadth of opportunity are the hallmarks of the Polytechnic educational experience. Educational programs can be taken on a full-time or part-time basis, in day or evening courses, and in summer sessions as well as fall and spring semesters. New programs of study are developed and traditional ones are updated to keep pace with technological change and to broaden areas related to science and technology.

Undergraduate
At the undergraduate level, science and engineering students receive thorough training in chemistry, physics, and mathematics, as the basis for more advanced specialized work. Students also take one sixth of their total course work in the social sciences, economics, history, and humanities, choosing from a wide variety of elective offerings. Undergraduates can take degrees in 17 different fields in liberal arts, science, engineering, and management.

Polytechnic programs extend beyond engineering and science – of particular note are undergraduate degree programs in humanities, journalism and technical writing, the social sciences and information management. These programs and the Liberal Arts Core Curriculum provide students with an opportunity to combine a major in the liberal arts with a wide range of science and engineering courses — a superb background for nontechnical careers in an increasingly technological society.

Graduate
Programs at the graduate level are designed to meet a variety of student needs. Programs leading to a master of science degree are available in 37 fields; engineer degrees are available in 10 fields; Ph.D. degrees are available in 22 fields. Specialized graduate certificate programs are also available for professional advancement.

The Master of Science programs are oriented toward professional career development. M.S. programs are given in engineering disciplines and in physics, chemistry, and math. In addition, M.S. degrees are offered in transportation management, specialized journalism, polymer science and engineering, telecommunications management, industrial chemistry, history of science, environmental health science, manufacturing engineering of electronic materials, imaging sciences, and information systems engineering. Some of these programs have been recently developed to meet emerging needs: telecommunications management and imaging sciences are examples of pioneering education at Polytechnic.

Other masters' programs, such as management of organizational behavior, approach traditional areas of study from a technological perspective – management of manufacturing, telecommunications, or information. These programs are particularly suited to students with an undergraduate engineering background who are preparing to assume management positions in high-tech companies.

The Ph.D. programs focus on developing independent research skills, and are closely intertwined with research programs at Polytechnic. The electrical engineering graduate program is recognized as one of the elite in the country. The chemistry department has national prominence in the field of polymers and polymer synthesis.

Research Programs

Polytechnic has a number of specialized research centers which apply expertise in many disciplines to fundamental technological challenges. The oldest such centers are the Weber Research Institute – exploring electromagnetics and wave propagation, condensed matter, and plasma theory; and the Polymer Research Institute – a leading center for synthesis, characterization, processing, and applications of polymers. Others have been created more recently: the Institute of Imaging Sciences, the New York State Center for Advanced Technology in Telecommunications Management, the Materials Research Group, and the Philosophy and Technology Studies Center.

In addition to interdisciplinary research centers, individual and collaborative programs of research continue. Among the fastest growing programs are those in chemical engineering, metallurgy/materials science, chemistry, and physics.

Faculty

The Polytechnic faculty, numbering over 200, is committed to teaching and research. The faculty originates, organizes and approves all curricula taught at the University and also establishes academic standards for student achievement. Most advanced undergraduate courses are taught by tenured professors. Faculty members act as student advisers and meet with students in lectures, seminars, laboratories and recitations. There are few large lecture courses at Polytechnic.

Undergraduate students have opportunities to work closely with senior research and teaching faculty.

Many faculty members have written undergraduate and graduate textbooks used throughout the United States. Many have received wide recognition for professional and

research activities. Recent awards to Polytechnic faculty include:
- **Ernst Weber,** President Emeritus, National Medal of Science
- **Athanasios Papoulis,** Professor of Electrical Engineering, Humbolt Award; IEEE Education medal, in national recognition for his contributions to education and teaching
- **Nathan Marcuvitz,** Professor Emeritus of Electrical Engineering, IEEE Microwave Career Award
- **Erich Kunhardt,** Professor of Electrical Engineering, Halliburton Excellence in Research Award
- **Herbert Morawetz,** Professor of Chemistry, American Chemical Society Award in Polymer Chemistry.

Polytechnic's faculty members have been among the founders of the National Academy of Engineering, the Institute of Electrical and Electronics Engineers, the American Institute of Chemical Engineers, and the American Society of Engineering Education.

Alumni

The Polytechnic Alumni Association is dedicated to the advancement of the University. The Association fosters fellowship and sponsors activities for alumni and students. These activities include continuing education, professional job placement, and new student recruitment.

For students, the Alumni Association helps sponsor various social activities including the annual Freshman Orientation. Career symposia featuring prominent alumni speakers are held for all interested students. These symposia illustrate the breadth of career opportunities open to Polytechnic graduates.

Scholarships are provided annually by the Association for students outstanding in student leadership and athletics. Special awards are presented to the student who is most proficient in each Polytechnic sport, in military service and in student government.

The Alumni Association has established a student group within its structure. This all-student committee works closely and meets regularly with the Association's Board of Directors to promote collaboration between alumni and students, to develop programs whereby student/alumni mutual interests may be more fully realized, and to acquaint students with benefits to be derived by their later participation as alumni in the Association's services and programs.

Periodically, the Alumni Association Office, located at Polytechnic, publishes a roster showing the location and occupation of all known alumni. Cable, the Association's newspaper, is published four times yearly to provide alumni with recent information concerning the activities of the Association and Polytechnic.

Alumni residing outside the New York City area have formed Poly Groups, providing opportunities for informal gatherings. Whenever they meet, they represent Polytechnic to the community.

The services of the Association are available to all through the Alumni Office and its director. Membership in the Association is automatic upon graduation, with classes represented on the Board of Directors through their elected representatives.

CAMPUSES AND FACILITIES

THE CAMPUSES

Brooklyn Campus

Polytechnic's Brooklyn campus is located at 333 Jay Street in downtown Brooklyn. This area is at a junction of public transportation lines and is accessible from all parts of New York City, Long Island, New Jersey and Connecticut.

Because of Polytechnic's central location, its students have at their disposal the vast cultural, political and technological assets of the metropolis. In effect, Greater New York is Polytechnic's campus.

Rogers Hall, named after Harry Stanley Rogers, Polytechnic's fifth president, is the main building. It houses faculty and administrative offices, classrooms, laboratories, the main library as well as the offices of the academic Deans and the Dean of Students.

The Administration Building, contains administrative and faculty offices, the Admissions, Bursar's and Registrar's Offices and the Office of Research and Graduate Studies.

William H. Nichols Hall, Johnson and Bridge Streets, houses the Career Services Office, research facilities, laboratories, offices and classrooms.

The Student Center, located at 311 Bridge Street, houses a cafeteria, lounges, a video game room, a 6-foot T.V. screen, and student offices, and is the focal point for student co-curricular activities. The building is open Monday through Friday; facilities are available to student groups at other times by reservation. Also in the Student Center are the Polytechnic yearbook, newspaper and student government offices. During the regular academic year, the Center is open from 9:00 AM to 7:00 PM Monday through Thursday, from 9:00 AM to 6:00 PM on Friday. Cafeteria hours are from 9:00 AM to 4:30 PM, Monday through Thursday and 9:00 AM to 2:00 PM on Friday.

Long Island Campus

The Long Island campus, on Route 110 in Farmingdale, was opened in the fall of 1961 for graduate study and research to fulfill the educational needs of Nassau and Suffolk Counties. In 1974 the Long Island campus was opened to undergraduates. There is a current enrollment of approximately 550 undergraduates with a wide range of student clubs and activities; there are also approximately 650 part-time graduate students. Located on 25 acres of land a half-mile east of the Nassau-Suffolk border, the campus is bordered by Republic Airport and is situtated near scores of major Long Island high technology industries.

The Main Administration Building contains classrooms, a cafeteria, an auditorium, conference and meeting rooms, a student lounge, faculty and administration offices and research laboratories. Areas of research include electro-magnetics; wave propagation; space-science radiophysics; quantum electronics; modern optics; laser techniques; high-frequency solid-state phenomena and devices; micro-waves; antennas; and ultrasonics. The science-engineering library has 35,000 volumes of periodicals and reference works specifically selected to support the courses and research conducted at the campus.

The Preston R. Bassett Research Laboratory contains offices and laboratories of the Weber Research Institute for research in plasma physics, electromagnetic propagation and antennas, pulse power, acoustics, gaseous electronics, solid state materials, quantum electronics, electric power engineering, automatic control and networks, and ultrahigh power microwaves, as well as teaching laboratories.

Grumman Hall, the student center, houses a lounge, a game room, a bookstore, the student organization offices the Career Services Office, the Residence Life Office, and the Office of the Associate Dean of Students. During the regular academic year, it is open from 8:00 am to 8:00 pm Monday through Thursday and 8:00 am to 5:00 pm on Friday. The cafeteria — in the main building — is open the same hours.

The Student Residence Hall, an apartment-style dormitory with kitchen facilities for single students, accommodates 50 undergraduate and graduate students.

The Athletic Facility is the newest addition to the Long Island campus.

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Westchester Graduate Center

Scientists, engineers and managers employed at high technology companies in the Lower Hudson Valley and Southern Connecticut turn to the Westchester Graduate Center to fulfill their educational needs through participation in part-time graduate degree programs and specialized courses for continuing education.

Classes at the Center in Hawthorne are held during late afternoons, evenings and on Saturdays, times most convenient for working professionals.

Educational offerings include courses in computer science, electrical engineering, materials science, metallurgical engineering, chemistry, management, and telecommunications management, and information systems engineering.

The Westchester Graduate Center is located at 36 Saw Mill River Road in Westchester, near major highways and particularly convenient for students not only from Westchester County but also from Southern Connecticut, Rockland county, and Northeastern New Jersey.

This modern facility contains classrooms, administrative offices, the Richard Laster Library, a computer terminal room and a personal computer laboratory.

POLYTECHNIC UNIVERSITY
Campus Locations

Brooklyn Campus
333 Jay Street
Brooklyn, New York 11201
(718) 260-3600

Long Island Campus
Route 110, Farmingdale, NY 11735
(516) 755-4300

Westchester Center
36 Saw Mill River Rd.
Hawthorne, NY 10532
(914) 347-6940

FACILITIES

LIBRARIES

The goal of the Libraries is to satisfy the recorded information and document needs of the students, faculty, researchers, and administration supporting the undergraduate, graduate, and research programs.

Services

Highly skilled librarians and information specialists offer the following:

1. Circulation of a book collection of over 100,000 volumes and a large Course Reserve Collection.

2. Reference assistance to locate the book, article, or information in Polytechnic which meets users needs.

3. InfoDash locates and retrieves journal articles requested from the Polytechnic Library or any of the major New York metropolitan area libraries.

4. Interlibrary Loan locates and retrieves books through a powerful international computer system (OCLC, with about 3000 libraries), and with other cooperatives such as the Academic Libraries of Brooklyn, the New York Metropolitan Reference and Research Library Agency, and the Long Island Library Resources Council.

5. Database Searching assists users, at cost, to do a detailed author, title, or subject search in virtually any area of interest from over 250 computer databases; prepares a printout of the journal, serial, and conference proceeding citations; and, in some instances, even provides abstracts of relevant papers and articles.

6. CD-ROM searching assists users to do a detailed author, title, or subject search in such data bases as Applied Science and Technology Index, Business Periodical Index, Books in Print Plus, Dissertation Abstracts, McGraw-Hill Encyclopedia of Science and Technology, Magazine Index, Microsoft Bookshelf, Reader's Guide to Periodical Literature, and Ulrich's Serials List.

7. Other services include library orientation; requested classroom instruction; the maintenance of about 1200 journal subscriptions; an excellent collection of encyclopedias, almanacs, indexes and abstracts, biographical dictionaries, and other reference material.

The Brooklyn Library — This library has three public service sections: the Circulation Department, located on the first floor of Rogers Hall; the Reference Department, and the InfoDash Department, both located on the second floor of the Administration building (accessible from the stairs on the first floor of Rogers Hall). This library is the center of Polytechnic's library system, containing one of the best collections of technical and scientific literature in the metroplitan area, as well as materials in the humanities, social sciences and management.

Reference Dept.

Monday to Thursday:	9:00 AM to 8:30 PM
Friday:	9:00 AM to 5:00 PM
Saturday:	1:00 PM to 5:00 PM

Circulation Dept.

Monday to Thursday:	8:00 AM to 8:30 PM
Friday:	8:00 AM to 5:00 PM
Saturday:	1:00 PM to 5:00 PM

Other Campuses and Programs

Long Island Campus — This library at Farmingdale offers the same full service but has a smaller local collection.

Monday to Thursday:	8:30 AM to 8:30 PM
Friday:	8:30 AM to 5:00 PM
Saturday:	10:00 AM to 2:00 PM

Westchester Graduate Center — Faculty and students can use the Richard Laster Library Lounge or call the Brooklyn Library for service.

NEW LIBRARY PLANS — Polytechnic University plans to break ground during the next fiscal year for a new 15 million

dollar library and information center which will access information electronically from resources throughout the nation and the world. This new prototype facility will enable users in homes, offices, classrooms, and laboratories as well as the libraries to locate and to retrieve information, books, journal articles, or documents.

COMPUTER CENTER

The Polytechnic Computer Center provides a wide range of equipment and services available to the entire University community — students, faculty, researchers, and administrative personnel.

Available equipment:
• A variety of Personal Computers (IBM, Texas Instruments, AT&T);
• Mini- and mainframe computers (IBM 4341s, DEC PDP 11/70, Gould PN6050, AT&T 3B2s);
• Graphics terminals and plotters (IBM 5080, IBM 3279, AT&T 5620 Bitmap Graphics terminals; Benson 22", HP plotters);
• Networking equipment (Ethernet, Proteon, state-of-the-art digital phone switch);
• and, of course, terminals at each campus to access the above equipment.

Available services:
• User services department to assist all users with computer related problems;
• Excellent response time and throughput;
• Seminars, classes and publications to familiarize users with available resources and allow new users to become computer-proficient more quickly.

Available software:
• Languages (APL, FORTRAN, Pascal, PL/I, SAS, SIMSCRIPT);
• Special purpose (graphics (CADAM, CATIA, CAEDS, CBDS, plus various packages on the PCs);
• Operating systems (IBM VM/CMS, IBM MVS, AT&T UNIX, plus many PC operating systems).

Ongoing projects and research include topics in imaging speech recognition, chemical modeling, and network simulation.

The Polytechnic Computer Center is heavily committed to maintaining facilities in anticipation of and response to changing user requirements.

RESEARCH CENTERS

CENTER FOR ADVANCED TECHNOLOGY IN TELECOMMUNICATIONS

The State of New York has designated Polytechnic as the host of the New York Center for Advanced Technology in Telecommunications (CATT). This designation recognizes Polytechnic's strong academic position in electrical engineering and computer science by providing funds for research and education in telecommunications.

Technological innovation is the sustaining force behind development of new industries, new jobs, and productivity improvements. To encourage the growth of technology based industries, New York State is implementing a

comprehensive strategy which relies on an active partnership among business, labor, government, and its educational institutions. A key component of this strategy is a closer collaboration between the State's industrial community and its major universities to promote technology transfer.

A number of research areas are active in the Center. Currently they are as follows:
Networks and Systems
Network Management
Devices and Propagation
Office Automation
Image Communications
Communications Software
Government Systems
Network Design

The Center also develops innovative educational programs to help users and providers of telecommunications services manage and innovate technological change and regulatory upheavals.

To this end, the Center has developed curricula combining special courses in telecommunications practices with electrical engineering, computer science, and management offerings. (Details of the graduate programs in telecommunications management and information systems engineering are listed separately.)

The laboratories and educational programs within the Center provide greater opportunity for students to learn about the academic disciplines related to telecommunications and computer science.

INSTITUTE OF IMAGING SCIENCES

Imaging Sciences are concerned with all aspects of information presented in visual form. The Institute of Imaging Sciences (IIS), founded in 1981 with a private gift of one million dollars, is involved in three major areas — image processing, optics and devices, and photoactive materials. The approach is strongly interdisciplinary, with participation from electrical engineering, computer science, chemistry and physics.

IIS conducts research and offers educational programs in these areas, in close cooperation with industry. Programs are guided by a Technical Advisory Committee of industrial representatives. In addition to conducting imaging research, and offering courses, IIS publishes a newsletter, *Imaging Quarterly*, and holds an annual research review.

POLYMER RESEARCH INSTITUTE

The Polymer Research Institute (PRI) was founded by Herman F. Mark soon after he joined Polytechnic in 1942. It has a commitment to interdisciplinary research and teaching which emphasizes an integrated approach to synthesis, characterization, structure, processing, properties, and applications of polymers.

Among its functions, PRI coordinates multidisciplinary polymer research; seeks opportunities and nurtures interactions for group and individual activities; supports short courses, seminars, and symposia; seeks expanded interaction with industry; works with research centers at Polytechnic and other universities; and encourages faculty interested in the development of PRI and its goals to be participating members.

This multidisciplinary program includes more than 20 faculty members from several departments and The Herman F. Mark Professor of Polymer Science, Otto Vogl. In addition, some research faculty are direct participants in the Institute. The Polymer Durability Center and a National Science Foundation sponsored Materials Group, are presently part of PRI. Research funding comes from many government agencies with a significant component from industry.

Former directors of PRI have included Herman F. Mark, Charles G. Overberger, Murray Goodman, and Herbert Morawetz. The present director is Eli M. Pearce.

As a result of the long tradition of research and teaching in polymer science and engineering, the Institute counts among its graduates a large number of both academic and industrial scientists and engineers active in polymers.

WEBER RESEARCH INSTITUTE

In 1985 the world renowned Microwave Research Institute (MRI) was renamed the Weber Research Institute in honor of Dr. Ernst Weber who in 1943 founded MRI and served as the first director.

In the early days of MRI, the research programs consisted primarily of projects involving electromagnetics and microwave engineering. At present, the research programs at the Weber Research Institute encompass a wide range of topics within the broad field of electronics, such as electromagnetic propagation and antennas, pulse power, acoustics, gaseous electronics, plasma physics, solid state materials, quantum electronics, electric power engineering, and automatic control and networks.

While the majority of faculty and students associated with the Weber Research Institute are in the Department of Electrical Engineering and Computer Science, there is also participation from the Physics, Chemistry, Mechanical and Aerospace Engineering Departments. The activities of the Research Institute have fostered specialized graduate degree programs in electrophysics and microwave engineering.

Weber Research Institute projects are supported by a variety of industrial organizations and government agencies. The Institute was among the five original academic research centers to begin receiving funding from the Joint Services Electronics Program (JSEP) in 1955. That support has continued to the present day where we are now among the select group of fourteen institutions funded by JSEP.

The enviable reputation of the Weber Research Institute rests on the research publications and textbooks produced by the faculty; the impressions carried away by the numerous visitors who have spent time working in its labs or attending its symposia and workshops; and the achievements of the students it has trained.

PHILOSOPHY & TECHNOLOGY STUDIES CENTER

The Philosophy & Technology Studies Center is a unique venture integrating the humanities, sciences, social sciences, engineering, and management. Established in 1984, the center promotes interdisciplinary research into the inner structure of technology; its relationships to science and art; ethical responsibilities and political problems arising from technological invention and design, innovation and production; aesthetic analyses of engineering processes and products; ergonomics of the workplace; and the cultural impact of technological development and transfer.

To serve its purpose, the Center is developing a special research collection and hosts an annual New York Colloquium on Philosophy and Technology. It also sponsors course development, visiting scholars, special projects and publications. Center Associates form an international, consultative, scholarly network.

Center associates have recently authored works on computer theory and practice, on the epistimology of technology, on ethics and technology, on energy policy, on technology transfer, and on engineering ethics. The Center has also received grant support from the Exxon Education Foundation, the J.M. Foundation, the MacArthur Foundation and the National Science Foundation.

TRANSPORTATION TRAINING AND RESEARCH CENTER

Polytechnic established the Transportation Training and Research Center (TTRC) in 1975 to focus its research and non-degree training related to transportation. The Center has encouraged such research and has involved faculty from a number of the Polytechnic's departments and programs in research proposals and projects. In recent years, prospective principal investigators have come from transportation, industrial engineering, mechanical engineering, electrical engineering, civil engineering, metallurgy, and social sciences.

Acting through the TTRC, Polytechnic is a participating member of the Regional Transportation Consortium, which consists of twelve universities in Federal Region II having a special interest in mutual interaction in transportation research, training, and technology transfer. Agencies may contract with Polytechnic directly or through the Consortium.

Students are encouraged to become involved in the Center's research as research fellows, research associates, and project aides. In some cases, the student's education is fully funded by research.

Recent projects within the Center have included the development of the 1985 edition of the Highway Capacity Manual and the related personal computer software development; demand estimation for a high-speed ferry system; trip generation estimation; tire-pavement noise investigations; evaluation of single cable communications in rail rapid transit; and policy studies on van-pooling, express buses, and local bus-routing. Training development work has covered highway capacity, transit management for middle managers, transit management for first line supervisors, and microcomputer applications.

The Center anticipates a continuing emphasis on its strengths in traffic and highway engineering, transportation planning, and transportation management, as well as stronger emphasis in infrastructure, computer aided engineering, telecommunications related to transportation, and freight and goods movement.

METROTECH

Polytechnic is the sponsor/developer of a $800,000,000 high technology center known as Metrotech. Working with New York City Public Development Corporation and a commercial co-developer, 16 acres surrounding Polytechnic's Brooklyn campus will be developed into a high-technology complex dedicated to creating closer industry-academic cooperation in research and development.

Metrotech will include Polytechnic's new Technology and Science Library linked electronically to worldwide data sources. This library will serve Polytechnic students, providing access to technological data and information not available elsewhere. Because the library will also be a major source of information for technologically based industries in Metrotech and the region, students will be able to keep pace with the most advanced information utilized by industries which provide employment opportunities for graduates of Polytechnic.

Over three million square feet of office, research and computer space will be made available to the private sector within the Metrotech complex. Corporations will have this space designed to meet their needs, with "intelligent" buildings developed to build in state-of-the art telecommunications, security, operations, and energy management systems.

Metrotech will also contain the Center for Advanced Technology in Telecommunications, a prestigious designation by the State of New York achieved by Polytechnic in 1983. Industrial and educational objectives will be met through a close working relationship between Polytechnic and corporate technical and management personnel within Metrotech and throughout the region. Students will have the opportunity to observe at close range the application of lessons learned in the classroom as they are applied within high-technology corporations.

Adjacent to Metrotech will be a hotel/conference center, which will make it possible to bring scientists, engineers and managers to conferences of mutual interest to private sector and academic groups. Such conferences and meetings will provide additional opportunities for students to interact with professionals within technical fields of their interest.
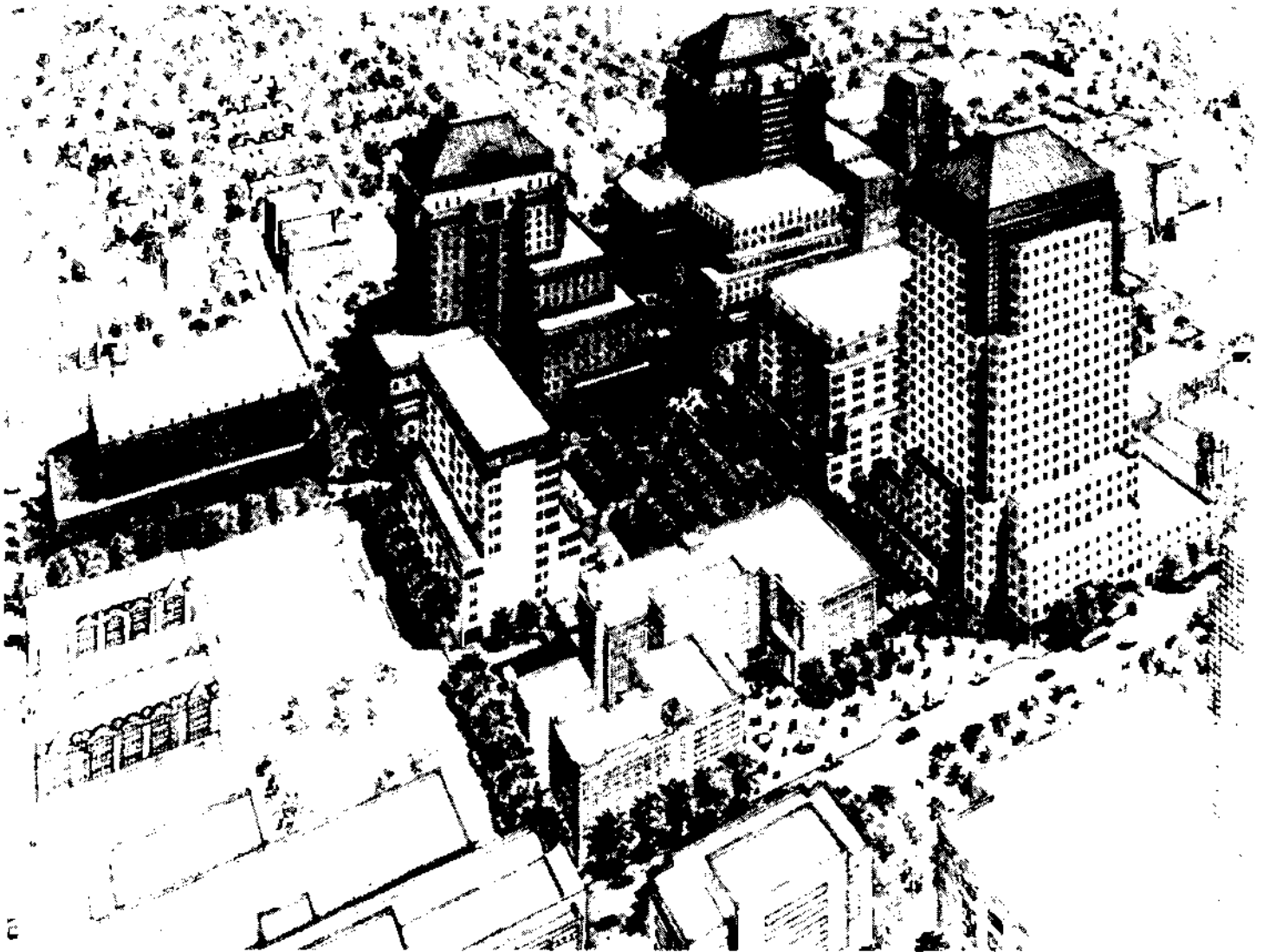
Rendering of Metrotech complex

INTER-INSTITUTIONAL AND COOPERATIVE PROGRAMS

Polytechnic University has made cooperative arrangements with other institutions to expand offerings available to students. Some of these programs are described in this section. All students who wish to participate in cooperative programs should discuss their needs and goals with advisers at both institutions.

NEW YORK UNIVERSITY/POLYTECHNIC COOPERATIVE PROGRAM

The two universities established cooperative interactions, dating to the 1973 merger of the NYU School of Engineering and Science and the Polytechnic Institute of Brooklyn, to form what is now Polytechnic University.

On the graduate level, this interaction takes the form of opportunities to pursue a master's degree in the NYU Graduate School of Public Administration while simultaneously pursuing an MS in engineering or science at Polytechnic, in a coordinated and complementary effort.

Details of the program of study vary, suited to the student's needs and the degree being pursued at Polytechnic. Not all departments have had students active in this program in recent years.

The Transportation Program cites the "Dual Degree" Program in its section of this catalog, and also has had a bilateral practice with the NYU Graduate School of Public Administration by which a student pursuing just one degree can attend a course in the other's program.

For further information related to other Polytechnic programs, contact the advisor in the specific Polytechnic program, or Professor Joachim Weindling (718-260-3586).

COOPERATIVE (3-2) ENGINEERING PROGRAM

The roles of engineers and scientists in our society have changed significantly during recent years. Engineers and scientists have been called upon increasingly to assume managerial and administrative responsibilities in both the private and public sectors. As a result, there are growing student demands for programs which make it possible to include more courses in the humanities and social studies than can be accommodated in standard engineering curricula.

The Cooperative (3-2) Engineering Plan has been developed so that the needs of these students are satisfied. Under the plan, students register at cooperating liberal arts colleges for three years of study, and then transfer to Polytechnic University as engineering majors for two additional years (nominally). At the end of five years, students have (normally) completed the requirements for bachelor's degrees at both the liberal arts college and Polytechnic, whereas usually at least six years of study would be required for those not availing themselves of this plan.

Those wishing to pursue studies under the combined plan should make inquiries at the cooperating liberal arts college of their choice and enroll in the plan at that school.

Upon satisfactory completion of the three-year segment of the combined program in the liberal arts college and with the official recommendation of that school, the student would be admitted to an engineering program at Polytechnic University to complete requirements for the bachelor's degrees from each institution. Polytechnic University is cooperating officially in the combined plan with the liberal arts colleges of the following institutions:

Adelphi University, Garden City, N.Y.
C.W. Post Campus, Long Island University, Brookville, N.Y.
St. John's University, Jamaica, N.Y.
State University College, Oneonta, N.Y.

COOPERATIVE (2-2) ENGINEERING PROGRAM

A similar cooperative program, leading to a Polytechnic bachelor's degree in engineering, but without provision for a bachelor's degree in liberal arts, has been developed jointly with various liberal arts and community colleges. Under this plan, students enroll at one of the cooperating schools for a two-year pre-engineering program. Upon satisfactory completion of the program, and with the official recommendation of the school, the student would be admitted to Polytechnic University to complete requirements for the bachelor's degree in one of the fields of engineering, a process expected to require four or five semesters of additional study. Polytechnic University has formal agreements for cooperation in this plan with the following institutions:

Brooklyn College (City University of New York), Brooklyn, N.Y. (See "Transfer from Brooklyn College")
Lehman College (City University of New York), Bronx, N.Y.
Westchester Community College, Valhalla, N.Y.

TRANSFER FROM BROOKLYN COLLEGE

Polytechnic University and Brooklyn College (City University of New York) have developed, under the Cooperative (2-2)

Engineering Plan, a coordinated engineering degree program. Students admitted to the Coordinated Brooklyn College/Polytechnic Program attend Brooklyn College for two years of pre-engineering studies. Upon completion of the Brooklyn College component of the coordinated program, students transfer to Polytechnic for two-and-one-half years additional study to fulfill requirements for the degree of bachelor of science in any of the following fields: aerospace, chemical, civil, electrical, industrial, mechanical, or metallurgical engineering.

Students who complete the Brooklyn College pre-engineering component with overall science and mathematics course grades of 2.5 or higher are guaranteed transfer into a Polytechnic engineering program with all Brooklyn College course credits transferrable toward the Polytechnic degree.

Polytechnic offers transfer students in the Coordinated Brooklyn College/Polytechnic Program financial aid, based on family need and scholarship, comparable to the assistance offered to continuing Polytechnic students in their junior year.

Further information and copies of the full four-year suggested programs in engineering may be obtained from:

Dr. Zirhat Sanhi
Brooklyn College (CUNY)
Bedford Avenue & Avenue H
Brooklyn, New York 11210
Phone: (718) 780-5785

AIR FORCE RESERVE OFFICER TRAINING CORPS

Students at both Brooklyn and Farmingdale campuses are eligible to enroll in the AFROTC program. Additionally, AFROTC scholarships are available to qualified applicants in both 4- and 2-year programs. Scholarships are based on merit and pay tuition, books, laboratory and incidental fees, plus a $100 monthly nontaxable allowance. Upon graduation the student will be commissioned as a Second Lieutenant in the United States Air Force, and assigned to a position commensurate with the degree specialty. Assignment and career opportunities exist for all types of academic majors.

Courses in the Air Force Reserve Officer Training Corps program are offered off-campus. Further information can be obtained from the Air Force faculty advisors, at AFROTC Detachment 560, Manhattan College, Riverdale, New York 10471-4098, telephone (212) 920-0201.

CROSS REGISTRATION WITH LONG ISLAND COLLEGES

Through a consortium of Long Island Colleges, LIRACHE (Long Island Regional Advisory Council on Higher Education), cross registration opportunities are available to both full- and part-time matriculated undergraduates during the *two regular semesters* of the academic year. Cross registration permits access to courses not available at students' home institutions.

The following conditions prevail; exceptions are made only under unusual or extenuating circumstances.

- Permission is granted *only* when the home institution does not offer such courses at any time.
- Students must receive approval from *both* home and host institutions for all cross-registered courses prior to admission.
- No cross registration fees are charged. Students are obligated to pay their home institution the regular tuition which would be charged if the courses were taken at the students' own schools; however, students are responsible for *any special* fees charged by host institutions. Such fees are paid directly by the students to the institutions at which they cross register.
- Grades for all courses are sent directly to the Registrar of the students' home institutions and are processed in the manner of those schools.
- Students participating in this academic enrichment program are subject to the academic regulations, including grading systems, calendar deadlines, and academic honor systems of the host institutions.

Participating institutions are:
In NASSAU County:
Adelphi University
C.W. Post of L.I.U.
Molloy College
Nassau Community College
N.Y. Institute of Technology
SUNY College at Old Westbury

In SUFFOLK County:
Polytechnic University (Long Island Campus)
St. Joseph's/Brentwood
SUNY at Farmingdale
Dowling College
SUNY at Stony Brook
Southampton College
Friends World College

LIRACHE reviews this program periodically, and it is therefore subject to change and/or cancellation. For further information consult the registrar.

CURRICULA

UNDERGRADUATE PROGRAMS

Students may work toward bachelor's degrees either in four years of full-time study or over a longer period of time. The number of credits full-time students may take each semester depends upon the curriculum and ranges from 12 to 20.

Students are admitted as freshmen in September and January. Full-time students entering in September follow normal curricula outlined for fall and spring semesters. Those entering in January follow programs determined in conjunction with their advisers.

Programs leading to some baccalaureate degrees may be pursued completely or largely through evening classes. In addition, individual courses or groups of courses may be pursued independently by qualified students who wish to concentrate upon particular subjects, or who want to achieve competence in a selected branch of engineering, the sciences, management, the humanities or the social sciences.

GRADUATE PROGRAMS

Graduate study at Polytechnic is open on a full-time and a part-time basis to persons who hold bachelor's degrees from accredited institutions. Students may work toward graduate degrees — master of science, or engineer, or doctor of philosophy — or take courses for personal or professional reasons. Not all graduate programs or courses are offered at all campuses; students are referred to the program descriptions under the various departments and to the Schedule of Classes available at the Office of the Registrar.

GRADUATE CERTIFICATE PROGRAMS

Polytechnic offers certificate programs in the following specialized areas:

Name of Program	Hegis Code
Management and Business Administration	(0506)
Applied Statistics	(1702)
Computer Applications	(1701)
Computer Mathematics	(1703)
Construction Management	(0599)
Econometrics and Forecasting	(2204)
Economics	(2204)
Economic Systems	(2204)

Engineering Statistics	(1702)
Finance	(0504)
Human Resources	(0515)
Industrial Engineering	(0913)
Mathematical Programming	(0704)
Mathematical Statistics	(1702)
Operations Management	(0506)
Operations Research	(0507)
Organizational Behavior	(0515)
Polymeric Materials	(0906)
Production and Inventory Control	(0913)
Public Policy	(2102)
Public Transportation	(0908)
Quality Control and Reliability	(0913)
Technology Management	(0599)
Traffic Engineering	(0908)
Transportation Facility Design: Operation	(0908)
Transportation Management and Economics	(0908)
Transportation Planning	(0908)

SUMMER COURSES

Polytechnic offers a wide variety of full-credit summer courses for full- and part-time, undergraduate and graduate students during the summer months. The schedule of summer courses may be obtained from the Office of the Registrar.

Civil engineering undergraduate students attend surveying camp for two weeks during the summer preceding their sophomore year.

Students enrolled in the Advanced Course of the Army Reserve Officers Training Corps attend an active Army camp for six weeks during the summer preceding their senior year. The military science department also offers during the summer Compression Programs to allow for advanced placement within the Reserve Officers Training Corps.

COOPERATIVE EDUCATION PROGRAM

The Cooperative Education Program is an alternative to the standard four-year educational program. It combines college studies with practical working experience in industry, government and public service. The five-year Cooperative Education Program offers experience at a professional level interspersed with a strong academic curriculum. See section "Cooperative Education Program."

REGISTERED DEGREES OFFERED AT POLYTECHNIC

Polytechnic's programs lead to the Bachelor of Science, Master of Science, Engineer, and Doctor of Philosophy degrees. For more information on degree titles, descriptions and requirements, please see departmental sections.

	B.S.	M.S.	Eng.	Ph.D.
Aerospace Engineering (0902)	■			
Aeronautics & Astronautics (0902)		■	■	■
Applied Mathematics (1703)	■			
Applied Mechanics (0921)		■	■	■
Applied Statistics (1702)		■*		■*
Bioengineering (0905)		■		■
Chemical Engineering (0906)	■	■	■	■
Chemical Physics (1902)		■		■
Chemistry (1905)	■	■		■
Civil Engineering (0908)	■	■	■	■
Computer Science (0701)	■	■		■
Dental Materials Science (1224) (Joint with New York University)		■		
Electrical Engineering (0909)	■	■	■	■
Electrophysics (0919)		■		■
Environment - Behavior Studies (2201)		■		
Environmental Engineering (0922)		■		
Environmental Health Science (0922)		■		
History of Science (2205)		■		
Humanities (4903)	■			
Imaging Sciences and Engineering (4904)		■		
Industrial and Applied Mathematics (1703)		■		
Industrial Chemistry (0906)		■		
Industrial Engineering (0913)	■	■	■	
Industrial Engineering & Operations Research (0913)				■
Information Management (0702)	■			
Information Systems Engineering (0990)		■		
Journalism and Technical Writing (0602)	■			
Management (0506)		■		
Manufacturing Engineering of Electronic Materials (0913)		■		
Mathematics (1701)	■	■		■
Materials Science (0915)		■		■
Mechanical Engineering (0910)	■	■	■	■
Metallurgical Engineering (0914)	■	■	■	
Operations Management (0506)		■		
Operations Research (0913)	■	■		
Organizational Behavior (0515)		■		
Physics (1902)	■	■		■
Polymer Science and Engineering (0906)		■		■
Specialized Journalism (0602)		■		
Social Sciences (2201)	■			
System Engineering (0901)		■	■	■
Telecommunications Management (0599)		■		
Transportation Engineering (0908)			■	
Transportation Management (0510)		■		
Transportation Planning and Engineering (0908)		■		■

*Registration Pending

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ADMISSIONS

UNDERGRADUATE

THE APPLICATION PROCESS

Application materials and information on undergraduate admissions may be obtained by telephoning or writing the Admissions Office at either of the following locations:

BROOKLYN	**FARMINGDALE**
Admissions Office	Admissions Office
Polytechnic University	Polytechnic University
333 Jay Street	Route 110
Brooklyn, NY 11201	Farmingdale, NY 11735
(718) 260-3100	(516) 755-4200

Undergraduate applicants should complete the admissions application form and forward it to the Admissions Office with either a $30 non-refundable application fee or a fee waiver request form. Upon submission of the application form, applicants should request that their secondary school or college forward official copies of transcripts to the Polytechnic Admissions Office. All freshmen applicants and all transfer applicants with less than two complete years of college are required to submit test scores of the Scholastic Aptitude Test (SAT) and Achievement Tests (ACH), or of the American College Testing Program (ACT).

Polytechnic's admission process operates on a rolling basis; however, applicants are encouraged to apply early. Preference will be given to applicants who submit all of their documents according to the following timetable:

Full-time undergraduate study:
    October 1—for the spring semester
    February 1—for the fall semester

Part-time undergraduate study:
    December 1—for the spring semester
    August 1—for the fall semester

Candidates for freshman admission to the fall term who submit their applications and all of their documents before January 15 will receive a decision by February 1. Freshmen candidates for the fall term who apply after February 1 will receive an admission decision within two weeks after submission of all documents. Admission of fall freshmen applicants, who apply after February 1, will, of course, depend upon the availability of space at that time.

The preceding timetable does not apply to international applicants. Because of the extra time required to process applications from abroad, consideration will not be given to foreign applications received after December 1 for the spring semester, nor after June 1 for the fall semester. All official records, together with notarized translations, must also be received by these dates. (See "Admission as an International Student.")

If accepted for admission, the applicant should submit an enrollment deposit of $100 in order to reserve a place in the entering class. This fee will be applied to tuition and fees for the first semester. This deposit is not refundable after May 1 for the fall semester, nor after December 1 for the spring semester.

Applicants accepted for the fall semester may begin their studies in the summer session. Polytechnic offers two summer sessions to help students who wish to accelerate or supplement their studies.

THE EARLY DECISION PLAN

Applicants who have selected Polytechnic as their first choice are encouraged to apply for early decision. The application and supporting documents should be submitted by November 1. Decisions will be announced on December 1.

EARLY ADMISSION

On occasion, Polytechnic offers early admission to outstanding high school juniors. Programs can be arranged so that students simultaneously satisfy high school requirements while completing their freshmen year of college. Candidates for this program must complete their entrance examinations in their junior year of high school, and must present, with their application, a letter from their principal stating the secondary school's approval.

CRITERIA FOR ADMISSION

ADMISSION AS A FRESHMAN

Examinations

Applicants for admission as freshmen are required to take the Scholastic Aptitude Test of the College Board. In addition, applicants for engineering and science should take achievement tests in English composition, one laboratory science (chemistry or biology), and mathematics level I. Humanities and social science applicants should take achievement tests in English composition and any other two achievements, preferably in the humanities. The American College Testing Program may be substituted for the College Board examinations.

Secondary School Record

The course of studies at Polytechnic is academically rigorous and intellectually challenging; therefore, admission to Polytechnic is highly competitive. Candidates for admission will be judged primarily on their potential for success.

The preferred course of studies on the secondary school level is:

English—4 years
Foreign Language—2 years
Science—3 years (physics and chemistry preferred)
Mathematics—3 years (elementary algebra, geometry, intermediate algebra, trigonometry)
Social Studies—3 years
Electives—2 years (technical courses such as pre-calculus, calculus, advanced laboratory science, computer science, etc., preferred)

This course of studies is only a directive, not an absolute requirement; the primary concern of the members of the Admissions Committee is to determine an applicant's potential for success at the university.

INTERVIEWS AND CAMPUS TOURS

Prospective students are strongly encouraged to visit the campus of their choice. Arrangements can be made by calling the admissions office at either campus. If arrangements are made in advance, prospective students are welcome to have an interview with a member of the admissions staff during their visit to Polytechnic.

ADMISSION TO A MAJOR

Polytechnic students may be admitted to a specific major program, or may be admitted as "undesignated majors." All students will have the opportunity to review their choice of major, or to initially declare their major, at the end of their first semester of study.

Curricula for the first semester of study do not vary significantly among the available majors, and students may select or change their designation without penalty before beginning the second semester of work. All students must declare a major before beginning their second semester, unless they are in the HEOP program.

Students admitted as "undesignated majors".

Typical programs for first-semester freshmen are given for each program in the appropriate section of this catalog. Students not wishing to declare a major upon admission will take the following typical program:

1. CS 112 - Programming in PASCAL - 3 credits*
2. MA 101 - Calculus I - 4 credits**
3. CM 101 - General Chemistry I - 2.5 credits***
   CM 111 - General Chemistry Lab I - 0.5 credits***
4. HU 101 - Writing and the Humanities I - 3 credits****
5. SS 104 - Contemporary World History - 3 credits****
6. PE 10x - Physical Education - 0 credits*****
7. SL 101 - Freshman Seminar - 0 credits
8. CP 101 - Cooperative Education (optional) - 1 credit******

All incoming freshman with fewer than 6 credits are required to take SL 101, Freshman Seminar. This important seminar includes weekly presentations describing all major programs available to Polytechnic students. It also includes discussions and presentations on time management, study and testing skills, available support services at Polytechnic, and many other subjects of great importance to beginning students. A short paper on the selection of a major is

required of all students in this course. No student will be permitted to register for the second semester without successfully completing this course.

In the last week of this seminar, students will formally select their major area of study. Students who have already declared a major may confirm their choice or choose to change. Students initially enrolled as undesignated majors must make their choice of major at this time.

Students are, of course, free to change their major at any time, given that their scholastic standing is acceptable to the program into which they wish to enter. It should be noted that such changes may involve some loss of credit if done later than the end of the first semester. Advisors will work with any student wishing to change majors to minimize loss of credit and disruption to the student's educational program.

In consultation with an advisor, the above program may be modified. For example, students with advanced placement in MA 101 may take MA 102. Students who are particularly well qualified, and who have done well in the Polytechnic Mathematics Placement Test may take PH 104, Introductory Physics I, and delay CM 101/111, CS 112, or SS 104 to a later semester.

Full-time students wishing to reduce their freshman Fall course load may defer CM 101/111, CS 112, or CS 100.

NOTES:
*   CS 112:   PASCAL is the required programming language for programs in Computer Science, Industrial Engineering, Electrical Engineering, Information Management, Mathematics, or Physics. Other engineering and science programs require FORTRAN (CS 100). For students selecting a program requiring FORTRAN after successfully completing PASCAL, Polytechnic offers a concentrated short course in FORTRAN between semesters at no cost to the student. As PASCAL is a more rigorous language, a student taking FORTRAN and selecting a program requiring PASCAL would be required to take the full PASCAL course. For this reason, students who enter as undesignated majors should take PASCAL. Students planning to major in electrical engineering must earn a C- or better in CS 112 when first taken.

**   MA 101:   Entering freshmen must take a Mathematics Placement Test in high-school algebra, geometry, and trigonometry, administered by the Office of Student Life, unless they have received advanced placement credit for MA 101. Well-prepared students are placed in MA 101 (4 hrs/wk) and take MA 102 (4 hrs/wk) in the second semester. Students requiring additional preparation are placed in MA 100 (7 hrs/wk), which includes coverage of pre-calculus, and must take MA 110 (7 hrs/wk) in the second semester. Students with superior mathematical ability may replace MA 101 with MA 111; consult the Department of Mathematics about your eligibility and course availability. Students planning to major in electrical engineering must earn a C- or better in MA 101 or MA 100 when first taken.

***   CM 101/111:   Chemistry courses count towards any baccalaureate, either as a required course or a technical elective.

****   HU 101/SS 104:   Prior to registration, all incoming freshmen must take the English Composition Placement Test, administered by the Department of Humanities through the Office of Student Life. Most students are

placed in HU 101. Students placed in HU 200 take HU 200 during their first semester, and replace HU 101 with any HU/SS elective meeting programmatic requirements. Students placed in HU 009 take HU 009 in their first semester, usually with either HU 119 or SS 189; they take HU 101 and SS 104 the following semester. Students placed in HU 008 take HU 008 and HU 120 in their first semester; they take HU 103 (instead of HU 101) in their second semester, and SS 104 in a later semester. SS 104 may be deferred for students taking a foreign language sequence. Foreign-speaking students may not elect a sequence in their native language without obtaining the written permission of the Department of Humanities prior to registration. Students who have completed HU 101 or HU 103 have the option of replacing SS 104 and HU 200 with IS 140 and IS 141. Required composition courses should be completed at the earliest opportunity. Students planning to major in electrical engineering must earn C- or better in HU 101 (or HU 103) and HU 200 (or IS 140) when first taken.

(For purposes of determining full-time status, each non-credit remedial course is counted as if it were 3 credits.)

***** PE 10x: Four semesters of physical education are required of full-time students. Courses with the same number may be repeated. Polytechnic team members may get term-by-term credit for PE, on approval from the Department of Physical Education. MS 101, 102, 201, or 202 are substitutes for any PE course on a 0-credit basis.

******CP 101: Students interested in the Cooperative Education option should register for this optional course (required of co-op students). Consult the "Cooperative Education" section of the catalog for more information about this program option.

FRESHMAN ADMISSION WITH ADVANCED STANDING

Freshmen may receive advanced standing with college credit at Polytechnic by scoring exceptionally well on the Advanced Placement Examinations given by the College Board. Similar consideration will be given to those with exceptionally good scores on the Higher Level of the International Baccalaureate Exam.

Specific requirements for administering college credit, for both the Advanced Placement and the International Baccalaureate Exam, vary from department to department.

COLLEGE PREVIEW

Through Polytechnic's College Preview Program, students may gain college credit during their senior year of high school. Courses are offered to College Preview students at reduced tuition.

ADMISSION UNDER THE HIGHER EDUCATION OPPORTUNITY PROGRAM

The Higher Education Opportunity Program (HEOP) provides educational opportunity to economically and educationally disadvantaged students of New York. Economic eligibility is based on federal economic guidelines which consider family size, family members who are students and family income.

Incoming freshmen in HEOP are required to take six weeks of remedial work before entering, to make up prerequisites and courses in which weakness is shown.

Transfer students may enter HEOP; however, only students coming from similar programs approved by the HEOP central office are eligible to transfer into the HEOP Program. HEOP is available at the Brooklyn campus only. For further information, contact the director of HEOP at the Brooklyn campus at (718) 260-3370.

Admission as an International Student

Foreign students must meet three basic criteria for entry into Polytechnic and receipt of a valid I-20:

1. The Test of English as a Foreign Language (TOEFL) is required of all students whose native language is not English.
2. The Polytechnic Certificate of Finance (Affidavit of support) must be duly signed and accompanied by a bank statement.
3. Academic credentials (grades, certificates, degrees) must be assessed as suitable for entry to the appropriate University program.

Students holding F-1 or J-1 visas must enroll as full-time students. Foreign students transferring from other U.S. institutions must notify Polytechnic's International Admissions and Foreign Student Adviser as soon as possible prior to their transfer.

If transfer credit is desired, candidates must include catalog or syllabus descriptions of courses completed. An official transfer credit evaluation will be done when the student arrives at Polytechnic and meets with a member of the Admissions staff and a departmental adviser.

ADMISSION AS A TRANSFER STUDENT

Polytechnic welcomes transfer students from accredited colleges and universities, provided they have maintained a strong academic record. Students who have not completed two years of college work should submit official transcripts of previous college and high school grades, and Scholastic Aptitude Test scores. Students who have completed two or more years of college need only submit official college transcripts.

If accepted, transfer students should meet with a member of the admissions staff and a departmental adviser to determine which credits are transferable. Students are required to submit their college catalog describing courses under consideration.

Transfer credits will only be evaluated prior to the end of the first semester the transfer student is enrolled at the University. Core courses are evaluated by the Admissions Office. Upper level courses are evaluated by individual major academic departments.

Transfer students must submit official transcripts accepted under the Undergraduate Waiver of Admissions Credentials Plan within 30 days of their first registration, or further registration will be blocked.

Transfer credit is awarded on the basis of current standards and curriculum. Therefore, it is possible that credits which Polytechnic had previously awarded for courses taken at

other universities may no longer be granted at this time. All transfer credit evaluations are conditional. Transfer credit will not be considered for any course with less than a "C" grade. Any student who completes a course in residence at Polytechnic for which transfer credit has already been granted will automatically forfeit the transfer credit for that course.

In certain instances, course requirements may be waived for students who demonstrate sufficient knowledge of a specific course content through either the oral or written examinations given by various departments. When course requirements are waived, the student will not receive credit for the course, but must substitute a more advanced course to satisfy the degree requirement.

The grades for transfer courses are not included in the computation of the Polytechnic grade point average. New transfer students may be admitted on a part-time or full-time basis and may be required to take some entrance examinations.

The minimum residence requirement for transfer students who wish to qualify for a bachelor's degree is thirty-four semester hours in approved upper class subjects taken at Polytechnic.

ADMISSION AS A PART-TIME STUDENT

Students seeking a bachelor's degree may enroll on a part-time basis (11 credits or less) at the Brooklyn or Farmingdale campus taking day or evening courses. Please see sections on individual disciplines to determine whether part-time evening studies are available.

Regulations concerning subject requirements and admissions procedures are given in the section "Admission as a Freshman." However, part-time undergraduate applicants are not normally required to take the entrance examinations.

Following notification of acceptance, students should contact the adviser of the major department. In some cases, this may be accomplished during registration.

SPECIAL AND VISITING STUDENTS

Undergraduate students may also register for a maximum of two courses per semester on a non-degree basis. Application for admission under this special status may normally be obtained during registration. A non-degree program may satisfy the requirements of:

- Applicants for graduate admission seeking courses to satisfy undergraduate or prerequisite deficiencies
- Students seeking specific courses
- Students seeking specialized proficiency in a major area of knowledge
- Students from other colleges wishing to transfer credit back to their college

Courses taken on a non-degree basis are not automatically applicable to a degree program. Some courses, however, may be transferred to a degree program with the approval of a departmental adviser.

READMISSION

Polytechnic students who have not been in attendance for one year or more are required to apply for readmission. Students applying for readmission will be expected to state their reasons for leaving the University, and are expected to explain why they desire to return.

GRADUATE

To be eligible for admission as a graduate student, an applicant must hold a bachelor's degree from an institution acceptable to Polytechnic. Attention will be given to listings by the Accreditation Board for Engineering and Technology (ABET), the American Chemical Society and the various regional accrediting associations. An applicant applying to a graduate program in an area of study different from the undergraduate field in which a bachelor's degree or its international equivalent was earned must anticipate the possibility of additional courses for which graduate credit may not be given. (See "Conditional Status.")

The previous program of studies must be acceptable, in quality and quantity, to Polytechnic. Reprints of published articles, copies of scientific patents, photostats of professional reports and other evidences of superior attainment and aptitude for graduate study and research are welcomed.

Graduate admission information can be obtained from the Office of Graduate Admissions, 333 Jay Street, Brooklyn, New York 11201, (718) 260-3200.

ADMISSIONS PROCEDURES

In addition to the application form and fee, an applicant must have transcripts of any previous undergraduate (and graduate) records sent directly to the Office of Graduate Admissions. An application should be supported by letters of recommendation from persons qualified to comment on the applicant's aptitude for graduate study and research. Action on an application will be taken as soon as possible after all supporting documents have been received.

EXAMINATIONS

The Graduate Record Examination (GRE) or Graduate Management Admission Test (GMAT) is required for admission to some graduate programs. Consult the departmental section of this catalog for specific requirements about the degree program to which you are applying.

Information about GRE and GMAT may be obtained from the Educational Testing Service, 20 Nassau Street, Princeton, New Jersey 08541.

INTERNATIONAL APPLICANTS

An international applicant must have a complete file by May 1 (fall term), October 15 (spring term) or March 1 (summer term) to be reviewed for the term requested. An incomplete file will delay review and perhaps entrance by at least one term.

The Test of English as a Foreign Language (TOEFL) administered by the Educational Testing Service, is required from all foreign applicants who have earned a bachelor's degree from an institution in a non-English-speaking country. The Test of Spoken English is required of all teaching fellowship applicants from non-English speaking countries.

Certification of ability to meet financial obligations is also required.

STATUS

Within the full-time and part-time classifications of graduate students are four status groups: regular, conditional, provisional, and special. A change in status from *conditional* to *regular* should be applied for when the conditions of admission are satisfied. A *special* or *provisional* student must file an application for graduate admission with the Office of Graduate Admissions.

Regular Status

A graduate degree applicant who is adequately prepared to begin the program applied for is assigned *regular* status upon the recommendation of the major department.

Conditional Status

A graduate degree applicant who is required to demonstrate additional ability to pursue the program applied for is assigned *conditional* status. Conditions may include introductory level or undergraduate courses, or attainment of a specified grade point average.

Provisional Status

A graduate degree applicant whose admissions file is lacking documents necessary for academic evaluation may be permitted to register for one semester with *provisional* status. The applicant must provide all required admission documents to the Office of Graduate Admissions before the sixth week of the semester. If the applicant is not accepted for admission, the semester can be completed or a withdrawal with full refund may be requested. Subsequent registration will not be permitted.

Special Status

An individual requesting permission to register for one or two courses in a specific semester is assigned *special* status. A formal application for admission may or may not have been filed with the Office of Graduate Admissions. Included in this status are individuals who want to take courses for professional advancement or personal development but who do not want to earn a degree, and part-time degree applicants with incomplete admission files. A maximum of six units or two courses may be taken in one semester and no more than nine units or three courses may be transferred to a Polytechnic degree program. A *special* student application must be filed each semester the individual remains in this status. Permission to take courses as a *special* student does not imply admission to a degree program. Special (graduate) students, whether or not they have or will apply for admission to a degree program, must hold a bachelor's degree from an institution acceptable to Polytechnic.

EARLY GRADUATE ADMISSION

A Polytechnic undergraduate student within 18 credits of completing the B.S. degree and otherwise meeting all criteria for graduate admission may apply for admission to graduate study in a given department. If accepted, the student will be pursuing two degrees simultaneously, taking both graduate and undergraduate courses for no longer than one year. Graduate courses taken during that year and not used to satisfy undergraduate degree requirements are not included in the nine credit transfer limit for a master's degree program.

FINANCIAL AID

UNDERGRADUATE

Polytechnic University administers a broad range of scholarship and financial aid programs designed to assist students in pursuing their educational goals. To meet the total cost of education, the student may draw upon available sources including student income, family income, and Polytechnic University, and independent and government funds.

All financial aid is limited to the needs of the students as determined by the College Scholarship Service. Students receiving financial assistance from Polytechnic University must notify the Director of Financial Aid of all scholarships, loans, and other forms of educational assistance from sources other than those directly administered by the Office of Financial Aid.

There are three basic types of financial aid:

Scholarships and grants—Funds awarded to students based on academic ability and financial need which do not require repayment.

Loans—Specific sums awarded to students with repayment conditions. Education loans generally have low interest with extended repayment terms.

Employment—Part-time and summer jobs either on- or off-campus.

About 85% of Polytechnic's undergraduate students receive aid in combinations of scholarships, grants, campus jobs, Perkins Loans (NDSL), and Guaranteed Student Loans.

To Apply

Incoming freshmen should file the complete Financial Aid Form (FAF) with the College Scholarship Service, Princeton, New Jersey, during the month of February. (Later applications will be considered on a rolling basis as funds are available.)

Transfer students should file the FAF by May 1, or as soon as possible thereafter, and request a financial aid transcript from the transferring institution to be sent to the Financial Aid Office at Polytechnic University by June 1.

To Renew

Students should obtain Financial Aid Packets from the Office of Financial Aid between March 15 and April 15.

Students should file the Polytechnic Financial Aid Application and Verification Supplement with the Office of Financial Aid by April 15. A copy of the parents' 1040, 1040A, EZ, and/or the student's 1040, 1040A, or EZ tax forms along with other requested material must accompany this application. Late or incomplete application material will result in a reduction or forfeiture of institutionally administered financial aid.

I. FEDERAL CAMPUS-BASED PROGRAMS

To be eligible for one of the federal campus-based programs, applicants must show need, be enrolled at least half-time (the equivalent of at least 6 credit hours), and be either US citizens or eligible non-citizens.

To apply for one of these programs, students must have been accepted to Polytechnic and have filed the FAF with the College Scholarship Service. Awards are determined by Polytechnic's Financial Aid Offices.

To continue to receive an award, a student must make satisfactory academic progress, provide the Financial Aid Office with all requested documentaion, and report any financial changes in their economic situations.

Supplemental Education Opportunity Grant (SEOG)

The SEOG is awarded to undergraduates with exceptional financial need, and need not be paid back. At Polytechnic, qualified applicants receive between $300 and $500 per year. Usually, the award will continue to be offered for four years, or up to five years for certain course programs.

Perkins Loans (formerly National Defense Student Loans, NDSL)

The Perkins Loan is a low interest (5%) loan. The loans, for both undergraduate and graduate study, are made available through the Office of Financial Aid. Perkins loans are usually awarded as part of a financial aid package, and at Polytechnic, are usually in the amount of between $1000 and $1500 per academic year. Perkins loans are limited to $4500 for the first two years of college study. Total undergraduate Perkins loans may not exceed $9000. Under the Perkins Loan, the maximum amount students may borrow is $18,000 for all college-related expenses, for all their years of undergraduate, graduate and professional study. Upon approval of the loan, the student signs an "Affidavit of Educational Purpose" and a promissory note.

The repayment period and the interest for the Perkins Loans do not begin until six months after the students complete their studies. In an exit interview, the student agrees to repayment — monthly, bi-monthly or quarterly. Interest of 5% per year is charged during the repayment period. Repayment begins 9 months after termination of full- or half-time study and may continue over a 10-year period. Terms for deferment of payment and cancellation of the loan may be found in the Perkins Loan Promissory Note.

College Work-Study Programs

The (CWS) Program provides part-time jobs for undergraduate and graduate students in need of financial aid. Earnings from these jobs help students meet college-related expenses. Awards are granted by the Financial Aid Office.

After eligibility is determined, work arrangements are made through the Personnel Office.

At Polytechnic, most eligible students are offered an award of $1000. Jobs are arranged on- or off-campus with public or private non-profit agencies. Most assignments average 15 hours per week, and the work schedule is adjusted to the needs of the student and the employer. The starting rate of pay is usually $4.00 per hour, but varies depending on the position. Students are paid bi-weekly.

II. FEDERAL AND STATE SPONSORED PROGRAMS

Federally Sponsored
PELL Grants

The PELL Grant is an entitlement program. Awards are determined by the US Department of Education according to an "eligibility index" and by the level of appropriations available. Grants are for study leading to a first bachelor's degree and are usually the first component of all financial aid packages. Currently, awards may not exceed 60% of the cost of education, or $2100, whichever is less.

To be eligible, students must be US citizens or permanent residents, be making satisfactory progress academically, be enrolled at least half-time (the equivalent of six semester hours), and meet PELL Grant income requirements.

If students received a PELL Grant for the first time in 1987-88, or if they receive one in 1988-89 year, the PELL Grant eligibility will usually be limited to five full years of study.

Students apply for the PELL Grant by checking the appropriate box on the FAF. Students applying for financial aid at Polytechnic (including the Guaranteed Student Loan) must also apply for a PELL Grant. Students must file an application by May 1, 1989, for the 88-89 academic year.

State Sponsored
Tuition Assistance Program (TAP)

The Tuition Assistance Program (TAP) attempts to minimize the difference in cost normally found between New York's Public and Independent colleges so that students are able to make their choice based on program characteristics alone and not the difference in cost. There is no competition for TAP support.

The amount of the TAP award depends on the level of study, tuition charge and net taxable income. (This income is adjusted to reflect other family members enrolled full-time in post-secondary study.) TAP awards range from $350 to $2850 per year for undergraduate students.

To be eligible for a TAP award, students must (1) be New York residents and US citizens or permanent residents, (2) be enrolled full-time at an approved New York State post-secondary institution, (3) be charged tuition (exclusive of fees) of $350 per year or more, (4) meet income requirements established by New York State, and (5) file by the required deadline, May 1, 1989, for the 1988-89 academic year.

To apply for the TAP award, students should check the appropriate box on the FAF, or students may obtain an application from their high school guidance counselor,

Polytechnic Financial Aid Office, or the New York State Higher Education Services Corporation, 99 Washington Avenue, Albany, New York 12255.

To continue to receive TAP benefits, students must demonstrate satisfactory academic progress. Standards of satisfactory progress are listed in the Academic Policies section of this catalog and are available in the Financial Aid Office. Students may apply for a one-time waiver of academic progress requirements; however, waivers are granted only under extraordinary circumstances. Additional information is available from the Financial Aid Office.

Aid for Part-Time Study (APTS)

The APTS program is intended to provide State Grants to less than full-time students.

To be considered for an award, students must (1) be working toward an undergraduate degree as part-time students, (2) have earned at least six credits or the equivalent, (3) be in good academic standing, (4) be residents of New York State, (5) be either US citizens, permanent resident aliens, or refugees, (6) not have used up TAP or other New York State student financial aid eligibility for full-time study, (7) apply for a federal PELL Grant, and (8) have, if dependent, a family net taxable income below $22,000, or if independent and not eligible to be a tax dependent, a single student's (or if married combined) net taxable income not in excess of $15,000.

The program provides up to $2000 annually but may not exceed tuition.

To apply for APTS, student should obtain an application from the Financial Aid Office, complete it, and return it as soon as possible to the Financial Aid Office. Students must apply annually. Applications should be filed no later than the second week of classes for the following semester.

Vietnam Veterans Tuition Awards Supplement (VVTA)

The Vietnam Veterans Tuition Award is an entitlement program. Applicants must (1) be residents of New York State since April 20, 1984, or at the time of entry into service and resumption of residency by September 1, 1988; (2) have served in the U.S. Armed Forces in Indochina between January 1, 1963 and May 1, 1975; (3) be honorably or medically discharged from the U.S. Armed Forces; (4) be enrolled in an approved undergraduate program in a degree-granting institution in New York State; and, (5) have applied for the Tuition Assistance Program (TAP) and Pell Grant awards. There are no income restrictions connected with this program.

The award provides up to $500 per semester (full-time attendance) or $250 per semester (part-time attendance). If a Tuition Assistance Program award is received, the combined awards cannot be greater than tuition. The TAP award will be reduced accordingly. Awards are available for up to 8 semesters (4 years), or 10 semesters (5 years) of undergraduate study, if programs specifically require 5 years for full-time study and double the amount of time for part-time study.

To apply, students should obtain applications and other materials available at the Financial Aid Office, any Veterans Office, or by writing to the New York State Higher

Education Services Corporation, VVTA, Albany, NY 12255. Applications for the Vietnam Veterans Tuition Award Supplement must be made by May 1, 1989 by part-time students. Full-time students must apply by submitting both Vietnam Veterans Tuition Supplements and the Student Payment Applications (TAP Application) by May 1, 1989.

To continue to receive the VVTA, students must reapply each year.

New York Regents Scholarship

Eligible recipients are determined by the New York State Education Department. Regents Scholarship winners must request payment each year by filing a TAP application. Awards are $250 per year.

III. POLYTECHNIC UNIVERSITY SCHOLARSHIPS AND GRANTS

Polytechnic Scholarships

Polytechnic has a history of scholastic recognition to numerous applicants with outstanding academic credentials. Such awards are based on need, academic achievement and recommendation.

Polytechnic Scholarships are awarded to freshmen and transfer applicants with strong academic backgrounds with full-time schedules (12 credit hours). Awards are determined through demonstrated financial need and merit. Students apply directly to the Financial Aid Office using the FAF. Awards range up to $5000. Continuance of the awards demands maintenance of a 2.5 cumulative grade point average and application to the PELL and TAP programs.

Polytechnic Special Scholarships

These are awarded to freshmen and transfer applicants with strong academic backgrounds regardless of need. Continuance of the scholarships is based on maintaining a 3.0 cumulative grade point average and application to the PELL and TAP programs. Awards range between $1000 — $3500.

Board of Trustee Scholarships

These scholarships are awarded to academically superior freshmen. Applications are made directly to the Admissions Office. Amounts of the scholarships are equal to tuition, less any outside aid for which students are eligible. Continuance of the scholarships is based on maintaining a 3.0 cumulative grade point average and application to the PELL and TAP programs. (This award does not cover graduate study.)

Geiger/Fialkov Scholarships

Awarded to superior freshmen and transfer students majoring in Engineering or Computer Science. Applications are made directly to the Admissions Office. The amounts of the scholarships are equal to tuition less any outside aid for which the students are eligible. Continuance of the award is based on maintaining a 3.0 cumulative grade point average and application to the PELL and TAP programs. (This award is intended for undergraduate study alone.)

Division of Arts and Sciences Scholarships

These are awarded to superior freshmen and transfer applicants majoring in Chemistry, Humanities, Mathematics, Physics or Social Sciences. Application is made directly to the Admissions Office. The amounts of the scholarships are equal to half-tuition. Maintenance of the awards is based upon recommendations by Department Heads and application to the PELL and TAP programs.

Metallurgy and Materials Science Scholarships

These are awarded to academically superior freshmen and transfer applicants majoring in Metallurgy. Applications are made directly to the Admissions Office. The scholarship award is up to $1000. Maintenance is dependent upon high academic performance.

Outstanding Achievement Scholarships

Awarded to full-time, continuing students (sophomore, junior and senior) with a cumulative grade point average of 3.5 or higher. Applications are made directly to the Financial Aid Office. Minimum awards are $500. Maintenance is dependent upon a 3.5 cumulative grade point average.

Polytechnic Grants

These are available to needy students on a limited basis. Students should apply directly to the Financial Aid Office.

National Action Council for Minorities in Engineering (NACME) Grants

These are awarded to minority (Black, Hispanic, American Indian) students with strong academic backgrounds who demonstrate financial need. Awards are determined by the Financial Aid Office after students begin classes and range up to $2,500. Maintenance is based upon a 2.5 cumulative grade point average.

Minority Scholars Program

Polytechnic Cooperative Education Minority Scholarships are awarded to superior minority students who participate in the Co-op Program. Newly admitted undergraduate students and students who are enrolled in or have completed at least one co-op course are eligible. Application is made directly to the Cooperative Education Office. The amount of the scholarships are equal to tuition less any outside aid for which the students are eligible. Continuation of the award is based on maintaining a 2.5 g.p.a. and continuing participation in the co-op program.

Polytechnic National Society of Professional Engineers Scholarships (NSPE)

The scholarships are awarded to academically superior freshmen majoring in Engineering. Awards are determined by NSPE and range up to $1,500. Maintenance is based on high academic performance.

Polytechnic Matching Mayor's Committee Scholarships

These are awarded to recipients of a Mayor's Scholarship. Scholarship amounts range between $100 and $650. The application deadline for Mayor's Scholarships is October 1. Applications are available at high schools or the Financial Aid Office.

Polytechnic Matching Regents Scholarship

Polytechnic will match the $250 Regents Scholarship for all eligible students.

Many of our Polytechnic Scholarships come to us through the generosity of sponsors. Students will be notified if their particular scholarship is corporate or individually donated. Students should thank them for their support.

A list of most of our current scholarship donors follows.

UNDERGRADUATE GRANTS AND SCHOLARSHIPS

The Sidney G. Albert Scholarship
The Alumni Scholarship
The ARCS Foundation Scholarship
The L.F. Case Foundation Scholarship
The J.B. Chittenden Scholarship
The Arthur Clapp Scholarship
The Samuel & Grace B. Cohen Scholarship
The DeWitt Scholarship
The Dow Chemical Company Foundation Scholarship
The Aaron and Simcha Dubitsky Scholarship
The W.E. Duryea Scholarship
The A.S. Dwight Scholarship
The Evinrude Foundation
The I.W. Fay Scholarship
The Polytechnic Fellows Scholarship
The J. Robert Fisher Scholarship
Kay & John Giba Scholarships (United Technologies)
The Richie Goldish Athletic Scholarship
The Alex Gruenwald Scholarship

The Alfred Helwig Scholarship
Hughes Communications Satellite Services, Incorporated
The Jabara Scholarship
The Jacob Kaplan Scholarship
The Ada H. Kent Scholarship
The Eugene R. Kulka Scholarship
The John F. Kunc Scholarship
The Litton Industries Scholarship
The Lyons Scholarship
The Maggio Scholarship
The P.R. Mallory Memorial Scholarship
The Raymond Mauro Scholarships
The Steven J. Meoli Memorial Scholarship
The NSC-Essie Mitchell Scholarship
The Colonel Frank Mott Scholarships
The New York Society of Codings Technology
The William Nichols Scholarship
The Nippon Electric Scholarships
The Nordheimer Scholarship

The Perkin-Elmer Corporation Scholarship
The Raytheon Company Scholarship
The Dr. Julian R. Reasenberg Memorial Scholarship
The Julian Rogoff Scholarship
The Myron Rosenthal Scholarship
The Samuel Ruben Scholarships
The Schlumberger Foundation Collegiate Award
The Schmidt Memorial Scholarship
The V.C. Silleck Scholarship
The Frank R. & Emile E. Stamer Scholarships
William Stolze Scholarship Fund
The Teagle Foundation Scholarship
The A.I. Thompson Scholarship
Michael Tuch Foundation, Incorporated Scholarship
The Ernst & Sonya Weber Grants
The Warren & Maryann Winsche Memorial Scholarship

IV. OTHER OPPORTUNITIES

ROTC Scholarships

Army ROTC offers four-, three-, and two-year scholarships. The four-year scholarships are awarded on a worldwide competitive basis to American citizens entering college as freshmen. The three- and two-year scholarships are awarded competitively to students enrolled in college and aligned with an ROTC program. Students who attend basic camp of the two-year program may also compete for two-year scholarships. The scholarships pay for tuition, textbooks and lab fees, plus a living allowance of up to $1000 for each year the scholarship is in effect.

Air Force ROTC scholarships are available to qualified applicants in both 2- and 4-year programs. Scholarships are based on merit and pay for tuition, books, laboratory and incidental fees, plus a $100 monthly nontaxable allowance.

Veterans Administration (VA) Educational Benefits

All veterans enrolled at Polytechnic should notify the Veteran Affairs clerk in the Office of the Registrar of the credits to be earned each semester. Any questions concerning veterans benefits or paperwork should be directed to the Veteran Affairs clerk either in person or by telephone.

Veterans who served over 180 days between January 31, 1955 and January 1, 1977 and (1) continue on active duty, (2) were honorably discharged at the end of their tour of duty, or (3) qualify because of service-connected disabilities, are eligible for benefits. Veterans are entitled to benefits for full-time study at an approved post-secondary institution, for one-and-one-half months for each month of active service (up to 45 months). Eligible veterans who served 18 continuous months are entitled to benefits for 45 months of full-time study. In each case, the equivalent in part-time study may be authorized. Eligibility extends for ten years after release from service, but not after December 31, 1989. Children, spouses and survivors of veterans whose deaths or permanent total disabilities were service-connected, or who are listed as missing in action, may be eligible for post-secondary education benefits under the same conditions as veterans.

To apply, students should obtain applications available at all VA offices, active duty stations and American embassies as well as the Office of the Registrar. Completed forms should be submitted to the nearest VA office.

Current monthly benefit rates are available through VA offices. Veterans may borrow up to $2,500 for an academic year of full-time study through a special loan program for veterans.

Students receiving VA educational benefits must report interrupted attendance or termination of study. Details of Polytechnic's requirements are given to all applicants. Eligible students must apply for certification each semester at the Office of the Registrar.

Higher Education Opportunity Program (HEOP)

HEOP is a New York State, and Polytechnic sponsored program for entering freshmen who meet special academic and economic criteria. All inquiries are handled directly through the HEOP Office. Consult the Admissions section of this catalog for more information.

Cooperation Education Program (CO-OP)

Co-op is an alternative means of financing education combining outside employment and school attendance. All inquiries are handled through the Cooperative Education Office.

Grant Aid To Non-New York State Residents

State aid programs frequently require that awarded funds be used within the state. However, some states sometimes allow funds to be used out of state. Contact the following agencies for more information if you are a resident of Pennsylvania, Rhode Island, Vermont or Washington, D.C.

Pennsylvania Higher Education Assistance Agency
Education Building
Harrisburg, PA 17126

Vermont Student Assistance Corporation
156 College Street
Burlington, VT 05401

Office of Scholarships
Rhode Island Department of Education
199 Promenade Street
Providence, RI 02908

Washington, DC, Grant Program
Educational Assistance Office
1329 E. Street NW
Roome 1050
Washington, DC 20004

V. LOAN PROGRAMS

Perkins Loan

Refer to section describing Federal campus-based programs.

Guaranteed Student Loan Program

The Guaranteed Student Loan Program gives students the opportunity to borrow money from a local lending institution to help them meet the costs of college or vocational school training. Students may borrow this money at a low interest rate and will not have to begin repayment of their loans as long as they meet the program's academic requirements or until six months after they graduate or withdraw from school.

To be eligible for a GSL, students must (1) be American citizens or eligible non-citizens, (2) be enrolled at least half-time and matriculated, (3) be making satisfactory progress and (4) demonstrate financial need. The 88-89 FAF must be filed to determine financial need and application for a PELL Grant.

Effective January 1, 1987 annual loan limits were raised to $2,625 for undergraduate freshmen and sophomores, $4,000 for upper level undergraduates and $7,500 for graduate students. Cumulative limits increase to $17,250 for undergraduates and $54,750 for undergraduate and graduate work. The interest rate charged on the loans for new borrowers will remain at 8 percent through the fourth year of repayment and will increase to 10 percent beginning in the fifth year of repayment. The effective date for interest rates for new borrowers is July 1, 1988.

Students with more than $5,000 in loans (GSL, Perkins, Supplemental Student Loan) can consolidate their loans into one repayment package with a 9 percent interest rate, or a weighted average of the rates on the loans consolidated. Repayment is extended up to 25 years depending on the aggregate amount borrowed. Lenders can offer a graduated or income-sensitive repayment option.

To apply, obtain GSL applications from participating lending institutions (banks, credit unions, etc.). In addition all students, (undergraduate and graduate) must have on file the Financial Aid Form (FAF), the Polytechnic Financial Aid Application and Verification Supplement, and all necessary income documentation. Eligible applicants will be certified and forwarded to the lender indicated and guarantee agency. To ensure that credit for approved GSL's will be given in lieu of payment at registration, GSL applications should be submitted to the Office of Financial Aid no less than eight (8) weeks prior to registration.

After graduating, withdrawing from school, or dropping to less than half-time study, the student borrower must see his or her lender and make formal arrangements for repayment of the loan. The borrower must actually begin repayment of the loan in the sixth month after graduating or withdrawal from school. Immediate repayment of a loan is required if the borrower does not enroll in shcool.

A student will be required to repay the total amount borrowed and all interest on the declining balance in accordance with the following regulations.

1. The minimum monthly installment will be $50 plus interest. (The monthly installment is determined by the amount borrowed).
2. The maximum repayment period for the whole of the loan is 10 years.
3. Repayment of part or all of the loan may be made in advance at any time without penalty.
4. The maximum period of a loan, from the date of the original note, may not exceed 15 years on all loans guaranteed after November 3, 1965, except in cases of authorized deferment (not to exceed three years) while student is a member of the Armed Forces or a volunteer under Title VIII of the Economic Opportunity Act of 1964.

The length of the payment period depends upon the date the promissory note matures as well as the total amount borrowed. A student borrower may be permitted to make payments of less than $50 per month under unusual and extenuating circumstances. Request for such forebearance must be made to the lender.

Supplemental Loans for Students

All students, except dependent undergraduates, are eligible for the Supplemental Loan program. Annual limits are increased to $4,000 and aggregate limits to $20,000, starting with the enactment of the bill.

These loans can be used to cover the expected family contribution required in determining need in other financial aid programs. Supplemental loans in combination with other financial assistance cannot exceed the cost of education.

A variable interest rate is established for both of these programs. Interest will be the one-year Treasury Bill rate, plus 3.75 percent, with a maximum of 12 percent. The new rates apply to periods of enrollment beginning on or after July 1, 1987.

To apply, obtain SLS applications from participating lending institutions (banks, credit unions, etc.) Although neither the FAF nor income documentation is required for processing the SLS, it is necessary for a student to submit the Polytechnic Financial Aid Application and Verification Supplement. Completed applications should be submitted to the Financial Aid Office no less than eight weeks prior to registration for any given academic period. Certified applications are forwarded to the student's lender and guarantee agency.

Supplemental Loans for Parents

Parents may borrow up to $4,000 per year for each financially dependent student. The total maximum aggregate for each child is $20,000. The amount borrowed in any year cannot exceed educational costs taking into account all other financial aid received. Repayment begins within 60 days from the date you receive the loan. The maximum repayment period is 10 years.

Supplemental Higher Education Loan Financing Program (SHELF)

New York State sponsored, SHELF is a Polytechnic administered program that does not require New York State residency. This program is available to undergraduate, graduate and professional students attending Polytechnic at least half-time. A credit evaluation is necessary, and the loan generally will be based on the credit of the parents or co-signer. Many students from families unable to qualify for other financial aid programs may be able to participate in SHELF.

Polytechnic University-Sponsored Loan

Polytechnic sponsored loans are available to both incoming and continuing students based on financial need and the availability of funds. Students are considered for Poly Loans when they apply for Financial Aid using the Financial Aid Form (FAF). Students are generally awarded between $1000 - $2000 per academic year. The current interest rate is 7%. Repayment begins after graduation or when the student withdraws from school.

Eligibility is primarily based on need; special circumstances can influence determination. Students must be U.S. citizens or permanent residents to apply and must be matriculated and enrolled at least half-time (6 credit hours).

VI. OTHER RESOURCES (MEETING THE FAMILY CONTRIBUTION)

Financial need is the difference between Cost of Education and Family Resources. There are programs at Polytechnic available for families to apply toward meeting family cost irrespective of income and financial need.

The Office of Financial Aid has summarized details of several plans currently employed by families to help meet college costs. Students should inquire in the Financial Aid Office for information concerning these programs, the companies that sponsor these programs, and the necessary application procedures.

Ten/Twelve-Month Payment Plans

University or external payment plans allow students and their families to finance fixed educational expenses over a 10/12-month period with no interest or finance charges. Participating families, make their first payment by May or June preceding the academic year in which it will be utilized.

Deferred Tuition Payment Plans

A deferred tuition plan may be used by students to defer as much as one-half of their tuition per semester or as little as the cost equivalent of one three-credit course. Students may select to defer by the semester or for an entire school year. If they choose the semester deferment option, payments begin no later than October 1st for the Fall term and February 1st for the Spring term. Total payments must be received by January 1st for Fall deferments and May 1st for Spring deferments. Applications must be filed one month in advance. An application fee and interest charge are attached to the program.

Extended Repayment Plans

An extended repayment plan enables students to pay for four or five years of college expenses over 10 years. Interest is charged only to the actual amount paid to the college and not yet repaid. Percentage rates are variable. Approval is generally based on a credit evaluation.

Home Equity Loan/Home Equity Line of Credit

Many parents are pleasantly surprised to discover the resource value of the equity in their homes or apartments. Currently, many lenders offer loans or lines of credit that enable families to put this significant asset to work in financing a college education. Those wishing to pursue this option are encouraged to contact a local lender.

VII. OTHER OPPORTUNITIES

There are some scholarship programs, usually directed by local and civic organizations, which are not based on need. High school guidance offices are the best source of information. Also, parents' places of employment sometimes sponsor programs for employees' children. These employer benefits are often full- or half-time tuition and sometimes merit/need based.

VIII. IMPORTANT FINANCIAL AID POLICIES

• To be eligible to receive financial aid, students must be enrolled at least half-time. All Polytechnic Scholarships, TAP grants, and Regents Scholarships, however, require students to be full-time to qualify.

- Financial Aid applicants (including GSL applicants) are expected to apply for a Pell Grant and, in the case of New York residents, for the Tuition Assistance Program.

  Out of State applicants must apply to their own state grant and scholarship programs.

- Although at Polytechnic the Admissions and Financial Aid Offices are associated, admissions decisions are not affected by financial aid decisions. Admissions officers have no access to financial aid records. Academic evaluations of a student's qualifications are made without the knowledge of the applicant's financial need.

- Prospective students should not wait until they have been admitted to apply for financial aid. These are concurrent processes. Applicants should make every effort to apply for admissions and financial aid by the preferred application dates. Once students are admitted, they are reviewed for financial aid.

- Financial aid is renewable annually, based on students reapplying, continuing to demonstrate financial need where applicable, and fulfilling other requirements stipulated by the awards. To renew most Polytechnic Scholarships, students must maintain a 2.5 cumulative grade point average. To renew a Board of Trustee Scholarship, students must maintain a 3.0 cumulative grade point average.

- Standards of achievement for scholarship maintenance are established annually. Students are reviewed after 2 consecutive semesters. Students who fall below the established criteria will be given one semester of grace to restore their GPA. If they are not successful the scholarship will be revoked. It will be reinstated when the student is successful. Scholarships cannot be received retroactively.

- Since Financial Aid and Scholarship Funds administered by Polytechnic are limited, students should be aware that it is very unwise to enroll at Polytechnic without financial aid support, on the assumption that at a later date financial aid will be available. Given the fixed amount of resources, Polytechnic deems it unethical to withdraw support from students who have based attendance at Polytechnic on the Financial Aid awarded them in order to release funds to assist new applicants. Funds from financial aid programs not administered by Polytechnic, such as the PELL Grants, TAP, and the Guaranteed Student Loan Program, are available to eligible students whether or not students have already received funds from these programs.

- Grants of Title IV Aid (Pell, Supplemental Educational Opportunity Grant, College Work Study, Perkins Loan and Guaranteed Student Loan) are contingent upon provision of the following documents: 1) properly signed Financial Aid Acceptance Forms explaining the terms of the awards; 2) Financial Aid Transcripts from all previously attended institutions of higher education; 3) copies of students' (or parents') IRS Form 1040 or 1040A/EZ, if requested; 4) signed affidavits acknowledging Selective Service Registration; 5) proof of permanent residency status, and 6) any other requested documents.

- Students must assume responsibility for reading, understanding and abiding by the terms of all financial aid documents you sign; you should also keep copies of them.

- Students must know each financial aid program's limits on the amount of aid and number of years they can receive such assistance, and make appropriate plans to finance that part of their education which exceeds the limits.

- Students must report any outside financial aid received or any changes in family situation, so that the Office of Financial Aid can make proper adjustments in awards offered.

- Students must not be in default on a Perkins Loan or a Guaranteed Student Loan, nor can they owe a refund on a PELL Grant or a Supplemental Educational Opportunity Grant, if they wish to continue receiving financial aid.

- In order to continue receiving financial aid, a student must maintain full-time, matriculated (degree) status and must complete a minimum number of quarter credit hours with a minimum grade point average to be considered making satisfactory academic progress toward his/her degree as illustrated in the academic policies section of this catalog. Failure to make satisfactory academic progress may result in the loss of financial aid.

- Students who have lost eligibility for financial aid may appeal to request reinstatement due to unusual or extraordinary circumstances. Students who wish to appeal must, within 20 days of notification, complete the Appeals Form and submit it to the Financial Aid Committee on Academic progress. On the form, describe the reasons for the appeal and provide documentation. If necessary, students will also be expected to appear in person to meet with a member of the Committee.

I. GRADUATE FELLOWSHIPS AND ASSISTANTSHIPS

Fellowships and assistantships are available for advanced study leading to the master's, engineer, or doctor's degree in engineering and science disciplines. An applicant must hold a degree from an institution of recognized standing. A new student can apply by completing the appropriate question on the "Application for Graduate Admission" form. A continuing student should consult the academic department.

Research Fellowships

Fellows are assigned to research leading to the fulfillment of the thesis requirement of the graduate curriculum in which they matriculate while pursuing a full-time program of study. Tuition for the academic year (less any other entitlements) is remitted.

Teaching Fellowships

Fellows are full-time graduate students who participate half-time throughout the academic year in teaching assignments. Tuition for the academic year (less any other entitlements) is remitted.

Special Fellowships

There are available a number of special fellowships sponsored by industry and foundations. Information may be obtained from the academic departmental office concerned.

Graduate Assistantships

Opportunities are available to full-time doctoral students who have completed 90 graduate units including all dissertation research credits to work on sponsored research projects. Assistants devote full-time to research leading to the fulfillment of doctoral research requirements of the graduate curricula in which they matriculate.

II. REDUCED TUITION PROGRAM FOR HIGH SCHOOL AND TWO-YEAR COMMUNITY COLLEGE TEACHERS

A reduced tuition program is offered for full-time high school and two-year community college teachers to encourage their pursuit of graduate studies at Polytechnic. The plan provides a tuition reduction of one-third for graduate courses, taken at any campus. Degree candidates and special students are eligible.

Written verification of employment as a full-time high school or college teacher, signed by the department head and an officer of the applicant's institution, must be submitted at each registration. Substitute, part-time, adjunct, or temporary appointments are not valid. Only those holding full-time, permanent teaching appointments in a public or private secondary school or accredited two-year community college, located in the New York metropolitan area, are eligible to participate in this program.

This policy is not retroactive, and students may not participate in more than one tuition reduction or remission program.

This policy is subject to annual review.

III. GRADUATE TUITION ASSISTANCE PROGRAM (TAP)

Graduate TAP is an entitlement/grant program administered annually by the New York State Higher Education Services Corporation (HESC) for New York State resident students.

Eligible applicants must (1) be New York State residents, U.S. citizens or eligible non-citizens, (2) be enrolled full-time as a matriculated student and (3) meet the following income requirements:

> If financially dependent on parents OR if financially independent of parents and are married or have tax dependents, have a New York State Net Taxable Income of less than $20,000.

> If financially independent of parents and single with no tax dependents, have a New York State Net Taxable Income of less than $5667.

Using the TAP Adjustment Supplement, the Net Taxable Income is divided by the total number of family members in full-time attendance.

The maximum annual award is $1200 and is reduced according to family income levels. No award is less than $100 per year. TAP may be received for 8 semesters of graduate studies.

Applicants must apply annually to HESC using the TAP Student Payment Application. Applications are available in the Office of Financial Aid and must be submitted prior to the May 1 deadline during the award year. TAP recipients will receive from HESC an award certificate which is to be presented to the Bursar's office for payment/deferment.

IV. LOANS

Funds donated by the United States Steel Foundation and the Ford Foundation, as well as funds donated in memory of Raymond Kirk, have made it possible for full- and part-time graduate students to obtain loans from Polytechnic.

In both programs the maximum amount of the loan is limited to one-half tuition per semester. An applicant must be registered in a degree program and be a U.S. citizen. More information can be obtained from the Schedule of Classes or the Office of Financial Aid.

TUITION AND FEES

Information on tuition and fees can be obtained from the Schedule of Classes available before the start of each semester. The Registrar, Bursar and Admissions offices also have data available.

For fall 1988, full-time tuition for undergraduate students (12 to 20 credits) is $5,450 per semester. Students enrolled for fewer than 12 undergraduate credits pay $390.00 per credit. Full-time tuition for graduate students is $5,650 per semester, and for part-time graduate courses $430 per unit.

More than 20 credits/units must be paid for individually per credit/unit.

The Polytechnic Corporation reserves the right to alter tuition charges with appropriate notice to students. Such alterations are announced in the *Polytechnic Schedule of Classes*, published as supplements to this catalog twice a year: spring and summer/fall.

Tuition covers instruction costs, use of the libraries and the facilities of the Student Center. Laboratory fees are charged for various laboratory classes. Details of these charges are given in the Schedule of Classes, since they vary from semester to semester. Courses requiring laboratory fees are indicated in the course listings.

Other costs, also detailed in the Schedule of Courses, include new student fee, facilities fee, student activity fee, application fees, transcript charges, add/drop fees, diploma fees and fees for special examinations and dissertations. Housing charges vary according to arrangements at Brooklyn and Farmingdale. For details, consult the Office of the Dean of Students.

The Bursar collects all payments at Polytechnic University. Full tuition and fee payments are due from all students at the time of registration. Payments must be made by cash, check, money order or credit card. Visa and MasterCard are accepted. Evidence of any financial aid should be presented at registration.

Deferred Payment

Polytechnic has no deferred tuition plan. However, outside agencies provide independent tuition deferment arrangements. Information about these agencies can be obtained at the Polytechnic Financial Aid Office. Special education loan programs for both graduate and undergraduate students enable families or students themselves to repay over extended periods in monthly installments and are available at many neighborhood banks. Families may qualify for a New York State Higher Education Assistance Loan. Applications are available at local banks. These loans normally take from six to eight weeks to arrange and process. Consult the Financial Aid section of this catalog for more information.

ESTIMATED COSTS—
ACADEMIC YEAR 1988-89
FOR UNDERGRADUATE STUDENTS

	Commuter	Dormitory	Off-Campus** Self-Supporting
Tuition	$10,900	$10,900	$10,900
Fees	280	280	280
Room and Board	1,657	4,000	5,428
Books and Supplies	350	350	350
Transportation	600	200*	200*
Personal Expenses	1,075	1,075	1,075
TOTAL	$14,862	$16,805	$18,233

ESTIMATED EDUCATIONAL COSTS—
ACADEMIC YEAR 1988-89
FOR INTERNATIONAL STUDENTS*

	Undergraduate	Graduate
Tuition	$10,900	$11,300
Fees	280	280
Living Expenses	5,000	5,000
Personal Expenses, Books and Supplies	3,500	3,500
TOTAL:	$19,680	$20,080

REFUND OF TUITION

All students upon registration, assume obligation for the semester's tuition and other fees. In the event of withdrawal, the right to a refund must not be assumed. Whenever students withdraw from a course or from all courses, tuition charges are adjusted according to the schedule outlined below, provided that

(1) the withdrawal notice is filed within the refund period;

(2) it is submitted in writing to the Registrar; and

(3) the withdrawal lowers the student's program to less than 12 credits.

Withdrawal forms are available in the Office of the Registrar. Filing a withdrawal form in that office is sufficient notification that an adjustment in the records is to be made.

The official withdrawal date is the date the notice of withdrawal is received in the Office of the Registrar, not the last date of class attendance.

Refunds must be requested from the Bursar's office in writing. If no requests are received, the refund amounts will be credited to the student's account. Students will be notified periodically of credit balances so that they may request refunds.

Refund Schedule:

The refund schedule is applicable only during the first four weeks of the semester. If students make official withdrawal from all courses at the University before the first day of classes, 100% is refunded; otherwise, the following refund schedule applies:

*Variable
**Does not include expenses for dependents

Withdrawal during	% Refund
First week of semester	90%
Second week of semester	75%
Third week of semester	50%
Fourth week of semester	25%
After the fourth week of semester	0%

The processing of credits and refunds occurs two months after the start of each semester.

Appeals to the refund schedule must be submitted in writing, with documentation of reasons that exceptions should be made, to the Registrar.

Financial Aid Refund Policy

If the University determines that a student is due a refund, and if that student has received Title IV aid, a portion of that refund will be returned to the aid program according to the following formula:

$$\text{Amount to be returned to Title IV programs} = \text{Institutional Refund} \times \frac{\text{Title IV aid for the payment period (minus work-study earnings)}}{\text{Total aid for payment period (minus work-study earnings)}}$$

In refunding monies to the various financial aid programs, the following priority listings will be used:

1. Guaranteed Student Loan Program (G.S.L.)
2. PELL Grant
3. Supplemental Educational Opportunity Grant (SEOG)
4. National Direct Student Loan (NDSL)

REGISTRATION

Polytechnic University endorses close faculty-student relationships. The faculty advising system is the basis for selection of courses and registration. Each academic department identifies a group of faculty to serve as student advisers. Before registration, students must meet with their advisers and receive approval for their anticipated program of study. A list of advisers and their office numbers may be obtained from each respective departmental office or the Dean of Students.

Information about registration and registration appointments is mailed to continuing students prior to each registration period.

Procedure

All continuing full-time students (graduates and undergraduates) must pre-register for the next semester during the middle of each ongoing semester. Continuing full-time students who do not pre-register will be charged late registration fees of $50. To receive academic credit, registration is required each semester for every course, including thesis. Attendance in class does not constitute registration.

To qualify for credit, students must fill out registration forms, prepare their program of study, have their course selections approved by their faculty advisers, pay appropriate tuition and fees to the bursar, and have their registration forms accepted by the Office of the Registrar according to published deadlines.

Program Adjustments (Add/Drop)

Additions or deletions may be made to a student's program only during the first five class days of the fall and spring semesters or summer sessions. Students may obtain program adjustment forms from the Office of the Registrar. To add or drop courses students must have written approval of the major adviser.

Fees will be charged for adding or dropping courses or changing sections, except where scheduled changes are necessitated by course cancellations, section adjustments, or other administrative changes.

Students may not add or change courses within the freshman English program, or change sections within the freshman mathematics or physics programs without the permission of the respective directors of these programs.

Authorized changes within these two programs will be allowed through the fourth week of the semester.

Final Day for Registration

Students are expected to complete registration during the official registration period, but must complete registration by the end of the fifth class day of each semester as indicated in the academic calendar. Students who do not complete registration by the end of that day of the semester will not be admitted until the following semester, except by special permission of the dean of the appropriate academic division and the course instructor. Students who register after the official registration period will be charged a late registration fee. Fees may be waived by the Registrar in clearly justifiable cases.

Course Prerequisites

To be eligible for admission to an advanced course, students must have passed all prerequisite subjects as listed in the description of courses. Any exception to this policy must be approved, in writing, by the major adviser and divisional dean.

Student Identification

All students are required to carry and maintain at all times photo-identification cards issued by the Office of the Registrar. The photo-IDs must be presented at each registration for validation and shown to staff members of the Office of the Registrar when requesting transcripts. IDs must be presented and/or surrendered to any official of the University upon request.

Student ID numbers are used to identify individual records (billing payments, grades, etc.) for students' entire tenure at Polytechnic, from the time of admission to the completion of degrees. Student ID numbers are sometimes social security numbers, but not always. If students do not have social security numbers when admitted (as in the case of international students), students are assigned numbers by the Admissions Office. These assigned numbers will be used throughout students' careers at Polytechnic, unless and until a social security number has been obtained. In such cases, the new social security number should be documented to personnel in the Office of the Registrar, from which time it will replace the number assigned by the Admission's staff as the student's regular ID number.

DEGREE REQUIREMENTS

CREDITS AND UNITS

Undergraduate semester credits are based upon the number of 55-minute periods scheduled each week during one semester. Normally one credit signifies either one 55-minute period of class work, or three hours of undergraduate laboratory, over a period of 14 weeks. The final examination period is an intergral part of the semester.

Graduate studies are expressed in terms of units. One 55-minute period of graduate class work for a semester carries 1 1/5 graduate units. A standard course meeting 2 1/2 academic periods a week would be equivalent to three units. Courses meeting more or less than 2 1/2 academic periods a week carry a proportionate evaluation.

CREDITS FOR COURSES TAKEN ELSEWHERE

Undergraduates

Students entering Polytechnic with advanced standing will receive appraisals of substitutions allowed based upon credit transferred from their former colleges. Senior subjects or their equivalent, determined in consultation with departmental advisers, are to be taken at Polytechnic. Minimum residence requirements for the bachelor's degree include the successful completion of 34 semester hours in approved upper-class subjects. See "Admission as a Transfer Student" page 17 for further details concerning undergraduate transfer credit policies.

Graduates

A limited number of units for graduate courses completed with honor grades (A or B) by students from accredited institutions may be allowed toward meeting the requirements for master's or doctor's degrees provided these courses were acceptable at those institutions for similar degrees, usually after obtaining the bachelor's degree. Such transfer credits/units are determined by the department.

Graduate courses taken at Polytechnic, while a student is pursuing an undergraduate degree at Polytechnic, subsequently may be applied toward a graduate degree if those courses were not used to fulfill undergraduate degree requirements. Such courses are not subject to the nine-unit transfer limitation for the master's degree.

Transfer Credits While in Residence

Students in residence are expected to take the course work which is required at Polytechnic. Exceptions can be made in cases in which Polytechnic does not offer courses of importance to the attainment of the student's academic goals.

To obtain credits/units for courses taken elsewhere while in residence at Polytechnic, written permission must be obtained from the academic advisers and the department heads of the courses for which credits are requested, before the start of courses (forms for such permission are available in the Office of the Registrar.) The following requirements may apply:

- The other institutions must be accredited.
- Grades earned must be at least C for undergraduate courses and B for graduate courses.
- Pass/fail courses are not acceptable.
- Only credits/units will be granted. (Grades are not computed in the cumulative averages).

In most cases, authorization to take courses at another school is required from the appropriate academic dean at Polytechnic.

REQUIREMENTS FOR THE BACHELOR'S DEGREE

In all fields of concentration, a program of study (curriculum) is prescribed. The student is admitted to register in one of these programs. Subsequent transfer to another program requires approval by the head of the new department. The change becomes official only after the proper form has been received by the Office of the Registrar. To qualify for the degree the student must complete the program as outlined in the respective departmental section of this catalog.

University Degree Requirements—In the humanities and social sciences, students must take HU 101 and either HU 200 and SS 104 or IS 140 and IS 141. Students placed in HU 103 on the basis of the English Composition Placement Test administered at Polytechnic to all incoming students may substitute HU 103 for HU 101. Students placed in HU 008 or HU 009 must complete this non-credit writing course before taking HU 101 (or HU 103).

All full-time undergraduate students are required to complete four semesters of Physical Education (no credit). ROTC courses (MS 101, 102, 201, 202) may be substituted for Physical Education.

Humanities and Social Science Requirements—The University requires that all undergraduates take at least 24 credits in the humanities and social sciences. Nine of these credits must be taken in the courses listed above under University Degree Requirements. As part of the remaining 15 credits, students are strongly urged to select a specific area in which to concentrate their studies (such as literature, communications, the arts, philosophy, or comparative religions in the Department of Humanities and Communications, or economics, history, anthropology, or psychology in the Department of Social Sciences). In consultation with their adviser, students elect a number of courses within the chosen area. A modern language may be chosen as a suitable area; however, students without prior knowledge of the language must plan to devote at least 12 credits to it. Additional courses in the humanities and social sciences may be taken as free electives.

HUMANITIES AND SOCIAL SCIENCES REQUIREMENTS FOR ENGINEERING AND COMPUTER SCIENCE MAJORS

All engineering and computer science majors are required to take the following courses:

HU 101 - Writing and the Humanities I - 3 credits
HU 200 - Writing and the Humanities II - 3 credits
SS 104 - Contemporary World History - 3 credits

The ability to communicate is critical to the success of the engineer and computer scientist. Polytechnic has a strong program to supplement HU 101/200. All incoming freshmen, and some advanced students, are given a Polytechnic Placement Exam in English Composition, prior to registration.

Students needing additional help replace HU 101 with HU 103, which covers the same subject matter, and is also 3 credits, but includes 3 additional hours per week of classroom guidance, with no additional tuition. Students needing extensive assistance are placed in HU 008 or HU 009, each of which meet for 6 hours/week, but are not given degree credit.

Students desiring additional help in public speaking (HU 119 or HU 120) or report writing (HU 110) are offered special courses in these areas. Some curricula require one or more of these. Consult the programmatic sections of this catalog for these requirements.

SS 104 is a sophisticated approach to contemporary history especially designed for engineering and computer science majors. SS 104 cannot be taken until the student has been placed in HU 101 or completed HU 103. No transfer credit is given for SS 104. An alternative to the HU 200/SS 104 pair is IS 140/141.

All undergraduates enrolled in an engineering program must take a minimum of 24 credits in the humanities and/or social sciences. The undergraduate computer science program requires 30 credits in these areas, and the electrical engineering curriculum requires 28 credits. Of these, 16 credits must meet the criteria of the Accreditation Board for Engineering and Technology (ABET) for humanities and social sciences content. These 16 credits MAY NOT include skills-oriented courses, such as public speaking, college composition, technical writing, or English as a Second Language. Courses in literature, foreign languages, history, psychology, philosophy, anthropology, sociology, economics, music and fine arts are acceptable. Because of the credit structure of humanities and social sciences courses at Polytechnic, this requirement is met by taking 18 credits meeting these ABET criteria, except in electrical engineering, where 17 credits is taken.

Of these content credits, 6 credits are provided as part of courses required of all engineering and computer science majors, HU 101/200 "Writing and the Humanities I and II" (3 of 6 credits) and SS 104 "Contemporary World History" (3 credits). ABET also requires that humanities and social sciences coursework reflect both breadth and depth of coverage. The depth requirement is met by selecting humanities and social sciences electives in areas of CONCENTRATION including some advanced coursework.

To assist students in selecting an appropriate area or areas of concentration in Humanities and/or Social Sciences, the following list of appropriate sequences is provided. Students must select their humanities and/or social sciences electives in a way which provides either (a) one sequence in an area of concentration consisting of a minimum of three courses, at least two of which are at an advanced level, or (b) two sequences in areas of concentration consisting of a minimum of two courses each, at least one of which is at an advanced level in each sequence.

Additional humanities and/or social sciences courses may be elected without restriction, as long as prerequisites are properly observed, at least 16 total humanities and social sciences credits meet ABET content criteria, and departmental degree requirements are met. All selections are subject to the approval of the student's major adviser. Advisers in the Departments of Humanities and Social Sciences are also available to assist students in their selection of electives.

APPROVED CONCENTRATIONS IN HUMANITIES AND SOCIAL SCIENCES FOR ENGINEERING AND COMPUTER SCIENCE MAJORS

I. Elective Sequences in the Humanities

For the following concentrations, students should complete HU 101 or HU 103 and HU 200 or IS 140 before taking concentration courses. With the permission of the major advisor and the appropriate HU advisor, the student may be permitted to take a concentration course concurrently with HU 200 or IS 140.

English Literature

INTRODUCTORY COURSES:
HU 211 English Literature from Beowolf to 1800
HU 212 English Literature 1800 to Present

ADVANCED COURSES:
HU 222 Shakespeare
HU 281 Comedy
HU 301 Special Topics in Literature (if relevant)
HU 213 Science and Literature
HU 264 The Short Story
HU 291 Short Fiction

American Literature

INTRODUCTORY COURSES:
HU 251 American Literature to 1880
HU 252 American Literature 1880 to Present

ADVANCED COURSES:
HU 258 American Thought*
HU 262 Contemporary American Novel
HU 264 The Short Story
HU 272 Contemporary American Poetry*
HU 281 Comedy
HU 283 Modern American Drama
HU 291 Short Fiction
HU 301 Special Topics in Literature (if relevant)
IS 145 The American: The New Man*
IS 146 Brooklyn: History and Culture*

European Literature

INTRODUCTORY COURSES:
   HU 202 Literature of Western Civilization II
   HU 203 Literature of Western Civilization III

ADVANCED COURSES:
   Any courses listed as advanced courses in the English
   Literature sequence.

Philosophy and Comparative Religion

INTRODUCTORY COURSES:
   HU 341 Introduction to Philosophy
   HU 348 Great Philosophers I
   HU 349 Great Philosophers II

ADVANCED COURSES:
   HU 302 Special Topics in Philosophy
   HU 244 Introduction to Logic
   HU 346 Ethical Theories
   HU 347 Ethics and Technology
   HU 352 Philosophy of Science
   HU 353 Philosophy of Technology
   HU 354 Social and Political Philosophy*
   HU 363 World Religions*
   HU 364 Philosophy of Religion*
   HU 365 Science, Technology, and Religion*

The Humanities, Science, and Technology

INTRODUCTORY COURSES:
   HU 349 Great Philosophers II
   and/or
   LA 110 Technology and Society in Historical Perspective

ADVANCED COURSES:
   HU 213 Science and Literature
   HU 300 Special Topics in the Humanities (if relevant)
   HU 301 Special Topics in Literature (if relevant)
   HU 302 Special Topics in Philosophy (if relevant)
   HU 347 Ethics and Technology
   HU 352 Philosophy of Science
   HU 365 Science, Technology, and Religion*
   LA 141 Materials and Social Issues
   LA 142 Machines and Humanities
   LA 143 Information, Communication, and Society
   LA 144 Energy Technology and Social Issues
   LA 150 The Making of Connections

Music and the Fine Arts

INTRODUCTORY COURSES:
   HU 271 Understanding of Music
   HU 382 Fine Arts I

ADVANCED COURSES:
   HU 300 Special Topics in the Humanities (if relevant)
   HU 375 Modern Music
   HU 383 Fine Arts II
   HU 389 Art of Asia*

Modern Languages

A sequence in any of the modern languages offered
requires that the student begin at his or her proficiency
level with the language and continue from there in the
following sequences. No student may receive HU/SS credit
for courses in his/her native language. At least three
courses must be completed to fulfill the concentration
requirements.

GERMAN (regularly offered): ML 111/112/113/114 - German
I, II, III, IV, any advanced German course not requiring
additional prerequisites.

FRENCH (regularly offered): ML 131/132/133/134 - French I,
II, III, IV, any advanced French course.

SPANISH (regularly offered): ML 161/162/163/164 - Spanish
I, II, III, IV, any advanced Spanish course.

RUSSIAN (offered upon sufficient demand): ML 151/152/
153/154 - Russian I, II, III, IV, any advanced Russian course.

At least one introductory course is offered each semester in
each concentration. Most advanced courses are offered at
least once every other year, unless marked by an asterisk.
Courses so marked are given less frequently. At least one
advanced course in each sequence is offered each
semester.

II. Elective Sequences in the Social Sciences

For the following sequences, Introductory Courses may be
taken concurrently with SS 104. Advanced courses require
both SS 104 and one of the Introductory Courses as
prerequisites.

Contemporary European and Russian History

INTRODUCTORY COURSES:
   SS 101 History of Western Civilization I
   SS 102 History of Western Civilization II
   SS 109 Birth of Modern Europe
   SS 120 History of Tsarist Russia
   SS 121 History of the Soviet Union
   SS 154 Russia, China, and the West
   SS 161 Politics and the Film* (if relevant)

ADVANCED COURSES:
   SS 221 The Contemporary USSR
   SS 348 Colloquium in the History of Socialism and
        Communism
   SS 347 Colloquium in Imperialism
   SS 345 Colloquium in 20th Century Thought
   SS 362 Special Topics in History (if relevant)
   SS 300/301 Guided Readings (if relevant)

American History

INTRODUCTORY COURSES:
   SS 101 History of Western Civilization I
   SS 102 History of Western Civilization II
   SS 123 History of the U.S. I
   SS 124 History of the U.S. II
   SS 126 Afro-American History
   SS 161 Politics and the Film* (if relevant)

ADVANCED COURSES:
   SS 226 Problems of American Foreign Policy
   SS 229 Growth of the U.S. Constitution
   SS 347 Colloquium in Imperialism

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* SS 161 may be taken for credit more than once if the content, which varies from semester to semester, is different. This course serves as an appropriate
  prerequisite for several advanced courses depending upon the topics covered. Consult a social sciences adviser for additional information on this course.

SS 345 Colloquium in 20th Century Thought
SS 362 Special Topics in History (if relevant)
SS 300/301 Guided Readings (if relevant)

Political Science

INTRODUCTORY COURSES:
SS 151 Introduction to Politics

ADVANCED COURSES:
SS 221 The Contemporary USSR
SS 226 Problems of American Foreign Policy
SS 229 Growth of the U.S. Constitution
SS 345 Colloquium in 20th Century Thought
SS 347 Colloquium in Imperialism
SS 348 Colloquium in the History of Socialism and
Communism
SS 361 Special Topics in Social Sciences
SS 300/301 Guided Readings (if relevant)

History of Science and Technology

INTRODUCTORY COURSES:
SS 101 History of Western Civilization I
SS 102 History of Western Civilization II
SS 109 Birth of Modern Europe
SS 110 Renaissance and Reformation
SS 133 Archaeo and Ethnoastronomy
SS 135 History of Science and Technology: Antiquity to
Galileo
SS 136 History of Science and Technology: Galileo to
Darwin
SS 138 Technology, Science and Society
SS 182 Man and the Environment

ADVANCED COURSES:
SS 354 Technology Forecasting
SS 330 History and the Environment
SS 332 Science and Technology in America
SS 357 Technology Transfer to Developing Nations
SS 333 Medieval and Renaissance Engineering
SS 338 Galileo Galilei: The Man, His Research, and His
Times
SS 363 Special Topics in History of Science and
Technology

Economics

INTRODUCTORY COURSES:
SS 250 Basic Economics**
SS 251 Micro Economics**
SS 252 Macro Economics**

ADVANCED COURSES:
SS 254 Economic Issues
SS 255 The Contemporary American Economy-Boom or
Bust Thought
SS 258 Comparative Economic Systems
SS 262 Collective Bargaining
SS 263 Labor Economics
SS 265 Money and Banking
SS 267 The Market for Engineers and Scientists
SS 357 Technology Transfer to Developing Nations
SS 358 Human Resource Development in Advanced
Developing Nations
SS 364 Special Topics in Economics
SS 300/301 Guided Readings (if relevant)

Psychology

INTRODUCTORY COURSES:
SS 189 Introduction to Psychology

ADVANCED COURSES:
SS 208/209 Experimental Psychology I, II
SS 203 Learning
SS 204 Physiological Psychology
SS 205 Applied Psychology
SS 206 Human Cognition
SS 214 Social Psychology
SS 215 Abnormal Psychology
SS 216 Personality Development
SS 217 Human Development
SS 310 Genes, Gender, and Society
SS 907 Human Computer Interaction
SS 365 Special Topics in Psychology
SS 300/301 Guided Readings (if appropriate)

Anthropology/Sociology

INTRODUCTORY COURSES:
SS 175 Introduction to Sociology
SS 177 Social Problems
SS 182 Man and the Environment
SS 185 Physical Anthropology
SS 186 Cultural Anthropology

ADVANCED COURSES:
SS 161 Politics and the Film
SS 221 The Contemporary USSR
SS 279 The Sociology of Human Disease
SS 310 Genes, Gender, and Society
SS 347 Colloquium on Imperialism
SS 354 Technological Forecasting***
SS 357 Technology Transfer***
SS 361 Special Topics in Social Sciences (if relevant)

All sequences are available on the Brooklyn Campus.
The following sequences are available on the Farmingdale Campus: English Literature, Philosophy and Comparative Religion, Fine Arts, History of Science and Technology, Psychology, Economics, and Anthropology/Sociology.

Degree Requirements

Students are required to fulfill the following three conditions in order to be certified for bachelor's degrees:

- Fulfill all University and departmental course requirements
- Earn the required number of credits for the Degree Program
- Maintain at least a 2.00 cumulative grade point average

Graduation Check List

Undergraduates who are nearing graduation receive a *graduation check list* which shows the completed courses and their assignment to required areas of study, and lists the courses which remain to be completed for the degree. After approval by the academic department, the graduation check lists are mailed to the students by the Registrar; this

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**SS 250 is a survey of material covered in SS 251/252. Students taking SS 251/252 cannot receive credit for SS 250, or vice-versa

*** SS 354/357 require an additional prerequisite - an introductory course in History of Science and Technology

is usually done during the summer of the year preceding the prospective graduation.

Full-time students receive their graduation check list after completion of 85 credits. This check list remains valid for one and one-half calendar years; a revised list may be issued for any student who does not complete the degree requirements within this time span.

Part-time students are issued a graduation check list after accumulating 105 credits. Students who complete their courses within eight calendar years from the time of their first entry may qualify for the degree under the curriculum in effect at that time, provided that the needed courses are still offered. The eight year period is proportionally reduced for transfer students and for students who were registered full-time during a portion of their attendance. After the expiration of the eight year period the department may issue a revised graduation check list.

Because of curriculum and course changes it is occasionally necessary to substitute courses to meet degree requirements. Such substitutions must be documented, either on the graduation check list or on the *adjustment of degree requirement* form obtainable from the Registrar. All substitutions must be approved by the student's department and by the dean of the academic division.

Students who interrupt the continuity of their registration by a period of one year or more must meet the requirements in effect at the time of the resumption of studies, unless they have been granted a leave of absence which explicitly allows them to pursue the old curriculum after reentry.

Senior Honor Students

Each spring departments select students with high grade point averages who will complete their B.S. requirements during the following year. Those students are listed as Honor Students in the commencement program for the spring they are selected, and are given special permission to make substitutions in their selection of senior courses (e.g., substituting more advanced or graduate courses in place of the usual requirements).

To be eligible for this designation, transfer students must complete at Polytechnic at least one-half of the credits needed to satisfy degree requirements.

Degrees with Honors

Degrees with honors will be awarded at commencement to undergraduate students of high scholastic rank upon unanimous recommendation of the faculty. Honors are based upon the following cumulative grade-point averages:

Degree *cum laude*	3.40 to 3.59
Degree *magna cum laude*	3.60 to 3.69
Degree *summa cum laude*	3.70 or higher

To be eligible for degrees with honors, transfer students must complete at Polytechnic at least one half of the credits required for the particular degree.

Dual Major

A student who meets the graduation requirements in two disciplines is to receive a bachelor's degree indicative of that accomplishment, provided that the student

1. is assigned a "home" department which will be responsible for the student's primary (first) major,
2. applies for and is admitted to the second program in the same manner as a student who wishes to change departments, and
3. has, prior to graduation, approval from each department of the courses for its major.

REQUIREMENTS FOR THE MASTER'S DEGREE

All students qualifying for the master's degree must complete not less than 36 units of advanced study and research in the program elected. To obtain any graduate degree or certificate, students must have a 3.0 grade-point average or better in **all** graduate courses taken (whether or not some of these courses are being used to satisfy specific degree requirements) and a B or better average in all guided studies (readings, project, thesis, and dissertation).

Students may offer no more than 12 units of project or thesis toward degree requirements. Registration for the project or thesis must be continuous until grades are recorded.

A maximum of nine units may be accepted as transfer and validation credits, the latter not to exceed six units. All requirements for the master's degree must be completed within a period of five years after beginning graduate studies at Polytechnic. Any extension of this period requires the recommendation of the departmental adviser and the approval of the Office of Research and Graduate Studies. A minimum of 27 units of work must be taken at Polytechnic.

In addition to required courses, each master's program may include a comprehensive examination, presentation of a seminar, or completion of a project or thesis.

REQUIREMENTS FOR THE ENGINEER DEGREE

Candidates for the Engineer degree must complete a minimum of 36 units of work beyond the master's degree. This work will include a project or evidence of equivalent experience. A maximum of 12 units of project may be submitted toward fulfilling degree requirements. At least 27 units of work must be completed at Polytechnic. Registration for project or thesis must be continuous until grades are recorded.

All work for the Engineer degree must be completed within five years after initiating work for this degree at Polytechnic. Any extension of this period requires recommendation of the departmental adviser and the approval of the Office of Research and Graduate Studies.

The student must maintain a B average for all courses and for the project (if submitted in partial fulfillment of the requirements for the degree).

REQUIREMENTS FOR THE DOCTOR'S DEGREE

Requirements for the doctor's degree are both qualitative and quantitative. Students will find that the formal requirements of residence, course units and dissertation

provide a framework within which they are free to construct individual programs for creative learning.

Graduate students who wish to enter into a systematic program leading to the doctorate must confer with an adviser in the department of major interest regarding selection of courses, major and minor fields of interest, formulation of guidance committees, qualifying and language examinations, and degree candidacy. Students must satisfy the detailed requirements of the degree program chosen.

All candidates for doctorates must complete three years of full-time study or the equivalent, namely, a minimum of 90 units of academic work beyond the bachelor's degree, including a minimum 24 units of dissertation research.

Once the student has started the dissertation, registration must be continuous until the dissertation has been completed and accepted, unless a leave of absence is granted.

Most departments have specific course requirements. A minimum of 30 units, including dissertation units, must be taken at Polytechnic. Each student must maintain an overall B average for all courses and for dissertation units completed for the doctoral degree.

Foreign language requirements, if any, are determined by individual departments.

Full-time students are required to complete all work for the doctorate within six years of initiation of graduate study at Polytechnic. For part-time students, the equivalent maximum time is twelve years. Any extension of these periods requires the recommendation of the Guidance Committee and the approval of the Office of Research and Graduate Studies.

GRADUATE CERTIFICATE PROGRAMS

Polytechnic offers certificate programs in a number of specialized areas (see section "Curricula"). "Application for Graduate Admission" must be completed and the applicant must be formally admitted to the certificate program. A student in a certificate program who subsequently decides to earn a graduate degree must apply to do so. Application to transfer appropriate courses taken for the certificate to the degree program must be made.

To earn a certificate, a minimum of 12 units must be taken at Polytechnic. An average of B or better in all courses is required. No courses applied to a certificate may be applied to other certificates. Requirements for certificates must be completed within three years.

APPLICATION FOR DEGREE

Formal application for the award of the degree must be filed by graduate and undergraduate students. Filing dates for each semester are published in the Schedule of Classes. Students who do not file by the published deadline dates become candidates for the next graduating class.

Applications for the B.S., M.S. and Engineer are available in the Office of the Registrar. Degrees are conferred at the spring commencement. Applications for the Ph.D degree are available in the Office of Research and Graduate Studies. Degrees are certified twice a year at the end of fall

and spring semesters. Filing fees for diplomas are payable at the time of filing in the Office of the Bursar. If award of the degree is delayed, diploma fees are not charged again.

By vote of the faculty, degrees are not awarded to members of the University teaching staff who hold the rank of assistant professor or higher.

THESES AND DISSERTATIONS

Undergraduate Theses

The purposes of the thesis is to apply the knowledge gained in the field of major interest and to familiarize the student with methods of planning, conducting and reporting research.

All students who plan to undertake a thesis project should report to the head of their major department for choice of a thesis topic at least one year prior to graduation. The head of the department will approve requests and appoint a thesis adviser. Students should contact their thesis adviser immediately and register for thesis at the next registration period. Thereafter, students must register for thesis every fall and spring (summers, with special permission) until the thesis is completed and the final grade is entered into the student's permanent record.

The thesis may be a dissertation upon a subject included in the student's courses of study, an account of original research, a report on a project, or an original design accompanied by an explanatory statement. Regulations covering thesis registration and thesis format are available in departmental offices.

All theses and results obtained in connection therewith are the property of Polytechnic University.

Graduate Research
(Projects, Theses, Dissertations)

The investigations undertaken for graduate research have as their primary purpose the development of independent and creative thinking. Through them students are trained in analysis, research and synthesis, and contribute to science and engineering.

Research for an advanced degree shall embody knowledge of the field of science or engineering chosen by the candidate, encompassing an understanding of basic principles, together with a commensurate acquaintance with current practices, the literature and the work of leaders in the field.

Research for the master's and engineer degrees shall exhibit a thorough understanding of advanced scientific thought or ability to apply advanced principles constructively to engineering planning and design.

Research for the doctorate shall exhibit critical and constructive thought as well as ability to use the techniques necessary in the exploration and development of new areas in science or new applications in engineering.

All research should be characterized by accuracy of observation and measurement, by thoroughness of analysis and synthesis' and by clarity and completeness in

presentation. The conclusions presented must be supported by adequate studies and investigations and supplemented by a complete bibliography.

Registration for Theses and Dissertations

After a project or thesis adviser or guidance committee has been appointed, the candidate should register for a number of units to realistically reflect the amount of time the candidate expects to devote to this research. *Registration must be continuous* (every fall and spring, summers with special permission) until an adequate research project and an acceptable thesis have been completed and the required oral examination has been passed. The registration pattern may not be interrupted except with the permission of the Office of Research and Graduate Studies until a grade is entered on the permanent record. If at the end of a semester the work covered by any unit of registration is deemed unsatisfactory by the adviser, re-registration for the same unit may be required; such registration will obligate the student for full tuition and laboratory fees. Registration for the last unit is required until a final grade is submitted to the Office of the Registrar.

Manuscript Presentation

The research is to be presented to the appointed guidance committee by the candidate in final manuscript form for official acceptance on or before the Monday seven weeks before commencement. Draft copies of research manuscripts toward advanced degrees in chemistry and in electrical engineering are required no later than nine weeks before commencement; in chemistry, four typewritten copies are required, in electrical engineering, a single copy.

Research Submission

The format of the bound dissertation is prescribed, and a brochure entitled "Regulations on Format, Duplication and Publication of Project Report, Thesis, and Dissertations" is available from the Office of Research and Graduate Studies and from the various departmental secretaries. Some of the regulations are summarized below.

Master's or engineer degree candidates are to submit four final bound copies of their research, and doctoral candidates must submit five final copies, of which one copy is to be left unbound for microfilming, while the four others are to be bound. Duplication processes of high quality are acceptable. In addition, each doctoral candidate is required to submit two copies of an abstract of not more than 350 words suitable for publication in "Dissertation Abstracts."

The four finished copies are to be submitted to the department for signature and presented to the Office of Research and Graduate Studies before noon on the first Friday in December (for fall degrees) or the first Friday in May (for spring degrees). At the same time, doctoral candidates must submit the unbound copy in a labeled envelope and the two copies of the abstract to the Office of Research and Graduate Studies. The original copy is kept permanently in Spicer Library.

Publication

Doctoral dissertations will be microfilmed at University Microfilms, Ann Arbor, Michigan, and abstracts of them will be published in the journal "Dissertation Abstracts." The cost of this service will be charged to the student. Copies of these microfilms may then be purchased from University Microfilms by any interested person.

The faculty regards publication of the major content of a doctoral dissertation in a recognized scientific journal as a necessary final step if the work performed is to achieve maximum usefulness. The publication must indicate, by footnote or otherwise, its basis is a Polytechnic University dissertation.

PRIZES AND AWARDS GIVEN AT GRADUATION

PROFESSOR TURNER ALFREY PRIZE
WILLIAM R. ALLEN AWARD
AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS
  AWARD
AMERICAN INSTITUTE OF CHEMISTS AWARD
AMERICAN SOCIETY OF MECHANICAL ENGINEERS AWARD
JOHN W. ANDREWS PLACEMENT AWARD
RICHARD W. BLOCK AWARD
JOHN R. BRIERLEY ALUMNI AWARD OF SERVICE
PEARL BROWNSTEIN DOCTORAL RESEARCH AWARD
PEARL BROWNSTEIN FRESHMAN AWARD
PEARL BROWNSTEIN SENIOR AWARD
DOW JONES WALL STREET JOURNAL STUDENT ACHIEVEMENT
  AWARD
SIMEON GANG AWARD
MARGARET GOLDSTONE MEMORIAL FUND AWARD
GRUMMAN AEROSPACE CORPORATION AWARD
GRUMMAN AEROSPACE CORPORATION SCHOLASTIC ACHIEVE-
  MENT AWARD
HAROLD HERTZBERG AWARD
JAMES H. J. HUGHES, JR. AWARD
INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS AWARD
INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS STU-
  DENT BRANCH AWARD
NOAH A. KAHN A.S.T.M. COMMITTEE E-7 AWARD
SYLVIA KERTESZ AWARD
KINSELLA HUMANITARIAN AWARD
RAYMOND E. KIRK AWARD
MERMAID CLUB AWARDS

OMEGA CHI EPSILON AWARD
DAVID B. PORTER AWARD
ALFRED RAYMOND PRIZE
RAYTHEON — SPECIAL SERVICES AWARD
JULIAN R. REASENBERG MEMORIAL AWARD
BERNARD AND FLORENCE RECHTSCHAFFEN HUMANITIES AWARD
ROBERT RIDGWAY STUDENT CHAPTER PRIZE
DEBORAH ROSENTHAL, M.D., AWARD
MYRON M. ROSENTHAL ACADEMIC ACHIEVEMENT AWARD (C.S.)
MYRON M. ROSENTHAL ACADEMIC ACHIEVEMENT AWARD (E.E.)
MYRON M. ROSENTHAL PRIZE (E.E. AND C.S.)
MYRON M. ROSENTHAL STUDENT COUNCIL AWARD
RICHARD ROSENTHAL AWARD
SIDNEY A. SAVITT AWARDS
GEORGE D. SCHAEFER AWARD
WILLIAM H. SEARIGHT AWARD
SEYMOUR L. SHAPIRO AWARD
SIGMA XI SENIOR RESEARCH AWARD
GENERAL JOSHUA W. SILLS AWARD
IRVING SKEIST AWARD
ALBERT E. SOBEL AWARD
SOCIETY OF AMERICAN MILITARY ENGINEERS AWARD
WILLIAM J. STOLZE AWARD
TECHNICAL WRITING AWARDS
THEODORE CLINTON TOWL AWARD
ROLAND WARD PRIZE
HELEN WARREN ENGINEERING AWARD
WARREN AND MARY ANN WINSCHE AWARD

ACADEMIC POLICIES

THE FAMILY RIGHTS AND PRIVACY ACT (Buckley Amendment)

Description of the Act: The Family Rights and Privacy Act of 1974 grants to students certain rights, privileges and protections relative to individually identifiable student educational records which are maintained by the University. Specifically, (1) the student's educational records (with the exception of directory information) will be released to third parties outside Polytechnic only with the student's written consent, (2) the student has the right to inspect his or her own individually identifiable educational records, (3) the student has the right to have the information contained in his or her individually identifiable educational records reviewed.

The Family Educational Rights and Privacy Act permits the release of *directory type information* to third parties outside Polytechnic without written consent provided students have been given the opportunity to withhold such disclosure. Polytechnic reserves the right to disclose, at its discretion, the following categories of personally identifiable directory information: name, class year, major field, dates of attendance at Polytechnic University, degree. Currently registered undergraduates and graduate students may withhold directory information by requesting this in writing to the Office of the Registrar each semester.

Long Island campus students' names, addresses and telephone numbers may be released to other students for the purpose of arranging car pools. If students wish this information to be withheld, they must notify the Office of the Registrar at the Long Island campus.

CLASS STANDING

Undergraduates. Students are classified at the end of each semester by the Office of the Registrar on the basis of earned and/or approved transfer credits beginning September 1 as follows:

Freshmen	1-27 credits
Sophomores	28 credits plus
Juniors	62 credits plus
Seniors	95 credits plus

CREDITS PERMITTED

Undergraduates

Full-time. A student who takes 12 or more credits is categorized as full-time. The maximum course load for full-time undergraduate students is normally 19 credits. Students in special situations (such as graduating seniors or ROTC cadets) must receive permission from the head of their major department for any program above 19 credits. Students who register for more than 20 credits will be charged the per credit rate for additional credits or half credits beyond 20.

International Students. International students on F-1 or J-1 visas are required to enroll in a full-time program of study each semester.

Part-time. Students registered for less than 12 credits per semester (except summer) are considered part-time students. Part-time students do not qualify for most financial assistance programs.

Summer and Intersessions. Students may register for seven credits for each six-week summer term and for no more than 14 credits for the combined 12-week summer session. Six credits for a given summer term is considered full-time status, particularly for financial aid purposes. Courses taken during intersession are treated as if they were taken during the subsequent semester or summer session for purposes of student records and credit.

Graduates

Full-time. Registration for 12 units or more categorize graduate students as full-time. Students who register for more than 20 units will be charged the per unit rate for additional units or half units beyond 20.

Part-time. Students registered for less than 12 units per semester (except summer) are considered part-time students. Part-time students do not qualify for most financial assistance programs.

GENERAL INFORMATION

COURSE WITHDRAWAL

Students may withdraw from a course or courses without academic penalty through the 10th week of the normal fall or spring semester. When the duration of the course varies, as in 6, 9 or 12 week courses, withdrawal must be filed before two-thirds of the sessions is completed. Withdrawals must be filed with the Office of the Registrar by 5:00 PM on Friday of the week indicated. In the case of a two week session, withdrawal must be filed by 5:00 PM of the seventh day. Students who file a course withdrawal form with the Office of the Registrar by scheduled deadline will automatically receive a grade of W. Once entered on the student's record, the grade of W cannot be changed to any other grade. A grade of F will be recorded for any student who ceases to attend a course without notifying the Office of the Registrar in writing.

TOTAL WITHDRAWAL FROM THE UNIVERSITY

Students who *withdraw completely* during a semester in which they are registered must notify the Dean of Students or the Office of Research and Graduate Studies. No withdrawal is official unless a written form is approved and submitted to the Office of the Registrar. Mere absence from classes does not constitute official withdrawal, but will lead to failure grades of F recorded for the semester.

AUDITING COURSES (Graduate Students)

Graduate Students have the option of auditing courses instead of receiving units and grades for them. Regular tuition is charged, and courses are treated as part of a full-

time load. An AUD notation is made on the student's permanent record.

Interested graduate students should see their advisers and must notify the Office of the Registrar within the first six weeks of the semester of their selections of audit status. Under no circumstances may an audit status be changed to credit status once elected.

CREDIT BY EXAMINATION (Undergraduate Students)

Undergraduate students with an outstanding record or with specialized competence may establish a maximum of 18 credits toward the baccalaureate degree by passing comprehensive examinations. Each department determines the courses in which such an examination is available and the examination format. Students must obtain approval of the department giving the course and the department of major study.

A grade of B+ or better is required to achieve credit. Students who register for or attend a course at the Polytechnic may not subsequently take the examination for credit for this course or for a course with similar content. No examination may be taken more than once.

A specified fee is paid to the bursar in advance of each examination. The course credits are posted on the permanent record without a grade, and do not count towards the minimum residence requirement for the bachelor's degree or for a degree with honors.

In the area of foreign languages, those presenting their native tongue or the language in which they were schooled are excluded from credit for the first four semesters of work in that language.

VALIDATION CREDITS (Undergraduate and Graduate Students)

When it is unclear whether a course taken outside Polytechnic is suitable for transfer credit, a student may qualify for transfer credit by passing a validation examination.

Permission to take such an examination must be recorded in advance on the student's transfer credit evaluation form. The format of the examination is at the discretion of the department giving the course. Scheduling of the examination is by mutual agreement, but in no event later than one calendar year after the student begins studies at Polytechnic. A grade of C or better is required to validate the course credits for undergraduate students. A grade of B or better is required for graduate students. An examination may not be taken more than once. A student who registers for or attends the course at Polytechnic forfeits the right to take a validation examination.

The sum of validation credits/units and transfer credits/units is limited to a maximum of nine units for the master's degree.

TRANSCRIPTS

Polytechnic complies with the provisions of Public Law 93-380 "The Family Rights and Privacy Act" and will issue

personally identifiable information only upon written authorization from students.

Official transcripts of the scholastic record of any student or graduate will be issued only upon written request or upon submission of a signed release. Official transcripts will be sent directly to the school to which the student is transferring or to other properly authorized parties. In no case, however, can a student receive *official* copies of his or her own transcript. Unofficial student transcripts are available to any student upon request in writing. The first transcript will be issued without charge.

Polytechnic reserves the right to withhold the issuance of a student's transcript because of failure to meet financial indebtedness to Polytechnic.

COMPUTATION OF GRADE-POINT AVERAGE

Undergraduate Grading

The weighted grade-point average of an undergraduate student is determined by the Office of the Registrar on the basis of the following numerical values assigned to the letter grades:

Grade	Point Value	Description
A	4.0	
A-	3.7	Excellent
B+	3.3	
B	3.0	Good
B-	2.7	
C+	2.3	
C	2.0	Passing
C-	1.7	
D+	1.3	Deficient Passing
D	1.0	
F	0.0	Failing
S	-	Satisfactory
U	-	Unsatisfactory Grades used in non-credit courses and as temporary grades in project and thesis courses.
W	-	Withdrawal
I	-	Incomplete (See paragraph "Incomplete Grades.")

In the computation of grade-point averages, courses are not considered for which the notation W or I is entered upon student records, nor where S or U has been assigned.

Grade-point averages are computed by multiplying the number corresponding to the grade in each course by the hours of credit for the course, adding these products for the courses taken and then dividing this sum by the total number of hours represented by the courses considered.

Course Repeats

If an undergraduate student takes a course two or more times, only the second and subsequent grades will count toward the student's grade-point average, provided the second taking of the course is completed within one year of the first. If the course is not offered within one year, it must be taken at the time of its first offering thereafter. This applies whatever the first and second grades.

Graduate Grading

For the purposes of computing graduate grade-point averages, the following schedule will be used:

Letter Grade	Grade-Points
A	4.0
B	3.0
C	2.0
F	0.0

When a student repeats a course, the lowest grade will not count towards the grade point average. All other grades in a repeated course will be included in the grade point average.

The AUD notation is used for audited courses. Notations AUD, W, and I are not counted in the grade-point average. S or U grades are used for continuing research registration until the work is completed, when the earned letter grade is entered on the permanent record. The grade-point average is not shown on the graduate permanent record.

INCOMPLETE GRADES

When for valid reasons, such as illness or some critical emergency, a student is unable to complete the course work at the usual time, the instructor may give a grade of I. Durations of these temporary grades are determined by instructors.

An I grade lapses into a grade of F if the student fails to complete course work within one year. If a student re-registers for a course in which an I grade was given, the I grade lapses to an F.

All I grades must be converted prior to graduation.

CHANGE OF DEPARTMENT

Even though students voluntarily indicate their field of special interest on their applications, it is expected and understood that some will change departments. Final approval for such action by undergraduates must be obtained from the adviser of the new department.

Graduate students must apply for a change of department through the Office of Research and Graduate Studies. Such applications will require the approval of the departmental adviser. Students changing departments at the graduate level may be required to satisfy new conditions consistent with the requirements for the degree.

LEAVE OF ABSENCE

Undergraduates

A student wishing a leave of absence must discuss this with the Dean of Students. A student desiring to re-enter after a period of absence may submit a request for readmittance by filing an application with the Office of Admissions.

Graduate

Part-time graduate students, who last attended Polytechnic within a three-year period before the semester for which they are seeking readmission, need no formal readmission. Full-time students who desire to interrupt their studies may request a leave of absence for a specified period, usually not exceeding one year. Such requests, when approved by the Office of Research and Graduate Studies, will constitute assurance of readmission to the degree program. Only if a full or part time student has received an approved leave of absence will the time limit be extended by the period of the leave of absence. Forms for requesting a leave of absence are available in the Office of Research and Graduate Studies.

Once a graduate student has begun the dissertation, registration must be continuous, and a leave of absence is required for semesters in which the student will not be registering for research units. Students failing to obtain a leave of absence who wish to be readmitted may be required to register retroactively for those semesters not attended.

CONCURRENT ATTENDANCE

Undergraduate students enrolled at Polytechnic may not enroll for academic credit in another institution at the same time unless they have written approval from their academic adviser and major department head for the courses for which they wish to receive credit. Permission must be obtained in advance of registration at other schools, and the combined number of credits may not exceed the total permissible at Polytechnic.

ACADEMIC STANDING

To remain in good standing, undergraduate students must maintain term and cumulative grade-point averages of 2.00 or greater. In addition, students must successfully complete a minimum number of credits during each term of full-time study. In this instance, "term" is used to refer to fall and spring semesters. "Term," in the case of part-time students, indicates the points at which 12 or more credits are undertaken. Thus, the first term of study ends where 12 credits are accumulated; the second is calculated from that time onward until 24 credits are accumulated. According to these term equivalents, grade-point requirements for part-time students follow those for full-time students.

The minimum numbers of cumulative credits to be achieved by the close of each term of full-time study appear in Table I.

TABLE I

Term	I	II	III	IV	V	VI	VII	VIII	IX	X
Minimum credits successfully completed	6	18	30	44	58	73	88	104	120	136

In calculating the number of successfully completed credits:

1. Credits undertaken for which the grade of F is earned count in calculation of total credits of enrollment. They do not, however, figure into the number of credits successfully completed.
2. Credits originally bearing the grade of F and repeated within one academic year will be recalculated using the second grade earned, thus entering into the number of credits successfully completed during the term in which it is repeated.
3. Credits assigned the grade of W do not appear in the calculation of credits undertaken, earned or successfully completed.
4. Credits with the grade of incomplete will be counted toward enrollment for one year. At the end of that time, any grade of I that has not been changed by the professor of record will go to the grade of F.
5. Transfer students will enter the standard as calculated from the point at which transfer credits place them. It is likely that they will fall between the credit grade-point minima in the same way as students pursuing 126 and 128 credit curricula and four year graduates.

A second requisite for enrollment is the maintenance of a grade-point average of 2.00 or above, or performance approaching 2.00 in a steady and realistic fashion. Grade-point averages are calculated by dividing the number of quality points achieved by the total number of credits undertaken. Accordingly, all credits assigned a letter grade, whether successfully or unsuccessfully completed, are used in establishing the grade-point average. Table II contains the absolute minimum cumulative grade-point average to be achieved by the close of each term of full-time enrollment.

TABLE II

Term	I	II	III	IV	V	VI	VII	VIII	IX	X
Minimum cumulative G.P.A.	1.30	1.40	1.50	1.67	1.78	1.88	1.95	2.00	2.00	2.00

ACADEMIC MONITORING

In an effort to acknowledge the academic accomplishments of our students, as well as to identify academic problems, the educational progress of each student is monitored by the Dean of Students. This monitoring system includes:

1. A review of each student's academic record after each semester;
2. Conferral with the student's academic advisor or other representatives from the student's major department;
3. Frequent meetings with those students determined to be encountering academic difficulties;
4. Assignment of an academic action code.

DEAN'S LIST

Undergraduate students who achieve both cumulative and semester grade point averages of 3.4 or better, with no failures or incompletes, are commended by the Dean of Students and placed on the Dean's list. This list is posted semi-annually for full-time and annually for part-time students. Only those who complete 12 semester hours or more during a regular academic semester (or academic year for part-time students) with a cumulative grade point average of 3.4 are eligible. Students who include project courses in their 12-credit-or-more programs are also eligible for the Dean's List, provided that these courses represent no more than one-half of the credit load for a given period and all aforementioned requirements are met. The Dean's List notation appears on students' permanent records.

PROBATION

Undergraduate

Academic Warning: Students whose grade-point average approaches 2.00 are placed on Academic Warning. Letters are sent to these students warning them of potential problems; urging them to make use of the support services available to them; encouraging them to take whatever measures are necessary to maintain good standing and inviting them to meet with the Dean of Students.

Continued Probation: Students are placed on Continuing Probation when their semester and/or cumulative grade-point averages fall below 2.00, but remain above minimum standards. Students falling into this category are notified by letter and are required to meet with the Dean of Students prior to registering for any further coursework.

Final Probation: Students whose academic record indicates an unacceptable level of academic progress are placed on Final Probation. Notified by letter of their standing, these students are required to meet with the Dean of Students to determine a program of study geared toward improving their performance. Failure to improve their performance will result in disqualification.

Disqualification: The Committee of Standing, comprised of the Dean of Students and representatives of the student's major department, shall jointly disqualify from the University any student whose cumulative average or number of credits successfully completed falls below the appropriate minimum shown in Tables I and II.

Additionally, a major department may disqualify a student at or above the minima listed, if it is indicated that further continued performance will not lead to successful completion of degree requirements. Unless accepted into another department, a student so disqualified will not be permitted to reapply to the University for at least one academic year.

Extenuating circumstances, such as serious medical and personal disorders, must be documented and can lead to the waiver of these criteria for one term. Performance in the subsequent term must meet minimal standards. Such arrangements must be made in concert with the head of the major department and the Dean of Students.

Graduate

A graduate student is expected to progress in the studies pursued and to maintain a B (3.0) average. Failure to do so can result in "academic probation." To compute a graduate grade-point average, the following schedule is used:

Letter Grade	Grade-Points
A	4.0
B	3.0
C	2.0
F	0.0

After the posting of spring grades, graduate students whose grade-point average is below 3.0 will be notified that they are on academic probation. The data for such determination will be provided by the Registrar's Office and copies of all probation notices will go to each department, which will check the accuracy of the grade-point determination. Students with GPAs less than 3.0 will be notified in August by the Dean of Research and Graduate Studies.

An academic department may request that a student be placed on academic probation at any time it finds a student falling below a 3.0 grade-point average. The request must be signed by the department head and sent to the Office of Research and Graduate Studies.

A graduate student on academic probation may not register for further courses without the written permission of the department head and concurrence of the Office of Research and Graduate Studies. When a student is permitted to register, the department will provide the student with a written statement of the academic performance required for the next academic year or semester to retain permission to register in future semesters. This statement will be kept on file in both the Office of Research and Graduate Studies and the departmental office. A student may be denied permission to register by the academic department or the Office of Research and Graduate Studies any time while on academic probation. Students are cautioned that failure to maintain a 3.0 grade-point average may result in loss of *regular* status and/or in refusal of permission to register.

No indication of academic probation will appear on the student's transcript but a record will be kept on file.

CAMPUS LIFE

OFFICE OF STUDENT LIFE

The Office of Student Life is concerned with the overall education of all Polytechnic students, both in the classroom and outside of it. Responsible for the operation and maintenance of student-oriented and student supporting programs and services, the office helps students obtain maximal benefits from their training — academically, culturally and socially — and supplements and reinforces the educational programs by:
- Providing Freshmen Services, including orientation, the SL101 course, academic monitoring, counseling/tutorial referrals, and other services as needed
- Providing services to guide students in obtaining the most satisfactory results in scholarship and personal adjustment
- Giving assistance to students in matters such as health insurance, housing and community resources
- Coordinating the cocurricular student activity groups and organizations
- Representing student interests in the decision-making processes of Polytechnic
- Keeping the student aware of the rules and policies of Polytechnic
- Administering the academic and disciplinary policies of Polytechnic

FRESHMAN SEMINAR:
SL 101 STUDENT SURVIVAL
COURSE DESCRIPTION

SL101 is designed to introduce entering freshman students to the University and to support their efforts to achieve success in an unfamiliar environment. New academic challenges and adult responsibilities, new people and situations, new time demands and commitments, and the need for a new level of personal organization are all factors in the transition to college. "Student Survival" provides freshman students with opportunities to develop new skills and resources which may enhance their chances for success.

Topics covered in the course include:

- An introduction to key academic and administrative policies, procedures, departments and personnel at Poly
- Study skills, including notetaking and critical reading
- Effective networking
- Time management
- University support services
- Health and Wellness
- Effective communication
- Test-taking techniques
- Problem-solving
- Goals, attitudes and values
- Career awareness
- Library research

SL101 is required for all entering freshmen as an orientation to the academic and social challenges of higher education, and as preparation for the critical choices and decisions college students must make.

STUDENT RETENTION

As required by the New York State Education Department, Higher Education Data System, the Polytechnic conducts a yearly cohort survival analysis. This study is designed to collect data for a group or cohort of first-time (never attended college before), full-time freshmen who enter Polytechnic. The data measure retention patterns, and indicate the amount of time needed to complete undergraduate degrees at Polytechnic.

The initial cohort for the fall 1986 study was the group of first-time, full-time students who entered as freshmen in the fall of 1980.

Of that entering class, 57.5% received their Bachelor of Science degree within four years; 65.8% graduated within five years; and 70.3% completed their degree within six years of their first term.

UNDERGRADUATE ORIENTATION

Orientation programs are planned for the beginning of each semester. Incoming students are introduced to the academic and social environments of Polytechnic. Informative sessions, advisement and activities related to student life are offered. New students are welcomed and assisted in making the transition from their former academic environment to Polytechnic as comfortable as possible. All new students are invited to participate in the New Student Overnight Trip, held annually at the beginning of the fall semester. All freshmen are required to take the freshmen seminar course, entitled "SL 101 Student Survival." This course provides freshmen with skills training as well as a continued orientation to college at Polytechnic.

UNDERGRADUATE ADVISERS

Freshmen are assigned an adviser in their major department who is available for individual counseling on all academic and related matters. Faculty members also serve as advisers to undergraduate extracurricular activities.

GRADUATE ADVISERS

Representatives of the various departments are assigned as advisers to assist graduate sudents in the selection of courses to meet their individual needs, to aid them in planning a program for an advanced degree and to guide them in their professional advancement.

COUNSELING SERVICES

Polytechnic offers no psychological services, other than referrals to outside sources. Often students require counseling in dealing with family problems, study habits or adjustment problems. These may be handled by the Office of Special Services. However, referral for psychological counseling is offered by the Office of Student Life at no charge. There may be a fee for services by these agencies, on a sliding scale based on income and expenses.

OFFICE OF SPECIAL SERVICES

Tutoring and counseling services are offered through Polytechnic's Office of Special Services. If students need academic assistance, the Office of Special Services provides tutoring on an individual or group basis. Qualified upperclass students serve as mathematics, physics, computer science and chemistry tutors.

Interested students can also take advantage of individualized study skills advisement or workshops dealing with note-taking, time management and test-taking. These academic-related skills assist students in successfully mastering the technical curriculum at Polytechnic.

Special Services also provides vocational and personal counseling. On-site visits and plant tours are arranged to help students explore the various opportunities available to them when they leave school.

Addressing the varied needs of the Polytechnic student is the primary goal of the Special Services Office. All tutorial, educational and counseling support services are provided free of charge. Because the Office of Special Services is sponsored in part by a grant from the United States Department of Education, some students requesting assistance must first meet the federal eligibility guidelines.

THE LEARNING CENTER

The Learning Center is a "drop-in" facility open daily on both campuses from 10:00 AM - 4:00 PM offering help to students having difficulties in chemistry, mathematics, and physics. It is not a tutoring program. A staff of qualified juniors, seniors, and graduate students assists students who have specific problems with their work. In addition, evening hours and help in computer science are available at the Farmingdale campus.

Nearly all student problems can be handled by these student helpers. More difficult problems are referred to the director or the course instructor. Students needing regular one-on-one tutoring are referred to the Office of Special Services.

INTERNATIONAL STUDENTS

All international students and scholars are REQUIRED to contact the International Students Office immediately upon arrival. Students must bring their immigration documents and passports with them for their initial meeting.

Polytechnic University has enrolled international students in both graduate and undergraduate studies for many years. Students holding visas make up approximately 10% of the Polytechnic population and are an integral part of Polytechnic. Faculty and administrators are sensitive to the needs of international students and strive to meet them. Services for international students are coordinated by the Student Life Staff and are primarily housed in the Student Center on the Brooklyn campus. Information regarding immigration compliance, housing, health insurance, special events and referrals are available through the International Student Office in the Student Center.

For further information, consult those sections dealing with graduate and undergraduate admissions.

HANDICAPPED STUDENTS

Polytechnic makes every effort to provide full program accessibility and barrier-free restrictions so that handicapped individuals may fully participate in the life of the community.

Polytechnic fully supports Section 504 of the Rehabilitation Act of 1973.

GUIDELINES ON STUDENTS AND RELIGIOUS OBSERVANCES

The faculty of the University has adopted the following guidelines on students and religious observances as recommended by the Commission on Independent Colleges and Universities (CICU). The intent of these guidelines is to encourage independent colleges and universities to reasonably accommodate individual students' religious obligations and practices without penalty.

1. No student will be expelled or refused admission to the University because he or she is unable to participate in any examination, study or work requirement because of his or her religious obligations and practices.
2. The University will accept the responsibility of making available to each student who is absent from school because of his or her religious obligations and practices an equivalent opportunity to make up any examination, study or work requirement which may have been missed because of such absence on any particular day or days.
3. The University requires students to notify the instructor in writing, no later than the fifteenth day after the first day of the semester, of each class scheduled for a day on which the student will be absent because of his or her religious obligations and practices.
4. In effecting these provisions the University's administration and faculty agree to exercise the fullest measure of good faith, and agree that no adverse or prejudicial effects should result to any student who avails himself or herself of these guidelines on religious observances.

CAREER SERVICES

As its name suggests, the Career Services Office is available to assist students in meeting their varied career needs. Polytechnic students are encouraged to begin taking an early and active role in planning for their career development. For this reason, the goals of the Career Services Office are to assist students in:

- Becoming better informed of their career options;
- Identifying and pursuing their abilities and interests;
- Providing experiences and services which will allow students the opportunity to apply their skills and academic background in paid and non-paid work assignments;
- Deciding whether to pursue graduate study or full-time employment; and
- Making a successful transition from the academic setting to the business, government and industrial sectors.

Students at every academic level are encouraged to speak with professional staff concerning both their career

development and job placement needs. On-going developmental career services include: career fairs; career exploration workshops and seminars; and individualized counseling concerning job skills (resume writing, job searching and interviewing techniques) and career decision-making.

Job placement services help students gain valuable work experience in both engineering and non-engineering positions. Full- and part-time job banks, summer job assistance and our extensive on-campus recruiting program meet the needs of job-seeking students. The demand for Polytechnic graduates is great, as evidenced by the more than 125 companies that recruit on campus each year. These companies conduct 4,000 interviews yearly, resulting in employment for a majority of our graduates. During the past four years, the placement rate for Polytechnic graduates has averaged 83%.

As the Career Services Office firmly believes that career planning and development is an on-going growth process, counseling and career planning assistance is available to alumni as well as to those students currently enrolled at the University. Alumni are encouraged to utilize the expertise of the professional staff and to consult the job banks when planning or making career or job changes.

ACCIDENT AND HEALTH SERVICES

Presently, all full-time undergraduates and graduates are covered by accident insurance. Emergency treatment is provided at a nearby hospital, and Polytechnic arranges for escorts to the hospital in case of an accident or health emergency occurring on campus.

Health insurance is recommended for all full-time students. For a specified fee, a student can be covered for health and hospitalization. Foreign students and residence hall students are required to enroll in the Polytechnic policy group or show comparable coverage from another source.

STUDENT ACTIVITIES

Student activities play a very important role in the development of leadership and interpersonal abilities of an individual. Polytechnic encourages involvement in student activities as a significant dimension of the educational process.

STUDENT CENTER

The focus of all student activities on both campuses is the Student Center. On the Brooklyn campus, the building contains a cafeteria, a video game room, student organization offices, lounge space, a six-foot TV screen, and the administrative offices of some Student Life staff.

On the Long Island Campus, Grumman Hall, the Student Center, houses a gameroom which contains video and pinball games, pool and ping pong tables, the bookstore, Career Services Office, Resident Life Office, a darkroom, student organization offices, and the Office of the Associate Dean of Students.

There are approximately 70 student organizations. Each group is responsible for fulfilling the purposes of the organization as set forth in a constitution. Those documents are filed with the Student Council on the Brooklyn Campus

and the Student Government on the Long Island Campus, when an organization is recognized.

STUDENT GOVERNMENT

The student government is the student voice at Polytechnic. The members of the student government are elected during campus-wide elections held every year. It is responsible for administering of student fees, social and cultural programming, and other co-curricular events. There are separate governing boards on the Brooklyn and Long Island campuses.

PUBLICATIONS

A number of student-run publications exist at Polytechnic. There is a newspaper and a yearbook produced on both the Brooklyn and the Farmingdale campuses.

ATHLETICS

For students who seek intercollegiate competition, Polytechnic maintains the following varsity teams for men: baseball, basketball, wrestling, judo, tennis, lacrosse, cross-country, and soccer. For women Polytechnic offers team competition in cross-country, judo, and volleyball.

All full-time undergraduate students who are in good academic standing are eligible for team membership, and are encouraged to participate. The University is a member of the NCAA (National Collegiate Athletic Association), the ECAC (Eastern Collegiate Athletic Conference), and the IAC (Independent Athletic Conference).

The Athletic Department also offers a wide range of intramural sports competition including touch football, basketball, handball, hockey, badminton, mini-marathons, paddleball, softball, tennis, and volleyball. These sports are open to all undergraduate and graduate students as well as the faculty and staff. Contests are held during club hours.

PROFESSIONAL AND DEPARTMENTAL SOCIETIES

Professional and technical societies are established in conjunction with the various departments to enhance the curricula at Polytechnic. The student chapters are branches of national parent organizations. In their chapter meetings, student members hear distinguished guest speakers, plan field trips and read professional papers. There are also four unaffiliated professional societies at Polytechnic.

Fraternities and Sororities
Six national fraternities, and one local sorority, are represented at Polytechnic. Some own or rent property in the Brooklyn area, with two offering live-in accommodations. The social fraternities not only administer an impressive array of social functions for their own members, but also serve the student body in many activities. These include the coordination of blood donation drives, dances, an annual charity drive and handball, basketball and bowling tournaments.

There is one national fraternity on the Long Island campus. This group is very actively involved in the social and community life of the campus.

Clubs
At Polytechnic, there are clubs to suit every interest, whether social, intellectual, religious, musical, cultural or athletic. Many have a long and distinguished history.

Honor Societies
On the basis of their superior records of academic and cocurricular achievements, students are elected during their junior and senior years to one of Polytechnic's chapters of the national honorary fraternities. Closely allied to the professional or technical societies, these honorary societies encourage and recognize outstanding scholarship and leadership.

RECOGNIZED COCURRICULAR ORGANIZATIONS

Professional Societies
American Institute of Aeronautics and Astronautics
American Institute of Chemical Engineers
American Society of Civil Engineers
American Society of Mechanical Engineers
American Society of Metals
Association of Computing Machinery
Institute of Electrical and Electronics Engineers
Institute of Industrial Engineers
Society of American Military Engineers
Society of Automotive Engineers
Society of Physics Students
Society of Women Engineers

Student Organizations
Association of Latin American Students
Association of Space Exploration and Development
Astronomical Society
Bohican (newspaper)
Celtic Society
Chess Club
Chinese Student Association
Christian Fellowship
Conflict Simulation Society
Demokritos (Greek Club)
Focus (Photography Club)
Haitian Student Association
Innovations (yearbook)
International Student Association
Iranian Student Association
Italian American Student Association
Jewish Student Union
Korean Student Association
Micro Computer Society
Musicians Guild
NARTU
National Society of Black Engineers
Pershing Rifles
Polywog (yearbook)
Radio Club
Resident Student Organization
Reporter (newspaper)
Robotics
Scabbard and Blade
Society of Arabic Students
Student Alumni Association
Vietnamese Student Association

Fraternities and Sororities
Alpha Phi Omega
Lambda Chi Alpha
Pi Kappa Phi

Tau Delta Phi

Honor Societies
Chi Epsilon, civil engineering
Eta Kappa Nu, electrical engineering
Omega Chi Epsilon, chemical engineering
Phi Lambda Upsilon, chemistry, chemical, and metallurgical engineering
Pi Mu Epsilon, mathematics
Pi Tau Sigma, mechanical engineering
Scabbard and Blade, military science
Sigma Gamma Tau, aerospace engineering
Sigma Xi, research
Tau Beta Pi, engineering

HOUSING

Residence life at Polytechnic is designed to provide students with comfortable places in which to live, grow and complete their education. There is a Coordinator of Residence Life who works with resident assistants on the Brooklyn campus and a Residence Facilities Manager on the Long Island campus.

Polytechnic students use the residence hall for studying, relaxing, sleeping and making friends. Students who take advantage of the residence hall programs can enrich their college years with a variety of experiences. They take part in tournaments, resident students organization functions, sports and many other activities.

Resident students on the Brooklyn campus are housed in the Richard L. Connolly Residence Hall of Long Island University, just four blocks from Polytechnic. Residents are assigned to double rooms. There are no facilities for children or married couples. There are no cooking facilities but an optional meal plan is available.

The residence hall on the Long Island campus houses 50 students. Each suite contains four private bedrooms, a common suite room complete with kitchenette, a shower room and a bathroom. Facilities include a recreation room with television and a laundry room. There are no facilties for children or married couples. Off-campus housing is available in the surrounding area.

Students are required to have a health examination form completed by their physician certifying their good health. Health forms may be obtained from the Office of Student Life.

Inquiries about housing should be made to the Office of Student Life on the appropriate campus.

To assure tranquility and appropriate living environment, all residents are expected to respect each other's privacy and rights. Inappropriate behavior is addressed through the following sanctions:

1. **Verbal Warning/Reprimand**
   A verbal warning is given to the student by a member of the Office of Student Life staff discussing the incident.

2. **Written Warning**
   An official written warning is sent to the student and discussed with the Office of Student Life staff members. The student is told that further violations will result in probationary action. A copy of the warning is put into the student's file for one year.

3. Probation

A student is put on dormitory probation by a member of the Office of Student Life staff for a specific length of time. If involved in any additional incidents, this may result in possible removal from the dormitory. A copy of the probationary letter is put into student's file for one year.

4. Suspension Removal

The Dean of Students convenes the Student Affairs Committee of the Faculty and the action of suspension or removal is discussed. The length of time of suspension or permanent removal is determined by the Committee.
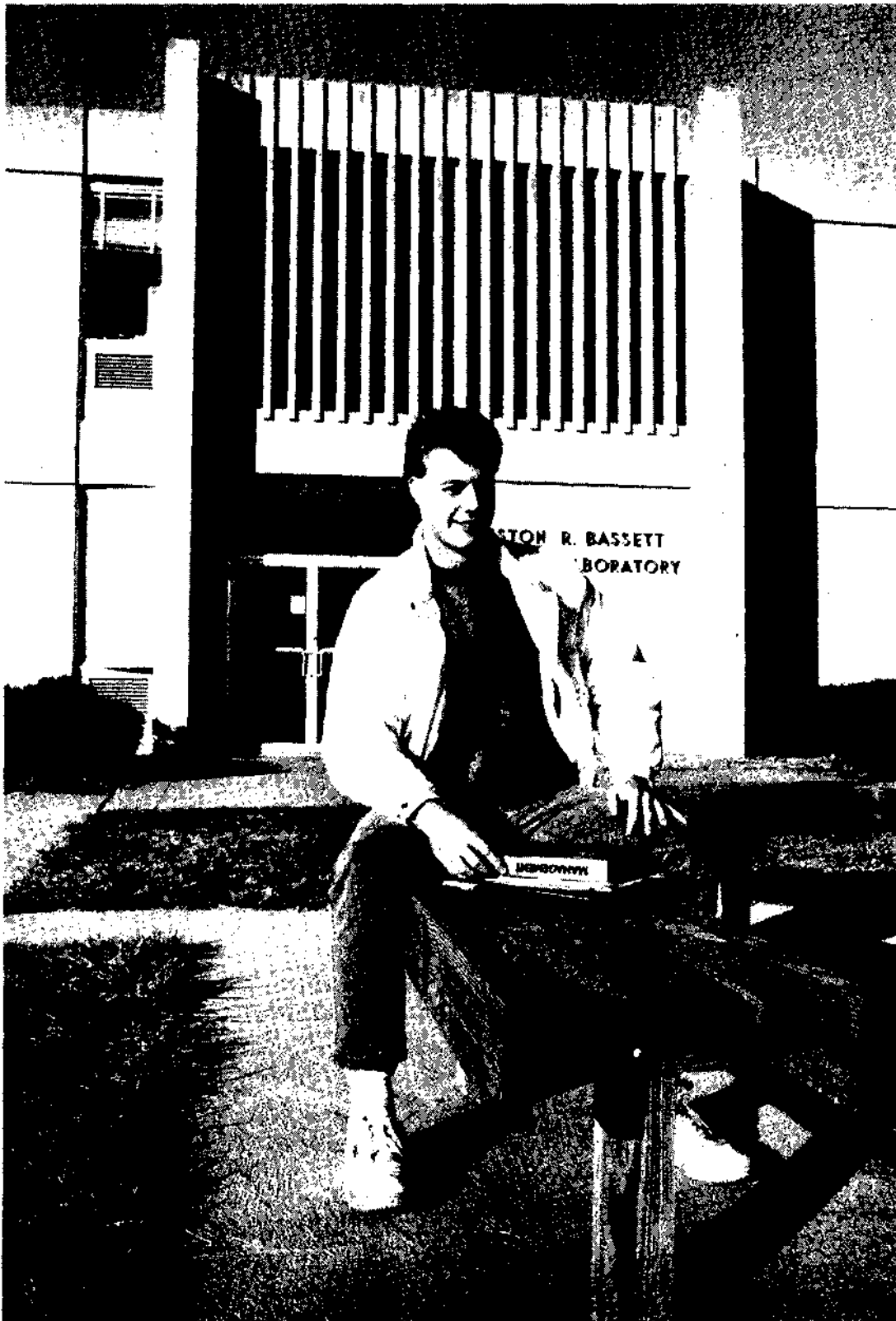
CODE OF CONDUCT

Polytechnic University draws a diverse population in pursuit of honest inquiry and academic excellence. The education and human interchange that ensue are grounded in academic freedom and mutual respect. The rights and responsibilities contained in municipal, state and federal statutes are provided and expected from all members of the Polytechnic community. The University reserves the right to note, investigate and take appropriate steps as described below.

ACADEMIC INTEGRITY

The faculty assumes that themes, term papers, results of laboratory experiments and examinations submitted by students represent their own work. The presentation for academic credit of the same work in more than one course is prohibited unless a joint project receives express and prior permission from the instructors involved in it. The following explanations clarify this for all students.

Written Work

All sources of assistance, published or unpublished, are to be acknowledged in every piece of writing.

Examinations

Students using, receiving, or providing unauthorized assistance from notes or from other students during examination, are in violation of academic regulations and are subject to academic discipline, including failure to receive credit for the course, probation, and dismissal from Polytechnic.

Laboratory Experiments

Although students may be permitted or required to cooperate with one or more fellow students in laboratory experiments, many are done independently; all require some independent work. For students to submit the results of others' work as their own, or to accept unauthorized help in experiments, constitutes academic dishonesty.

I. RULES OF CONDUCT
A. All members of the Polytechnic community — students, student organizations, faculty members and members of the staff — shall comply with city, state and federal laws and ordinances affecting the maintenance of order on Polytechnic premises.
   1. Conduct which violates such laws and ordinances on Polytechnic premises is subject to Polytechnic discipline and public sanctions as circumstances may warrant or dictate.
   2. Conduct in violation of such laws and ordinances occurring off Polytechnic premises is ordinarily not subject to Polytechnic discipline unless such conduct:
      a. seriously affects the interests of Polytechnic or the position of members within the Polytechnic community, or
      b. occurs in close proximity to Polytechnic premises and is connected with offensive conduct on Polytechnic premises.

B. All members of the Polytechnic community are prohibited from engaging in conduct leading to or resulting in any of the following:
   1. Interference with or disruption of the regular operations and activities of Polytechnic.
   2. Denial of, or unreasonable interference with the rights of others — including persons not members of the Polytechnic community who are present as invitees or licensees — on Polytechnic premises. These include the right of academic freedom as well as constitutionally protected rights.
   3. Injury to Polytechnic property, real or personal.
   4. Unauthorized access to or occupation of nonpublic areas on Polytechnic premises, including but not limited to classrooms, seminar rooms, laboratories, libraries, faculty and administrative offices, auditoriums, and recreational facilities.
   5. Unauthorized access to or use of personal property, including files or records.
C. Visitors, including invitees or licensees, shall at all times conduct themselves in a manner which is consistent with the maintenance of order on Polytechnic premises; their privilege to remain on Polytechnic property shall terminate upon breach of this regulation. Polytechnic in addition reserves the right, at its discretion, to withdraw at any time the privileges of invitees or licensees to be on Polytechnic premises. Trespassers have no privileges of any kind on Polytechnic property but are nonetheless subject to these regulations governing the maintenance order.
D. Nothing contained in these rules is intended, nor shall it be construed to, limit or restrict the freedom of speech or peaceful assembly.

II. PROGRAM OF ENFORCEMENT
A. Visitors (invitees, licensees or trespassers). When administrative officers or members of the protection services of Polytechnic in their discretion determine that the privileges of invitees or licensees to be on Polytechnic premises should be withdrawn, they ask the invitees or licensees to leave the premises; the invitation or license shall thereby be terminated. If any person, whether initially trespasser, licensee or invitee, fails to leave Polytechnic premises promptly upon request, Polytechnic will use all reasonable means, including calling for assistance of the police, to effect removal.
B. Disciplinary Action. Members of Polytechnic who are charged with violations of Polytechnic rules set forth in Section I above are subject to apppropriate disciplinary action as follows:

   1. **Students**
   a. Disciplinary actions are taken by the Student Affairs Committee of the Faculty and the Office of Student Life. Academic performance falls within the purview of the instructor who may seek the assistance of the department head. In instances of broader consideration, the services of the Dean of Students are requested. That person contacts all parties involved, collects facts and requests the advice of the monitoring bodies within the academic community. In order to inititate this process, written complaints are submitted to the Dean of Students.

Matters of sufficient gravity which affect the general operation and policies of Polytechnic are addressed at administrative hearings. At that time, persons may personally introduce relevant information in support of particular positions. Persons may also have advisers present. Such deliberations are taken by the Student Affairs Committee. The recommendations of that body may be appealed.

2. **Faculty Members**
   a. When faculty members are charged with violations of these rules, efforts are made to resolve matters informally under the direction of the dean of the respective division at the departmental level or with a committee of the faculty of that division.
   b. When matters cannot be resolved as provided in the preceding paragraph, disciplinary actions proceed as follows:
       i. If the faculty member charged with a violation has permanent or continuous tenure, the Rules of Tenure in the Code of Practice apply.
       ii. If the faculty member does not have continuous or permanent tenure, the case is referred to a special committee of the faculty designated for that purpose. The special committee adopts its own rules of procedure. It has the authority to impose penalties other than dismissal and to recommend dismissal.

3. **Polytechnic Staff:**
   Administrative Officers and Other Employees
   When members of the Polytechnic staff, other than faculty members, have been charged with violations of Polytechnic rules, the charges are considered and determined administratively in accordance with established practices of Polytechnic. If the person against whom the charges have been made is both an administrative officer and a faculty member, the case is governed by this section unless the conduct was of a nature to cast doubt upon the person's continued qualifications for service on the faculty; in the latter event, disciplinary action proceeds in accordance with Section II-b-2, above.

4. **Student Organizations**
   If a student organization is charged with a violation of Polytechnic rules, the charges are considered by the Dean of Students, and the penalty assessed is in accordance with those outlined below.
   Student organizations can appeal decisions of the Dean of Students to the Student Affairs Committee.

III. PENALTIES
   Penalties for violation of Polytechnic rules which may be imposed upon members of the Polytechnic community include the following:
   1. Reprimand
   2. Censure
   3. Removal of privileges
   4. Suspension
   5. Dismissal or explusion
   6. Discontinuance of permission for student organizations to operate on campus
   7. Other sanctions deemed appropriate
Students receive no tuition or fee refunds for semesters during which they are suspended or expelled for disciplinary reasons.

ALCOHOL

Polytechnic University does not condone the use of alcohol on campus. Polytechnic strictly adheres to the New York State law requiring individuals to be at least 21 years of age to drink.

All student groups wishing to hold events where beer or wine is served must have permission of the Dean of Students.

DRUG ABUSE

The State of New York has legal restrictions on the use of drugs which are enforced throughout the state. Because Polytechnic cannot protect those who disobey the laws of the state, it does not interfere with law enforcement agencies which may act upon information they obtain regarding illegal acts. The community may also desire, as in any other concerns, through the disciplinary system, to be responsible in cases which involve campus abuse (both public and private) or drugs.

HAZING

Polytechnic complies with Section 6450 of the Education Law of the State of New York (as amended in 1980). Accordingly, any actions or situations which recklessly or intentionally endanger mental or physical health or involve the forced consumption of liquor or drugs for purposes of initiation into or affiliation with any organizations is prohibited.

Code of Conduct is subject to change based on annual review.

A BRIEF GUIDE TO COURSE DESCRIPTIONS

A variety of different symbols appear in the course listings for each of Polytechnic's departments and programs. The hypothetical example below contains all possible notations, and is followed by a complete explanation of its elements:

MA XXX† Experimental Design*   2½:1½:4
Principles of modern statistical experimentation, including practice in the use of basic designs for scientific and industrial experiments and testing. Single factor experiments, randomized block design, Latin squares, Graeco-Latin squares; factorial and fractional factorial experiments; surface fitting designs. Prerequisite: MA 224. Co/Prerequisite: MA 153.
Also listed under IE 889.

EXPLANATION

"MA XXX" is the course number for which you must register. The dagger following the course number indicates that this course may be taken for *either* undergraduate or graduate credit.

"Experimental Design" is the course title. The asterisk following the title indicates that the course is *not* regularly offered each year. Such indicated courses may be offered *either* on a regular basis (every second or third year), or when there is sufficient student demand for the subject.

A course *without* an asterisk is normally offered at some time each year on one or more campuses. Check with the appropriate department to see which criterion applies to any particular course.

"2½:1½:4" means that the course meets for 2½ lecture hours and 1½ laboratory hours each week, and that a total of 4 credits (for undergraduate courses) or units (for graduate courses) are awarded upon successful completion of the course.

"Principles of modern. . .surface fitting designs" is the actual description of the curriculum to be covered in the course. Prerequisite: MA 224—means that a specific course (MA224) must be successfully completed before registering for the course being described (in this case MA XXX). Co/Prerequisite: MA 153 indicates that a specific course (MA 153) may be taken concurrently (during the same semester), or it must be successfully completed before registering for the course described, at the discretion of the adviser.

"Also listed under IE 889" means that the identical course is listed by another department, and therefore you may register under either course number. If one of the two departments offering the course is your major department, you should register under that department.

DIVISIONS

THE DIVISION OF ARTS AND SCIENCES

Polytechnic University's Arts and Sciences Division provides a distinctive focus as an integral part of a major technological university. The division consists of the following departments:

> Chemistry
> Humanities
> Communications
> Mathematics
> Physics
> Social Sciences

For arts and sciences majors, and for engineering students and others who plan to enter the world of business and industry or enroll in a professional school, the division seeks to provide a broader perspective in a world increasingly defined by science and technology. The division's close relationship with the divisions of engineering and management also provides options for careers and further study not normally available outside the technological university.

Space, biotechnology, electronics, urban infrastructure, communications — these are examples of our departmental interests in technological applications affecting society's future. Our departments are exploring such areas as development of advanced materials and physical concepts, the application of mathematics and statistics, technical writing for improved communications, and the effect of technology on human behavior and its ethical implications.

Unlike most arts and science divisions, we offer undergraduates unique opportunities for early participation in research experiences, working directly with graduate students and faculty members. Undergraduates working within our extensive graduate programs have access to state-of-the-art instrumentation and facilities that would be unavailable to them in many institutions. We provide individualized attention to all our majors, combining the virtues of a small college and a major technological university. Arts and science students have direct contact with top-flight faculty deeply involved in current research and scholarship — the foundation for Polytechnic's strong graduate programs and its outstanding reputation as a teaching university.

The division offers the B.S., M.S. and Ph.D. in chemistry, mathematics and physics, and the B.S. and M.S. in humanities and communications, and in social sciences at the Brooklyn campus. Several joint departmental degree programs are offered, including a joint B.S. major in mathematics and physics, mathematics with a computer science option, B.S. dual majors in engineering and sciences with social sciences or humanities, and M.S. and Ph.D. programs in chemical physics and polymer science and engineering. We also offer graduate-level certificates and M.S. programs in specialized journalism and environmental behavior studies.

The division offers a contemporary liberal arts core curriculum in the departments of social science, and humanities and communications. Innovative courses relating science and technology to society are open to liberal arts students and to majors in chemistry, mathematics, physics and engineering.

The division exposes its students to comprehensive and advanced computer applications within their disciplines, and makes available substantial merit scholarship and financial aid programs. Students also have opportunities to participate in the Polymer Research Institute, the Center for the Study of Philosophy and Technology, the Center for Advanced Technology in Telecommunications and the Weber Research Institute (See Research Centers, p. 8).

The hallmark of the arts and sciences division is a deep concern to help students relate what they learn to significant developing technologies impacting society. We strongly believe it is vital to educate the total person, in order that he or she will be prepared to contribute effectively throughout a constructive professional life.

THE DIVISION OF ENGINEERING

The Division of Engineering at Polytechnic houses all academic departments offering engineering and computer science degrees at the B.S., M.S., ENG., and Ph.D. levels. These departments are the following:

> Department of Aerospace Engineering
> Department of Chemical Engineering
> Department of Civil and Environmental Engineering
> Department of Electrical Engineering and Computer Science
> Department of Mechanical and Industrial Engineering
> Department of Metallurgy and Materials Science

The Division has an excellent faculty, many with international reputations as educators and researchers in their field of specialization. Approximately one-half of the students enrolled in engineering programs are at the graduate level. They benefit from the extensive experience and active participation of the faculty in state-of-the-art research efforts. Among the areas of research for which Polytechnic faculty are nationally and internationally known are:

> Telecommunications
> Electrophysics
> Space Electronics
> Microwaves
> Materials
> Earthquake Performance of Structures
> Military Logistics
> Transportation
> Aeronautics and Astronautics
> Bioseparation
> Imaging Sciences
> Software Engineering
> Acoustics
> Quantum Electronics
> Pulse Power

Graduate and undergraduate students have the opportunity to study under faculty who are themselves doing the work which defines the state of the art in their fields. Polytechnic's philosophy is one in which the linkage between research and academic programs is strong. The most prestigious researchers continue to teach graduate and undergraduate courses on a regular basis.

Engineering curricula are designed for the complete education of the beginning engineer. Fundamentals of mathematics and the physical sciences are augmented by strong treatment of engineering science. Design and laboratory components of engineering curricula stress the creative and "hands-on" activities which are so important to a successful engineering career.

In humanities and social science courses, young engineers are exposed to the societal issues and problems which society hopes to improve through technology. Oral and written communications skills are developed and sharpened in these courses, and further improved in laboratory and design presentations of engineering courses.

Upon receipt of a B.S. in an engineering discipline, a Polytechnic graduate is prepared to enter one of the most exciting professions in existence, and is ready to make meaningful contributions to the practice of engineering.

At the graduate level, students have the opportunity to work side by side with internationally renowned faculty in the classroom, and in research. An M.S. graduate of Polytechnic is equipped with a depth of knowledge in his/her field of specialization, and is capable of making significant contributions in engineering design and analysis.

The Polytechnic Ph.D. recipient is steeped in a background of engineering research and application, and has, through the dissertation, already exhibited the ability to advance the state of the art of his/her field of specialization. Polytechnic Ph.D.'s will help define the future of engineering and technology through their effective research and innovative application of engineering design and analysis.

Above all, an engineering education from Polytechnic prepares the graduate for a lifetime of education and growing knowledge. The ability to continue learning is perhaps the most lasting gift of education, and in the rapidly-advancing field of technology, is the most important one. By giving its students a comprehensive education in the basic principles of science and engineering, and by developing the creative skills required for engineering design and analysis, Polytechnic provides its graduates with the ability to continue to grow and learn as their careers progress.

THE DIVISION OF MANAGEMENT

The management of top-flight technology is no longer a luxury in today's fast-paced industrial and business environment. The extent to which working professionals can differentiate themselves with regard to their skills in managing the complexities of technology, and the personal involvement with technology will ultimately determine their success, and the competitive success of the firm.

The Division of Management offers four graduate degrees and one undergraduate degree designed to teach those skills that make a difference in today's highly-charged, growth-oriented environment.

The Master Of Science In Management

While the M.B.A. is a product of yesterday's industrial revolution, our program is a product of today's technological revolution. It combines the traditional, financial and managerial skill of an M.B.A. with knowledge of modern technology.

Polytechnic is the only university in the metropolitan area that offers the MSM degree for professionals who want to manage companies whose success depends on technology. Polytechnic's management concentration meets this challenge, without slighting traditional financial and marketing training. Our teachers are experienced managers who put innovation, entrepreneurship, and technology into real business perspective.

Students get individualized attention from our faculty, improve their communication, interpersonal and decision-making skills, and enhance their understanding of the integrative nature of management.

The Master Of Science In Operations Management

In a world of accelerating technological and social change, and expanding international competition, the operations executive is compelled to master skills which will help to insure the productivity growth of the firm. The increasing prevalence of high technology services, products, and processes makes it imperative that this executive employ state-of-the-art methods for coordinating the design, production, and distribution functions. Moreover, to be totally effective, he or she must assure the application of these methods in a manner consistent with the motivational needs of the employee.

The master's degree program in operations management is designed to sensitize the student to the productivity needs of the firm, and to equip him or her with the pertinent skills for effectively dealing with those needs. The operations management student is not trained to be an expert in any particular discipline, but rather is educated in how to be an integrator of specialized techniques required to meet the organization's objectives. For this purpose, the MSOM graduate is equipped with a strong appreciation for a wide spectrum of quantitative and behavioral science methods that can enhance decision-making effectiveness in the areas of project planning, capacity allocation, inventory management, workforce management, and quality control. The rationale behind the MSOM curriculum is that the manager will become most effective by gaining a sufficient level of expertise in relevant disciplines, so that he or she can most accurately perform staffing, coordinating, and controlling functions. In other words, this master's program teaches people how to "step back" and look at the organization's needs from a variety of perspectives — that is, they are equipped and encouraged to act as managers.

The Master Of Science In Organizational Behavior

Rapidly changing technology has had a major impact on the knowledge and skills required of human resource professionals. In response to such newly emerging requirements, this program was designed for personnel specialists who need to be prepared for today's high-tech work place. This program provides the latest knowledge and techniques for dealing with the human problems in rapidly changing organizational environments, and is open to human resource practitioners who need to upgrade or update their knowledge as well as career changers who wish to enter the field.

In addition to traditional courses in personnel labor relations and organizational development, the program offers a variety of courses designed to bring students up to speed with the latest approaches to human resource information systems, performance and motivation management and career management that deal with the impact of technological change.

The Master Of Science In Telecommunications Management

"Today, the biggest challenge facing American companies—both users and providers of telecommunications services—is finding men and women who not only understand today's technology but can manage that technology and apply it to their company's immediate and long-term goals." . . .these words and thoughts have been echoed by one company after another in the telecommunications industry. And they represent the driving force behind Polytechnic's Master of Science in Telecommunications Management program.

Polytechnic started this master's degree program in 1984 with the express purpose of providing education for executives faced with these new challanges and opportunities.

The master of science in telecommunications management is a rigorous 2-year, 4-semester program. It consists of 12 individual courses and an independent research project. The strength of the program is the interdisciplinary approach of the carefully structured set of courses.

Traditional subjects in management . . .marketing, finance, and accounting. . .are taught not as specialties but as basic tools for the telecommunications manager.

At the same time, students learn the technical skills needed to assess and apply new and emerging technologies in telecommunications.

Bachelor of Science in Information Management

The student who studies Information Management at Polytechnic University prepares to apply computer skills to the solution of business problems.

The program, which is a unique blend of courses from management, computer science, social science, humanities, mathematics and industrial engineering, educates young women and men who will be able to:

- Take advantage of the improving performance and declining cost of electronic information processing systems;

- Apply computer based techniques to assist organizations in management decisions;

- Become creative problem solvers who will know how to gather, store, retrieve, analyze and manage electronic information.

The advantages of studying Information Management at Polytechnic are that the student is required to take higher levels of math and science normally not required in other management programs. Also, since the student has studied at one of the most respected engineering and science schools in the United States, the employer knows that the student is prepared to deal with and understand the most up-to-date developments in the computer field, and how they best can be applied.

A degree in Information Management is also excellent preparation for an advanced degree in business, or the professions, such as law.

AEROSPACE ENGINEERING

Among the programs offered by the Department of Aerospace Engineering is the undergraduate program leading to a bachelor of science degree in aerospace engineering. Others lead to graduate degrees in aeronautics and astronautics. All programs are offered at both the Brooklyn and Long Island campuses. Graduate degrees are offered at the master of science, engineer, and doctor of philosophy levels.

THE AEROSPACE ENGINEERING PROFESSION

Aerospace engineering is the art and science associated with the design and performance of aircraft, missiles, and spacecraft. The scientific aspects of space vehicle design are rooted in the broad areas of the flow of liquids and gases, strength and stability of extremely lightweight structures, propulsion, guidance and control, materials, environmental conditions, thermodynamics, and heat transfer.

From the standpoint of complexity, scope of engineering and scientific problems, and sheer audacity of the mission, vehicles currently being designed or projected for the future stagger the imagination. Until recently, long range missiles, moon vehicles, deep space probes and space habitats, had been contained within the realm of science fiction. To meet the challenges of the design of these vehicles, aerospace engineering training is based on scientific principles that provide the engineer with the greatest possible potential and flexibility. Conflicting requirements imposed by considerations of safety, reliability, cost, maintenance, production, and handling often demand compromises based upon the engineer's skill and experience in order to attain an optimum design. It is the responsibility of the aerospace engineer to resolve such issues.

UNDERGRADUATE PROGRAM

The undergraduate aerospace program not only affords students an understanding of basic scientific principles but trains them in the applications of such principles to the challenges of their profession. The sophistication of aerospace systems is such that students must necessarily master some of the more powerful analytic techniques to evolve efficient designs. The training is broad, so that graduating students can apply their knowledge to such diverse problem areas as air and noise pollution, land and sea vehicles, oceanographics, and biomechanics.

During the first two years of study, the foundation for future professional subjects is established by courses in each of the basic sciences; physics, chemistry, and mathematics.

Although the student begins training in a number of engineering science areas such as computers, mechanics, material science and strength of materials, the emphases are primarily on principles and concepts in fundamental and basic sciences.

In the junior and senior years, professional courses include fluid mechanics, solid mechanics, guidance and control, dynamics, flight mechanics, propulsion, and design.

The undergraduate program leads to the degree of bachelor of science in aerospace engineering and is accredited by the Accreditation Board for Engineering and Technology (ABET), of which the American Institute of Aeronautics and Astronautics (AIAA) is a participant.

TRANSFER STUDENTS (Undergraduates)

Qualified graduates of two-year pre-engineering programs, such as those at liberal arts and community colleges, may fulfill the requirements for the B.S. degree in aerospace engineering in two additional years. Since pre-engineering programs vary, a prescribed program is not possible; consequently, students should consult with an undergraduate adviser.

Graduates of technology programs may be able to fulfill the requirements for the B.S. degree in aerospace engineering in two to three and a half years depending on the scope and level of their previous education. Consult with an undergraduate adviser for details.

Transfer credits for courses taken at other schools are subject to frequent changes based on evaluation of content and level. Thus students completing the same program, but in different years, may receive different amounts of transfer credits. Consult the aerospace engineering undergraduate adviser for current information.

Transfer students must arrive and present their records for initial evaluation at least one week before the regular registration period of their first semester at Polytechnic and must have all transfer credit requests acted upon within one year of such registration.

GRADUATE PROGRAM

Programs of study are offered leading to the degrees of master of science, engineer, and doctor of philosophy in aeronautics and astronautics. Bachelor's degrees in aerospace or mechanical engineering are generally required. Applicants with degrees in other fields may be admitted with deficiencies.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE

AE 731	Analytical Methods in Thermal & Fluid Mechanics	3
AE 732	Computational Methods in Thermal & Fluid Mechanics	3
AE 740	Principles of Fluid Dynamics	3
AE 741	Compressible Flow	3
AE 742	Vicous Flow	3
AE 810	Theory of Propulsion	3
AE 971-72	Seminar in Aerospace Engineering	0
	Electives	18
		36

In the above master's degree program students may pursue a project (up to six units counted toward the degree) or a thesis (up to twelve units counted toward the degree) under the guidance of a faculty sponsor or may elect to complete the program solely with courses. All elective courses must be approved by a graduate adviser and should be consistent with a definable objective associated with the master's program.

The department limits to nine the total of transfer, reading (guided studies), and validation credits which can be offered toward master's degrees. The certification of validation credits is administered by the departmental graduate advisers.

To obtain any graduate degree or certificate, a student must have 3.0 grade point averages or better in all graduate courses and B or better averages in all guided studies (readings, project, thesis, dissertation). Additionally, students must establish overall B averages in those departmental courses submitted in partial fullfilment of degree requirements. All courses submitted for degrees must have been completed within the four-year period prior to the awarding of degrees.

REQUIREMENTS FOR THE ENGINEER DEGREE

Master's degrees in aerospace or mechanical engineering which meet one of the department specialization area requirements are generally required. Applicants with master's degrees not meeting these requirements may be conditionally admitted with deficiencies as evaluated by a departmental graduate adviser. All candidates must complete programs of study of at least 36 units beyond master's degrees as approved by an appropriate departmental graduate adviser. These programs of study normally include at least 24 units of work within the department; part of this work includes a project of 6 but not more than 12 units. Course work may be substituted for the project if applicants' backgrounds include satisfactory evidence of equivalent experience as evaluated by the guidance committee. In addition, satisfactory attendance in AE 971-72 (Seminar in Aerospace Engineering) is required for two semesters.

To obtain any graduate degrees or certificates, students must have 3.0 grade point averages or better in all graduate courses and B or better averages in all guided studies (readings, project, thesis, dissertation).

REQUIREMENTS FOR THE DOCTOR OF PHILOSOPHY DEGREE

Students interested in the Ph.D. program are required to consult as soon as possible with department graduate advisers regarding eligibility to the qualifying examinations and other regulations.

Master's degrees in aerospace or mechanical engineering are generally required. Applicants with degrees not meeting these requirements may be admitted with credit for previous work as evaluated by a departmental graduate adviser.

In order to enroll in a doctoral program of study, each candidate must pass a set of qualifying examinations in certain basic fields. Upon passing these examinations, a guidance committee is formed, and the candidate may then register for dissertation research.

All candidates for the Ph.D. must complete a minimum of 36 units of approved courses beyond master's degrees in addition, registration for a minimum of 24 units of dissertation research is required at the rate of a minimum of three units per term, continuously, until the dissertation is completed and accepted. Satisfactory attendance in AE 971-72 (Seminar in Aerospace Engineering) is required each semester (normally, two semesters for the M.S. and four additional semesters for the Ph.D.). All of the above requirements must be met within a seven-year period, prior to awarding degrees.

Typical Course of Study for the Bachelor
of Science Degree in Aerospace Engineering

Freshman Year

First Semester			Hours/Week			Second Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.	No.		Subject	Cl.	Lab.	Cr.
CM	101	General Chemistry, I	2½	0	2½	CM	102	General Chemistry, II	2½	0	2½
CM	111	General Chemistry Lab I	0	1½	½	CM	112	General Chemistry Lab II	0	1½	½
MA	101	Calculus I	4	0	4	MA	102	Calculus II	4	0	4
CS	100AE	Intro. to Programming	2	0	2	PH	104	Intro. to Physics I	3	0	3
HU	101	Humanities I	3	0	3	HU	200	Humanities II	3	0	3
SL	101	Student Survival	0	1	0			Hum/SS[4]	3	0	3
SS	104	Contemporary History	3	0	3	PE	102	Physical Education II	0	2	0
PE	101	Physical Education I[2]	0	2	0						16
					15						

Sophomore Year

MA	103	Calculus III	3	0	3	MA	104	Applied Diff. Equations	3	0	3
PH	105	Intro. to Physics II	3½	0	3½	PH	106	Intro. to Physics III	2½	0	2½
PH	115	Physics Laboratory II	0	1½	½	PH	116	Intro. to Physics Lab. III	0	1½	½
MT	302	Structure of Metals	2	0	2	ME	112	Mechanics II	3	0	3
ME	101	Graphics	1	3	2	ME	121	Mechanics of Materials	3	0	3
ME	111	Mechanics I	3	0	3	AE	341	Introduction to Aerodesign	2	3	3
HU	110	Report Writing I	3	0	3			Hum/SS[4]	3	0	3
PE	103	Physical Education III	0	2	0	PE	104	Physical Education IV	0	2	0
					17						18

Junior Year

MA	260	Vectors and P.D.E.	3	0	3	AE	232	Fluids II	3	0	3
ME	201	Thermodynamics I	3	0	3	AE	251	Space Dynamics	3	0	3
AE	231	Fluids I	3	0	3	AE	272	Fund. Stress Analysis II	2½	1½	3
AE	271	Fund. Stress Analysis I	3	0	3	AE	342	Aircraft Design I	2	3	3
AE	311	Mechanics of Flight I	3	0	3	EE	370	Princ. of Elect. Eng.	3	0	3
		Hum/SS Block Sequence[4]	3	0	3			Hum/SS Block Sequence[4]	3	0	3
					18						18

Senior Year

AE	233	Fluids III	3	0	3	AE	241	Propulsion	3	0	3
ME	261	Vibrations	3	0	3	AE	344	Spacecraft Design	2	3	3
AE	281	Advanced Stress Analysis I	2½	1½	3	AE	350	Fluids Laboratory	0	3	1
AE	312	Mechanics of Flight II	3	0	3			Technical electives[3]	6	0	6
AE	343	Aircraft Design II	2	3	3			Free Elective[1]	3	0	3
		Technical Elective[3]	3	0	3						16
					18						

Total credits required for graduation: 136

[1]Free electives are subject to departmental advisers' approval.

[2]ROTC students may substitute four (4) military science courses of zero (0) credits for PE 101-104. Additionally, up to three (3) credits from the following four (4), 2-credit courses: MS 301, 303, 401, or 403, may be used to substitute for the free elective which exists in the aerospace engineering programs.

[3]Technical Electives must be of senior-year quality, taken during the senior year after approval by an aero adviser has been secured.

[4]Requirements in humanities and social sciences — the student must take HU 101, HU 110, HU 200, and SS 104. Students who are placed in HU 103 on the basis of the English Composition Placement test administered at Polytechnic to all incoming students may substitute HU 103 for HU 101. Students placed in HU 008 or HU 009 must complete this noncredit writing course before taking HU 101 (or HU 103) and HU 110.

At least 18 of the credits students select in the humanities and social sciences must meet the requirements of the Accreditation Board for Engineering and Technology (ABET) These credits may **not** include skills-oriented courses such as technical writing, public speaking, or English as a second language. Courses in literature, foreign languages, history, economics, and others are acceptable. Students should consult their advisers to ensure that these criteria are met.

In addition, students should select an area of concentration (such as literature, communications, the arts, or philosophy and comparative religions in the Department of Humanities or economics, history, anthropology or psychology in the Department of Social Sciences) and elect a number of courses in this concentration, in consultation with departmental advisers. A modern language may be chosen as a suitable concentration but a student without prior knowledge of the language must plan to devote at least 12 credit hours to the subject.

For the remaining credits in the humanities/social science requirement, the student should select courses in areas other than that of the concentration; the total number of humanities and social science credits required is at least twenty-four.

For further details and descriptions see the section of this catalog entitled "Humanities and Social Sciences Requirements for Engineering and Computer Science Majors."

UNDERGRADUATE COURSES

AE 231   Fluids I   **3:0:3**
Fluids, kinematics, hydrostatics, thermodynamics. Derivations of continuity, momentum and energy equations. Flux concepts and relation with divergence theorem. Control volume equations and applications. Bernoulli equation. Discussion of vorticity and stream function. Potential flows over simple geometric configurations. Co/ Prerequisites: AE 201 and MA 260.
Also listed under ME 231.

AE 232   Fluids II   **3:0:3**
Flow in pipes and ducts. Students required to design flow measuring and piping systems. One-dimensional gas dynamics. Convergent-divergent nozzles. Normal and oblique shocks. Expansion fans. Effects of friction and heat addition. Prerequisite: AE 231.
Also listed under ME 232.

AE 233   Fluids III   **3:0:3**
Introduction to viscous flow theory. Viscous effects. Stress-strain relations. Derivation of Navier-Stokes equations. Rayleigh problem and diffusion time. Similarity theory. Prandtl boundary layer equations, flow over a flat plate. Approximate methods, numerical methods. Separated flows. Prerequisite: AE 232.

AE 234   Fluids IV   **3:0:3**
Incompressible airfoil theory, circulation, lift, Kutta condition. Finite wing theory. Acoustic motion. Methods of characteristics. Compressible airfoil theory. Oblique shocks and expansion fans. Prerequisite: AE 232.

AE 241   Propulsion   **3:0:3**
Operation, performance, design methods for flight vehicle propulsion systems. Airbreathing engines: turbojet, turboprop, turbofan and ramjet. Liquid and solid propellant chemical rockets. Elements of nuclear and electrical rocket propulsion systems. Prerequisite: AE 232.

AE 242   Rocket Propulsion*   **3:0:3**
Development and design of rocket engines. Basic principles of mechanics, thermodynamics, aerodynamics and combustion reviewed. Propellants, rocket engine elements (solid and liquid), heat transfer, cooling accessories, rocket testing and problems associated with rocket design and development. Senior elective. Prerequisite: senior status.

AE 251   Space Dynamics   **3:0:3**
Motion of a particle, systems of particles, rigid bodies. Momentum and energy principles and applications. Impulsive forces and moments. Projectiles with air resistance. Gyroscopic theory. Prerequisites: ME 112 and MA 104.

AE 271   Fundamentals of Stress Analysis I   **3:0:3**
Stress, equilibrium equations, strains, compatibility conditions, stress strain relations, superposition, strain energy. Bending of beams: unsymmetric bending of arbitrary section beams, bending stresses, deflections, shear stresses on thin-walled section beams, shear center. Prerequisite: MA 104 and ME 121.
Also listed under ME 271.

AE 272   Fundamentals of Stress Analysis II   **2½:1½:3**
Torsion of thin-walled open and closed section beams. Membrane and hydrodynamic analogies. Bredt's formula, multi celled cross sections. Strain energy. Castigliano's theorems. Statically indeterminate beams, frames, rings. Laboratory: experimental stress analysis, strain gages, brittle coating, photoelasticity, analogies. Prerequisite: AE 271.

AE 281   Advanced Stress Analysis I   **2½:1½:3**
Elastic and inelastic buckling of columns, frames, plates, shells, effective width, sheet-stringer combinations, torsional instability, energy methods for approximate solutions. Continuation of experimental stress analysis methods developed in AE 272. Prerequisite: AE 272.

AE 282   Advanced Stress Analysis II   **3:0:3**
Matrix algebra. Matrix analysis of framed structrues: truss, beam, frame, grid. Static and kinematic indeterminacies. Flexibility and stiffness coefficients, reciprocal relations, symmetry. Displacements in determinate structures. Flexibility and stiffness methods applied to statically indeterminate structures. Current programming techniques. Prerequisite: AE 272.

AE 311   Mechanics of Flight I   **3:0:3**
Principles of powered flight; development of equations of motion, performance of subsonic and supersonic airplanes, discussion of characteristics of various power plants. Properties of fluids, dimensional analysis, one-dimensional flows, subsonic airfoil and wing and propeller theory and practice. Prerequisites: ME 112 or ME 117.

AE 312   Mechanics of Flight II   **3:0:3**
Static and dynamic stability of aircraft and missiles. Development of rigid body equations of motion, linearization disturbed motion of airplanes. Manual and automatic control systems and handling qualities criteria. Prerequisite: AE 311.

AE 341   Introduction to Aerodesign   **2:3:3**
Introduction to lift and drag. Air-foil, wing, and body characteristics. Description of various propulsion systems. Elementary aircraft and missile performance. Application of above to wing sizing, engine selection, and preliminary airframe design through the use of design projects. Prerequisite: AE adviser's approval.

AE 342   Aircraft Design I   **2:3:3**
Preliminary design of commercial jet transport. Development of aerodynamic configuration, power plant selection and lay-out weight and balance estimation. Performance, stability and control analyses, airload estimations. Prerequisite: AE 311 and AE 341.

AE 343   Aircraft Design II   **2:3:3**
Structural designs of airplanes based on specification and aerodynamic requirements. Discussions of construction materials, forming, fasteners, fittings. Structural arrangement of landing gear, fuselage, stress analysis. Prerequisite: AE 342.

AE 344   Spacecraft Design   **2:3:3**
Designs of hypervelocity vehicles. Trajectory and orbit analyses, problems of re-entry, propulsion system design, staging. Design of a boost vehicle for satellite missions, and a re-entry vehicle for earth return. Prerequisite: AE 343.

AE 350   Fluids Laboratory   **0:3:1**
Laboratory experiments in the area of inviscid and viscous flows. Prerequisite: AE 233.

**AE 381-382   Senior Honors Work in Aerospace
                      Engineering I, II   credit to be arranged**
Independent work undertaken by qualified honors students in aerospace engineering. Course material arranged by faculty steering committee. Prerequisite: senior status.

**AE 391-392   Guided Studies in Aerospace
                      Engineering I, II   credit to be arranged**
Senior-year sequence for qualified students in aerospace engineering. Course material arranged by committee of faculty members.

GRADUATE COURSES

**AE 623   Computational Methods in Mechanical and
                      Aerospace Engineering I***   **2½:0:3**
Integrated survey of principal methods in obtaining approximate solutions to boundary value problems that occur in structural analysis. Particular attention to continuum techniques such as Fourier, Ritz, Galerkin, least square and collocation methods.
Also listed under ME 623

**AE 624   Computational Methods in Mechanical and
             Aerospace Engineering II***   2½:0:3
Continuation of AE 623 with particular emphasis on numerical techniques of analysis, such as finite differences, iteration procedures and Runge-Kutta method. Consideration of recently developed hybrid methods. Illustrative examples from contemporary literature in structural analysis. Prerequisite: AE 623.
Also listed under ME 624.

AE 651   Advanced Dynamics I   2½:0:3
Kinematics and dynamics of a particle in space; translating and rotating frames of reference. Systems of particles; plane motion of rigid bodies. Two-body central force problem. Lagrange equations with holonomic and nonholonomic constraints: applications.
Also listed under ME 651.

AE 652   Advanced Dynamics II   2½:0:3
General motions of rigid bodies, Euler's equations, gyroscopic motions and stability, impulsive motions, Linear oscillations of two-degree and n-degree of freedom systems, matrix formulationa, applications, variational principles. Prerequisite: AE651.
Also listed under ME 652.

AE 682   Aero- and Hydroelasticity*   2½:0:3
Analysis of problems with nonconservative type forces. Divergence and flutter phenomena, flutter prevention. Applications to vibrations and instabilities in aerospace, mechanical and civil engineering. Prerequisite: AE adviser's approval.

AE 704   Aerothermochemistry*   2½:0:3
Fundamentals of chemical thermodynamics, fluid dynamics and chemical kinetics. Applications to combustion and emission phenomena, fluid lasers, plasmas and hypersonics. Prerequisite: ME 701.

AE 714   Radiation Gas Dynamics*   2½:0:3
Conservation equations for gas flows with radiation transport. Significant inviscid and viscous flows: one-dimensional flows with radiative transport according to various optical properties; laminar flows with simple transport properties; laminar flows with some complex properties; and turbulent diffusive flows. Prerequisite: AE adviser's approval.

**AE 731   Analytical Methods in Thermal
             and Fluid Mechanics***   2½:0:3
Classifications of differential equations of fluid and thermal mechanics. Methods of characteristics for supersonic flow and wave propagation. Potential methods including complex variable applications for transforms techniques for convection and conduction. Prerequisite: AE adviser's approval.

**AE 732   Computational Methods in Thermal
             and Fluid Mechanics**   2½:0:3
Numerical analyses. Finite difference approximations, error and stability analyses, numerical dispersion and damping, matrix inversion methods. Implicit and explicit procedures, SOR, ADI, hopscotch and direct solvers for evaluating linear and nonlinear diffusion and convection problems. Prerequisite: AE adviser's approval.
Also listed under ME 732.

AE 740   Principles of Fluid Dynamics*   2½:0:3
Conservation laws of mass momentum and energy. Elements of potential theory and gas dynamics. Applications of inviscid flow to simple internal and external geometrics; control volume and differential approach to fluid dynamic problems. Prerequisite: AE adviser's approval.
Also listed under ME 740.

AE 741   Compressible Flow*   2½:0:3
Subsonic, transonic and supersonic flows over two dimensional and axisymmetric bodies. Shock wave development in both one-dimensional unsteady and two-dimensional steady flow systems. Internal and external flows are considered. Prerequisite: AE adviser's approval.

AE 742   Viscous Flow*   2½:0:3
Molecular and macroscopic transport, concepts of stress and strain, and derivation of the Navier-Stokes equations. Applications to problems of diffusion, boundary layers and slow motion. Analytic and numerical methods are presented. Prerequisite: AE adviser's approval.

AE 743   Turbulent Flow*   2½:0:3
General theories of turbulence, basic concepts, transition, homogeneous turbulence, analysis of turbulent shear flows, turbulent heat and mass transfer, experimental methods. Prerequisite: AE 742.

AE 744   Viscous Compressible Flow*   2½:0:3
Effects of compressibility in both subsonic and supersonic flows on boundary layer behavior including heat transfer effects, diffusion; numerical approaches to solving these problems. Quasi-one-dimensional flows in ducts and channels including effects of viscosity, heat transfer, mass transfer. Prerequisite: AE 741 and AE 742.

AE 745   Hydrodynamics*   2½:0:3
General theorems of hydrodynamics. Analytical techniques including formulation of boundary conditions. Analyses of hydrofoils, planing, cavitating propellers and hydrofoils, flow about partially submerged bodies, wave drag, underwater propulsion, cascades, surface impact, geophysical problems. Prerequisite: AE adviser's approval.

AE 746   Fluid Dynamics or Rotating Machinery*   2½:0:3
Methods of analysis of flow in rotating machines. Cascades, performance, radial equilibrium, secondary flows, viscous flows. Supersonic and transonic flows in compressors and turbines. Prerequisite: AE adviser's approval.

AE 748   Dynamics of Rarefied Gases*   2½:0:3
Treatment of fundamental gas kinetics and introduction of pertinent physical and mathematical concepts. Phenomenology and analysis of low-denisty flows of neutral and ionized gases. Selected applications to flight problems, heat transfer and vacuum technology. Prerequisite: AE adviser's approval.

AE 749   Magnetofluid Dynamics*   2½:0:3
Dynamics of electrically conducted gases in electric and magnetic fields. Moving fields and electromagnetic equation: Maxwell stresses, field and momentum-energy tensors. Thermodynamics of fluids in electromagnetic fields. Magnetofluid dynamics, characteristics, waves, shock waves. Applications: MHD propulsion and power generation. Prerequisite: AE adviser's approval.

AE 750   Ocean Waves and Tides*   2½:0:3
Generation, propagation and decay of surface waves and well, internal waves, Rossby waves, seiches, storm surges, tides. Relations between theory and observation. Methods of observation. Prerequisite: AE adviser's approval.

AE 751   Aerodynamics of Urban Environment I*   2½:0:3
Aerodynamic forces and pressures on non-aeronautical shapes including vehicles, buildings, other structures. Unsteady forces and dynamic interaction with structures. Motion and thermal characteristics of atmospheric boundary layer. Air flow and thermal characteristics over urban regions and various topographical configurations. Prerequisite: adviser's approval.

AE 752   Aerodynamics of Urban Environment II*   2½:0:3
Travel and dispersal of atmospheric pollutants. Plume rise and dispersion theories with application to uniform and nonuniform atmospheres. Effects of boundary configurations of various scales; buildings, urban regions, bodies of water, mountains, valleys. Prerequisite: AE 751

AE 753-754   Wave Turbulence I, II*   each 2½:0:3
Analysis of inhomogeneous and nonstationary turbulent fields. Kinetic and fluid dynamic descriptions of many-particle systems at both quasilinear and nonlinear levels. Wave-particle and wave-wave instabilities treated as collision processes both classically and quantum theoretically. Determinations of self-consistent kinetic equations for both particles and waves. Applications to space-time evolution of coupled background and turbulent wave fields. Prerequisite: AE adviser's approval.
Also listed under EL 781-782

**AE 755   Experimental Methods in Thermal and
            Fluid Mechanics***   2½:0:3
Measurement principles including mechanical, electrical, electromagnetic, thermal and optical techniques. Applications to measurements of forces, pressures, heat transfer, velocity and electron density. Schlieren, interferometry, laser, Raman scattering. Prerequisite: AE adviser's approval.

AE 759   Special Topics: Fluid Mechanics*   2½:0:3
Topics of particular current interest in fluid mechanics. Prerequisite: AE adviser's approval.

AE 801   Trajectories and Orbits*   2½:0:3
Two-body problem, formulas for orbital motion, optimum orbit transfer and rendezvous problem, interplanetary trajectoris. Re-entry trajectories, maximum acceleration and heat transfer, effect of aerodynamic lift. Prerequisite: AE adviser's approval.

AE 802   Space Mechanics*   2½:0:3
Treatment of celestial mechanics including n-body problem, 3-body problem, restricted 3-body problem. Jacobi integral and applications, including effects of atmospheric drag, oblateness of the earth, and presence of additional bodies; motion of the moon. Prerequisite: AE 801.

AE 803   Vehicle Dynamics I*   2½:0:3
Atmospheric flight mechanics of airplanes, quasisteady and dynamic performance in various flight regimes, energy methods. Space vehicles, partial motion in central force field, launch and re-entry trajectories. Land and seaborne vehicles: automobile, tracked vehicles, ship and GEM vehicles. Prerequisite: AE adviser's approval.

AE 804   Vehicle Dynamics II*   2½:0:3
Dynamics of aircraft in symmetric and asymmetric atmospheric flight. Stability and automatic control of launch vehicles. Dynamic stability of high-speed tracked vehicles. Automobile handling characteristics. Stability of seaborne vehicles. Hulls, hydrofoils and GEM vehicles. Prerequisites: AE 803.

AE 806   Physics of the Atmosphere*   2½:0:3
Origins of solar system, planets, atmospheres. Structures, compositions of planetary atmospheres. Minor constituents, natural and manmade, gravitational effects and distribution, escape of gases. Sun and its relationship to earth, planets. Atomic, molecular processes, stratosphere, ozone, winds and synamics, mesosphere, thermosphere. Prerequisite: AE adviser's approval.

AE 810   Theory of Propulsion*   2½:0:3
Principles of modern propulsion based on chemical energy sources. Air-breathing engines, combustion thermodynamics, flows with chemical reactions, thermochemisty of solid and liquid rocket engines. Engineering parameters in engine design. Prerequisite: AE adviser's approval.
Also listed under ME 810.

AE 811   Engine-Airplane Integration*   2½:0:3
Basic concepts underlying interaction of power plant and airframe flow fields. Air inlet and jet exhaust region design requirements: estimation of net axial forces. Uses of thrust vectoring for attainment of VISTOL performance and for improved high-speed maneuvering capabilities. Prerequisite: AE adviser's approval.

AE 812   Helicopter Theory*   2½:0:3
General development of rotating-wing aircraft. Hovering and vertical flight analysis and performance. Autorotation, blade motion and rotor control. Analysis of forward flight. Rotor blade stall. Stability and vibration problems of helicopters. Prerequisite: AE adviser's approval.

**AE 819   Special Topics:
            Aeronautics and Astronautics***   2½:0:3
Topics of particular current interest in aeronautics and astronautics. Prerequisite: AE adviser's approval.

AE 901-904   Guided Readings I, II, III, IV   each 3 units
Open to qualified graduate students interested in special advanced topics. Directed study including analytical work and/or laboratory investigations. Prerequisite: written permission of departmental head.

SEMINAR, PROJECTS, THESIS AND DISSERTATION

**AE 971-972   Seminar in Mechanical and
            Aerospace Engineering   0**
Recent developments through lectures by representatives from industry, research, educational institutions. Discussions from floor. Satisfactory attendance required of master's or engineer students for two semesters; four additional semesters required of Ph.D. students.

AE 996   Project   each 3 units
Engineering project pursued with guidance of faculty member. Project titles submitted in writing to department head and adviser appointed. May be extended to thesis with project adviser's recommendation. Credit only upon completion of project. Reregistration fee: 3-unit charge. Prerequisite: degree status.

AE 997   M.S. Thesis   each 3 units
Master's thesis to present results of original investigation in field of student's specialty. Thesis an extension of AE 996, on recommendation of project adviser. Continuous registration required. Maximum of twelve units of AE 996-997 counted toward degree. Reregistration fee: 3-unit charge. Prerequisite: AE 996.

AE 998   Engineer Project   each 3 units
Analytical, experimental or design project under guidance of faculty member. Oral examination on project and related topics required of candidates. Continuous registration required until satisfactory project completed. Minimum of six, maximum of twelve units of AE 996-997 counted toward degrees. Reregistration fee: 3-unit charge. Prerequisite: post-master status.

AE 999   Ph.D. Dissertation   each 3 units
Doctor's dissertation evincing independent study and original contributions in field of specialization. Oral examination on subject of dissertation and related topics required. Minimum of 24 units; also continuous registration at minimum of 3 units per semester required until dissertation completed. Reregistration fee: 3-unit charge. Prerequisite: degree status.

FACULTY

Pasquale M. Sforza, Professor and Head of Aerospace Engineering
B.Ae.E., M.S., Ph.D., Polytechnic Institute of Brooklyn
Theoretical and experimental fluid dynamics, aircraft and engine design

Robert J. Cresci, Professor
B.Ae.E., M.Ae.E., Ph.D., Polytechnic Institute of Brooklyn
Gas dynamics, heat and mass transfer, industrial aerodynamics

Joseph Kempner, Professor
B.Ae.E., M.Ae.E., Ph.D., Polytechnic Institute of Brooklyn
Structural analysis, shell theory, structural dynamics

Jerome M. Klosner, Professor
B.C.E., CCNY; M.S., Columbia University; Ph.D., Polytechnic Institute of Brooklyn
Structural dynamics, fluid-structure interaction, thermal stress analysis

Samuel Lederman, Professor
Dipl. Ing., Technical University of Munich (Germany); M.E.E., Polytechnic Institute of Brooklyn
Wind and shock tunnel testing, diagnostics of fluids microwaves, spectroscopy, lasers, and plasma

Morris Morduchow, Professor
B.A., Brooklyn College; B.Ae.E., M.Ae.E., D.Ae.E., Polytechnic Institute of Brooklyn
Fluid dynamics, solid dynamics, numerical analysis

James Bentson, Associate Professor
B.S., M.S., Ph.D., Polytechnic Institute of Brooklyn
Computational methods, hydrodynamics, vehicle dynamics

Morris P. Isom, Associate Professor
A.B., Harvard University; M.S., Massachusetts Institute of Technology; Ph.D., Princeton University
Acoustics, gas dynamics, applied mathematics

Gabriel Oyibo, Associate Professor
B.Eng. (Aero) Imperial College, Ph.D. (Aero) Rensselaer Polytechnic Inst.
Aeroelasticity, unsteady aerodynamics, transonic flow.

Jack E. Werner, Associate Professor
B.S., M.S., Massachusetts Institute of Technology; Ph.D., Johns Hopkins University
Low-speed aerodynamics, shock waves, fluid mechanics

EMERITUS FACULTY

Martin H. Bloom, Institute Professor Emeritus
B.M.E., M.S., Ph.D., Polytechnic Institute of Brooklyn
Fluid and thermal studies; aerospace engineering; energy conservation

Gino Moretti, Professor Emeritus
Ph.D., University of Turin (Italy)
Fluid mechanics, numerical techniques

Sebastian V. Nardo, Professor Emeritus
B.M.E., M.Ae.E., Ph.D., Polytechnic Institute of Brooklyn
Structural mechanics, dynamics, and solar energy

Simon Slutsky, Professor Emeritus
B.C.E., CCNY; M.S., Columbia University; Ph.D., Polytechnic Institute of Brooklyn
Urban noise, engine noise, and vibrations

ADJUNCT FACULTY

Robert S. Levy, Adjunct Associate Professor
B.M.E., City College of New York; M.M.E., Ph.D., Polytechnic Institute of Brooklyn

BIOENGINEERING PROGRAM

The dual-discipline program of bioengineering introduces the student to engineering in the health-related sciences. The curriculum includes engineering and life-science class work where both hardware and analytic applications are presented. Material covered includes the instrumentation to acquire physiologic data and the techniques to analyze and process such data.

Bioengineers bring new viewpoints to the life sciences. By use of their engineering training, they may conduct, direct or collaborate in research that provides a quantitative understanding of the living systems. Their knowledge of the life sciences, when applied to related engineering problems, assures that the solution to the problems takes full account of the special properties of living systems. In short, bio-engineers provide the intellectual link between engineering and the life sciences, a role increasingly important in biological and medical research and in industry.

DEGREE PROGRAMS

Polytechnic offers programs that lead to the master of science and doctor of philosophy degrees in bioengineering. While there is no undergraduate program at the present time, students may take a bioengineering concentration within most undergraduate engineering curricula.

REQUIREMENTS FOR THE MASTER'S DEGREE

It is expected that the undergraduate training of many students who enter the master's degree program will be deficient in certain areas. For this reason the program specifies a number of undergraduate requirements in chemistry, biology, mathematics and systems. These requirements (or their equivalents) must be completed before the student is permitted to register for graduate level courses in bioengineeing. The required courses are offered as electives in the undergraduate school so that Polytechnic students who are interested in the program may complete them in their seniors tear. Students from other schools take these courses or show equivalent preparation.

The master's programs consist of 36 units: 6 in mathematics, 18 in bioengineering, 6 in research and 6 in electives. This sequence permits students to maintain and expand their engineering background and to acquire experience with living systems simultaneously.

UNDERGRADUATE REQUIREMENTS

No.	Required Subjects	Credits
CM 122	Organic Chemistry I	3
CM 164	Physical Chemistry of Living Systems	3
LS 105	General Biology I	4
BE 201-202	Systems Approach to Biomedicine I, II	4

MA 001	Review of Calculus	0

GRADUATE REQUIREMENTS

No.	Required Subjects	Units
BE 600	Physiology Laboratory	3
BE 602	Clinical Techniques Laboratory	3
BE 603	Biophysics I	3
BE 610-611	Physiology for Bioengineers	6
BE 621	Instruments and Measurements in Physiological Systems	3
BE 961-962	Colloquium in Bioengineering	0
	Electives in Mathematics (chosen with the approval of the adviser)	6
	Electives in Bioengineering	6
BE 966	Project	6
	Total	36

Some laboratory sessions for the program are held at the nearby Long Island College Hospital, where live animal studies may be performed. The hospital has made many of its animal facilities available to the Polytechnic bioengineering program, and has allocated space for live animal research. In addition students associated with the program are exposed to the hopital environment and equipment used in clincial and diagnostic studies.

REQUIREMENTS FOR THE DOCTOR'S DEGREE

To be accepted into the bioengineering doctoral program, the student is required to pass a comprehensive qualifying examination. All students who have completed the course work toward the master's degree (excluding the project) with a B average or better are eligible to take the exam if they have been registered in the program for at least the two semesters preceding the examination date.

After passing the qualifying examination, the candidate (in consultation with program advisers) plans a program of study which includes additional background for bioengineering (as noted below) and course work in two minor fields chosen by the candidate. In addition, the student must exhibit an ability to read scientific literature in a foreign language and finally must present an acceptable doctoral dissertation on an elected research program. This research study for the doctor's degree is carried out under the direction of (and finally approved by) a guidance committee appointed by the vice president for research and graduate affairs.

Required Subject Areas	Units
Advanced Laboratory or Internship (as arranged with adviser)	5
Transportation Phenomena or Equivalents	6
Graduate Biochemistry	3
Bioengineering Electives or Equivalents	9
Research and dissertation (BE 999)	36
	59

UNDERGRADUATE COURSES

**BE 201-203 Systems Approach to
Biomedicine I, II** each 2:0:2
Introduction to modeling and simulation in biomedicine. Characterization of resistive and storage properties of physiological systems and their analogs. Analysis of systems with combined properties. Transform notation and transfer functions. Impedance concepts with applications to pulmonary function and diffusion. Periodic signals as related to physiological systems. (breathing, EKG), Fourier expansion and frequency response. Introductory concepts associated with feedback. BE 201 prerequisite: MA 102 or equivalent and permission of student's departmental adviser. BE 202 prerequisite: BE 201.

GRADUATE COURSES

BE 600 Physiology Laboratory 0:4:3
Studies of physiological specimens. Microscopic studies of tissue, nerve and muscle. Animal studies. Co/Prerequisite: BE 610

BE 602 Clinical Techniques Laboratory 0:4:3
Laboratory tests and measurements in biological specimens and relation to pathological states. Determination of fluid properties—viscosity, refractive index, etc. Characteristics of pH meters, pH determinations, colorimetry, spectrophotometry, fluorimetry, flame photometry. Separation techniques—centrifuge, chromatography, electrophoresis. Tracer techniques. Co/Prerequisites: LS 105 and BE 610 and CM 164 or equivalent.

BE 603 Biophysics I 2½:0:3
Physical properties of biological systems. Structural strength, elasticity of bones, muscle, other tissue. Flow properties through tissue, diffusion of gases and liquids, flow through vessels. Compartmental analysis, models, trace analysis. Prerequisite: BE 201-202 or equivalent and Co/Prerequisites: LS 105 and CM 164 or equivalent.
Also listed under PH 635

BE 604 Biophysics II 2½:0:3
Transport processes in and models of specific organs. Application of radionuclides and dyes for imaging. Nerve conduction with a detailed discussion of the Hodgkin-Huxley and current models. Prey-predator interactions on the cellular level, in radioimmunoassays, and in population control. Prerequisite: BE 603.
Also listed under PH 636

**BE 605 Radiation Physics with Biological
and Medical Applications*** 2½:0:3
Principles of atomic and molecular physics. Problems of radiation protection and biological effects of ionizing radiation. Radiation dosimetry and relationship between dose, biological behavior or radionuclides, radiation safety levels, effects of acoustical, microwaves, and thermal radiation. Prerequisite: PH 355 or equivalent.
Also listed under PH 637

**BE 610-611 Physiology for
Bioengineers I, II** each 2½:0:3
Intensive course in human physiology. Overall organization of the body: colon cells, tissue, organs, structure, fluids. Properties and transportation of body fluids; renal function; cardio-pulmonary, nervous, and gastrointestinal systems. BE 610 Prerequisites: CM 122 and LS 105 or equivalent. BE 611 Prerequisite: BE 610.

BE 612 Advanced Physiology Laboratory* 1:6:6
Live animal experiments and demonstrations to illustrate principles of physiology, principles of biological laboratory experimentation and techniques of animal experimentation. Prerequisites: BE 600, BE 611 and BE 621.

**BE 621 Instruments and Measurements
in Physiological Systems** 2½:0:3
Theoretical and practical aspects of measurement problems in physiological systems. Volume conductors: microelectrodes; technique for acquiring body-generated signals. Multi-phasic screening systems. EMG, EEG, EKG. Readout devices and computer interface; digital instrumentation; telemetry. Analog and digital computer simulation of biological systems. Prerequisites: BE 201-202 and Co/Prerequisite: LS 105.

**BE 623 Mincomputer Instrumentation
for Scientific Research*** 1:2:3
Fundamentals of digital electronics and minicomputers; computer-automated laboratory instrumentation; programming and interfacing required for data acquision and control in scientific research. Experiments with minicomputers and with laboratory apparatus interfaced directly to minicomputers. Prerequisite: instructor's permission.
Also listed under PH 612 and CM 760

BE 650 Biomechanics* 2½:0:3
Fundamental basics of biomechanics interpreted in terms of human engineering and engineering mechanics. Applications to industrial and medical problems. Significant anatomical, kinesiological and physiological considerations. Demonstration of applications to industrial as well as medical problems.
Also listed under ME 651

BE 670 Biosystems* 2½:0:3
Examination of control functions in the body. Types and properties of receptors. Feedback mechanisms. Performance tests, analysis and simulation of the cardiovascular, respiratory and fluid regulation systems. Examination of pathological states based on simulated models. Prerequisite: adviser's approval.

BE 675 Sensation and Perception* 2½:0:3
Review of different sensory systems: vision, audition, taste, smell, touch temperature sensitivity, vestibular, kinesthetic senses and their relation to nonsensory controlling stimuli, techniques of obtaining psycho-physical data on each sensory system, and the relation of these techniques to theories of discrimination. Available to undergraduate majors in social science with permission of the instructor. Prerequisite: SS 189 or equivalent or instructor's permission.
Also listed under SS 912

BE 676 Comparative Psychology 2½:0:3
Comparsion of behavior of different species as function of ethnological and psychological variables. Behavior genetics, neural and hormonal control of behavior, behavioral consequences of special sensory structures, species-specific behavior, critical period, communication. Prerequisite: SS 189 or equivalent, or LS 106 or equivalent or instructor's permission.
Also listed under SS 914

BE 692 Neurophyaiology* 2½:0:3
An in-depth discussion of basic nerve cell physiology covering such topics as resting potential, sodium pump, action potential, synaptic mechanisms and local neuronal circuits. Prerequisite: LS 106 or BE 611.
Also listed under LS 600

BE 693 Topics in the Neurosciences* 2½:0:3
A review and in-depth discussion of various topics in the neurosciences. Typical topics will be neurotransmitters, motor control, developmental neurobiology, circadian rhythms, pain, neuronal modeling, neural correlates of central nervous system disorders, etc. Topics will vary from semester to semester and course may be taken for repeated credits. Prerequisite: LS 106 or BE 611 or instructor's permission.
Also listed under LS 601

BE 695   Physiological Psychology*   2½:0:3
Review of physiological bases and correlates of behavior. Physiology of sensory systems, emotions, motivations and electrophysiological correlates of learning. Prerequisite: SS 198 or BE 111 or instructor's approval.
Also listed under SS 913

BE 741   Bioengineering Metallurgy I*   2½:0:3
Metals and alloys for use in the body environment. Examination of corrosion, excessive plastic deformation, fracture and stress-corrosion-cracking. Characterization of metals and alloys, atomistic, microscopic and macroscopic structures. The phase diagram. Preparation of dental amalgams and other alloys.
Also listed under MT 727

BE 742   Bioengineering Metallurgy II*   2½:0:3
Designs of alloys for bioengineering applications. Mechanical property requirements for alloys. Effects on plastic deformation of work hardening, recovery and recrystallization. Techniques for avoiding creep and fatigue failures. Principles of oxidation and corrosion. Composite corrosion-resistant materials. Prerequisite: BE 741.

BE 800   Selected Topics in Bioengineering*   2½:0:3
Topics of special current interest in bioengineering as announced in advance of a particular semester offering. Prerequisite: adviser's approval.

**BE 935   Engineering Projects
        Related to Public Administration   each 3 units**
See Polytechnic's Cooperative Program with New York University's Graduate School of Public Administration on page 000 for details.

THESIS, COLLOQUIM AND INTERNSHIP

BE 961-962   Colloquium in Bioengineering*   no credit
Recent developments in the field of bioengineering through lectures given by engineers, scientists and physicians from industry, research, medical and educational institutions by staff members, and by qualified graduate students. Required for two semesters of all graduate students seeking degrees.

BE 971-972   Bioengineering Internship*   each 3 units
Assignments of graduate students as members of selected hospital teams to observe hospital practice and participate where appropriate. Work directed by adviser from Polytechnic and leader of hospital team. Normally limited to students who have completed one full year of graduate study. Prerequisites: BE 602, BE 611, adviser's permission.

BE 996   Project   each 3 units
Bioengineering project under guidance of qualified faculty member subject to approval of program adviser. Projects may deal with any aspect of engineering applications in biological studies. Six units of project are required for the M.S. degree.

**BE 999   Thesis for
        Degree of Doctor of Philosophy   each 3 units**
Thesis to give results of independent investigation of problem in bioengineering; requires thorough search of the literature and may involve experimental work or may be of a theoretical and analytical nature. Dissertation to show that original contribution has been made that is worthy of publication in recognized journals. Candiate required to take oral examination on subject of thesis and related topics. Total registration of 24 credits required. Prerequisites: degree status and successful performance on qualifying examination.

FACULTY

Jesse F. Crump, Associate Professor and Director of Bioengineering
B.S., M.D., University of Nebraska
Physiology, bioengineering

William B. Blesser, Professor of Bioengineering
B.M.E., Rensselaer Polytechnic Institute; M.E.E., Polytechnic Institute of Brooklyn
Instrumentation; control systems; bioengineering

George Bugliarello, President and Professor
Dr. Ing., University of Pauda (Italy); M.S., University of Minnesota; Sc. D., Massachusetts Institute of Technology
Biorheology; social technology

Alfred L. Copley, Research Professor of Life Science and Bioengineering
M.D., University of Basel (Switzerland)
Biorheology

ADJUNCT FACULTY

Gabor B. Levy, Adjunct Professor of Bioengineering
Ph.D., St. Thomas Institute of Cincinnati

Carl P. Mason, Adjunct Lecturer in Bioengineering
B.S.M.E., M.S. Bio.E., Polytechnic Institute of New York

PARTICIPATING FACULTY

Robert C. Ackerburg, Professor of Chemical Engineering

Patrick T. Cahill, Professor of Physics

Herbert Morawetz, Professor of Polymer Chemistry

Shirley M. Motzkin, Professor of Biology

Kurt Salzinger, Professor of Psychology

Saul W. Rosenthal, Associate Professor of Electrophysics

SUPPORTING AND ADVISORY STAFF

Doris Escher (Montefiore Hosptial and Medical Center)
M.D., New York University
Pacemakers; cardiovascular studies

Henry Freedman (Long Island College Hosptial)
M.D., New York University
Geriatrics

Paul Fried (Veterans Administration — Brooklyn)
M.S., Polytechnic Institute of Brooklyn
Biomedical engineering

Seymour Furman (Montefiore Hospital and Medical Center)
M.D., SUNY (Downstate Medical Center)
Pacemakers; cardiovascular studies

Raphael Henkin (Veteran's Administration Hospital, Brooklyn)
M.S., Bioengineering

Paul Kaplan (Maimonides Medical Center, Brooklyn)
M.S., Bioengineering

Parviz Lalezari (Montefiore Hospital and Medical Center)
M.D., University of Teheran (Iran)
Hematology

Harold A. Lyons (Downstate Medical Center and Kings County Hospital) M.D., Long Island College of Medicine
Pulmonary function

Robert Robertazzi (Maimonides Mediocal Center, Brooklyn)
M.S., Bioengineering

Lenore R. Zohman (Montefiore Hospital and Medical Center)
M.D., SUNY (Downstate Medical Center)
Exercise cardiology

CHEMICAL ENGINEERING

Students of chemical engineering are taught to develop knowledge and analytical skills to bridge the technological gap between scientific advances and the economical production of new and useful products.

Chemical engineers rely heavily on science, engineering methods, experience and ingenuity to invent the processes and equipment required to make these products. Chemical engineers have contributed to the development of virtually every material common to modern life. They are involved with the production of petroleum products, plastics, pharmaceuticals, foodstuffs, synthetic rubber and rocket propellants, to name a few. Their influence has been felt in developing nuclear reactors, fuel cells, automatic controls, water desalting plants, missiles, and artificial kidneys.

Students may choose a very wide range of activities, including research, process and product development, design and supervision of the construction and operation of industrial plants, technical sales and services, consulting, management and teaching. Opportunities are virtually unlimited.

The foundations of chemical engineering are the sciences, with emphasis on chemistry, mathematics, physics and the engineering sciences, including thermodynamics, fluid mechanics, kinetics and heat and mass transfer. Chemical engineering courses include the analysis, design and control of equipment, operations and processes.

UNDERGRADUATE PROGRAM

The undergraduate program in chemical engineering provides a sound foundation in science and the engineering sciences and builds on this a strong and integrated set of courses in chemical engineering. Thorough instruction is given in chemistry, physics, mathematics and in the engineering sciences basic to the understanding of physical and chemical operations and processes. Courses in engineering science include engineering thermodynamics, reaction kinetics, process dynamics, fluid mechanics, heat transfer and mass transfer.

The chemical engineering curriculum provides a background which enables the graduate to select a professional career from an extremely broad spectrum of opportunities. Graduates are prepared to take employment in a number of capacities in industry or to enter graduate school for advanced study in chemical engineering or other fields.

The Department of Chemical Engineering offers undergraduate degree programs at two campuses, Brooklyn and Long Island, with identical curricula and courses.

Students wishing to specialize in certain subject areas may do so through judicious selection of technical electives. Chemical engineering students may be particularly interested in the medical-related field, in environmental problems, in computer applications or management. For example, students interested in medical or biosystems might choose technical elective courses such as LS 105, LS 115, BE 201, BE 206, BE 610, and BE 603, while those interested in environmental studies might choose SS 182, LS 105, LS 140, CE 340, CE 341, CE 770, CE 342 and CH 752. A management emphasis might be developed by choosing MG 300, SS 251 & 252, IE 252, IE 327 and MG 601. Similarly, an emphasis in computer sciences could be arranged. Specializations can be developed with departmental advisers.

An undergraduate program leads to the degree of bachelor of science in chemical engineering and is recognized by the Accreditation Board for Engineering and Technology.

Polytechnic requires a 2.0 minimum average for graduation. Students must meet the academic standards of the department. For students to advance to the senior year, a 2.0 grade average must be maintained in chemical engineering courses CH 123, CH 124, CH 220, CH 221, CH 251, CH 261; the same course must not be failed twice. Students who do not meet these requirements will not be allowed to register for senior courses. All listed prerequisites must be satisfied before the students are permitted to enroll in chemical engineering courses.

Typical Course of Study for the Bachelor of Science Degree in Chemical Engineering

Freshman Year

First Semester			Hours/Week		
No.		Subject	CL.	Lab.	Cr.
MA	101	Calculus I	4	0	4
CM	101	General Chemistry I	2½	0	2½
CM	111	General Cehmistry Lab I	0	1½	½
CS	100	Introduction to Computer Science	2	0	2
HU	101	Writing and the Humanities I[1]	3	0	3
SS	104	Main Themes in Contemporary World History[1]	3	0	3
SL	101	Student Survival	0	1	0
PE	101	Physical Education I	0	2	0
					15

Second Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
MA	102	Calculus II	4	0	4
PH	104	Introductory Physics I	3	0	3
CM	102	General Chemistry II	2½	0	2½
CM	112	General Chemistry Lab II	0	1½	½
HU	200	Writing and the Humanities II	3	0	3
		Hum./Soc. Sci. Elective			3
PE	102	Physical Education II	0	2	0
					16

Sophomore Year

			CL.	Lab.	Cr.
MA	103	Calculus III	3	0	3
PH	105	Introductory Physics II	3½	0	3½
PH	115	Physics Laboratory I	0	1½	½
ME	116	Engineering Mechanics I	2	0	2
CH	123	Chem. Proc. Anal. I[3]	2	0	2
CM	122	Organic Chem. I	3	0	3
		Hum./Soc. Sci. elective[1]			3
PE	103	Physical Education III	0	2	0
					17

MA	104	Applied Diff. Eq.	3	0	3
ME	117	Engineering Mechanics II	2	0	2
CH	124	Chem. Proc. Anal. II[3]	2	0	2
CM	161	Physical Chemistry[4] I	3	0	3
CM	123	Organic Chem. II	3	0	3
PH	106	Introductory Physics III	2½	0	2½
PH	116	Physics Laboratory II	0	1½	½
PE	104	Physical Education IV	0	2	0
					16

Junior Year

CH	220	Transfer Operations I	4	0	4
CH	251	Chemical Engineering Thermodynamics	4	0	4
CM	124	Organic Chemistry Lab I	⅓	5	2
CM	162	Physical Chemistry II	3	0	3
		Technical elective[2]			3
		Free elective			3
					19

CH	221	Transfer Operations II	4	0	4
CH	261	Multistage Separation Proc.	3	0	3
EE	370	Principles of Electrical Eng.	3	0	3
EE	374	Instrumentation Lab	0	3	1
		Hum./Soc. Sci. elective[1]			3
		Technical elective[2]			3
					17

Senior Year

CH	301	Chemical Engineering Lab I	0	6	2
CH	322	Chemical Reactor Eng.	3	0	3
CH	351	Process Dynamics & Control	3	0	3
CH	361	Process Design I	3	0	3
		Hum./Soc. Sci. elective[1]			3
		Technical elective[2]			4
					18

CH	302	Chemical Engineering Lab II	0	6	2
CH	371	Engineering Materials	3	0	3
CH	362	Process Design II	3	0	3
		Technical elective[2]			7
		Hum./Soc. Sci. elective			3
					18

Total credits required for graduation: 136

[1] See item a under "Electives" on page 67.
[2] See item b under "Electives" on page 68.
[3] See item c under "Electives" on page 68.
[4] PH106 must be a co- or prerequisite.

ELECTIVES

Elective courses are chosen in consultation with the chemical engineering undergraduate adviser according to the following guidelines:

a. In the humanities and social sciences, the student must take HU 101 and either HU 200 and SS 104 or IS 140 and IS 141 (total 9 credits). Students placed in HU 103 on the basis of the English Composition Placement Test administered at Polytechnic to all incoming students may substitute HU 103 for HU 101. Students placed in HU 008 or HU 009 must complete this noncredit course before taking HU 101 (or HU 103). All students must also elect at least 15 credits in humanities and social sciences in addition to the above 9 credits.

At least 18 of the credits students select in the humanities and social sciences must meet the requirements of the Accreditation Board for Engineering and Technology (ABET). These credits may not include skills-oriented courses such as technical writing, public speaking, or English as a second language. Courses in literature, foreign languages, history, economics, and others are acceptable. Students should consult their adviser to ensure that these criteria are met.

Students should select an area of concentration (such as literature, communications, the arts, or philosophy and comparative religions in the Department of Humanities, or economics, history, anthropology, or psychology in the Department of Social Sciences) and elect at least three courses in this concentration in consultation with their adviser. A modern language may be chosen as a suitable

concentration, but students without prior knowledge of the language must plan to devote at least 12 credit hours to it.

For further information, students should refer to the section of this catalog entitled Humanities and Social Sciences Requirements for Engineering and Computer Science Majors.

For the remaining credits in the humanities/social sciences requirement, students should select courses in areas other than that of concentration. Additional courses in humanities and social sciences may be taken as free electives.

b. A total of 17 credits of technical electives is necessary. In fulfilling this requirement, the student must choose at least 3 credit hours of mathematics, 3 credit hours of chemistry or biosciences and 6 credit hours of chemical engineering electives from an approved list available in the chemical engineering office. The remaining 5 credit hours may be taken in any advanced level technical area in consultation with the departmental adviser.

c. Junior transfer students should take CH 123 and CH 124 in junior year in place of electives.

ROTC Adjustments — ROTC students should note that freshmen and sophomores may substitute zero-credit military science courses for PE 101 - 104 (physical education); juniors and seniors may substitute three of the following two-credit courses: MS 301, 303, 401 or 403 for six credits of technical or free electives.

GRADUATE PROGRAM

The graduate programs in chemical engineering are designed to introduce students to advanced designs, research and development. The Department of Chemical Engineering offers graduate programs leading to degrees of master of science, engineer and doctor of philosophy in chemical engineering.

The Departments of Chemical Engineering and Chemistry jointly offer programs leading to degrees of master of science and doctor of philosophy in polymer science and engineering. (See page 00.)

A degree in chemical engineering is generally required for admission to graduate study. An applicant who has earned a bachelor's degree from a foreign institution is required to submit Graduate Record Examination and TOEFL scores. Students must have had differential equations. Applicants with degrees in other fields or from other colleges may be admitted with undergraduate and/or graduate deficiencies as evaluated by the graduate adviser. The program leading to the master's in chemical engineering may be used as either a terminal course for development and advanced design, or as a research degree giving preliminary graduate training for the doctorate in chemical engineering.

The degree of engineer in the chemical engineering program is oriented toward chemical engineers who wish to achieve a level of education in advanced process design beyond that normally possible for the master's degree.

The doctor of philosophy in chemical engineering degree program provides advanced graduate study and research

for qualified students interested in research and development.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE IN CHEMICAL ENGINEERING

Candidates for the degree of master of science in chemical engineering are to plan their programs in accordance with the following required courses:

No.	Required Subjects	Units
CH 631-632	Transport Phenomena I, II	6
CH 771-772	Thermodynamics I, II	6
CH 781	Chemical Process Kinetics	3
CH 821	Process Dynamics and Control	3
CH 991-992	Seminar in Chemical Engineering	0

Project/Thesis Option
either

CH 902	Guided Studies in Chemical Engineering	6
Electives (including 9 units chosen from CH 600 to CH 910)		12

or

CH 997	Master's Thesis	9
Electives (including 6 units chosen from CH 600 to CH 910)		9
		36

All electives are to be chosen in conference with the graduate adviser.

To meet graduation requirements, students may not obtain grades of C (or lower) in more than three required subjects listed above, including required courses retaken for purposes of improving grades. This requirement is in addition to Polytechnic's requirements for master's degrees.

REQUIREMENTS FOR THE ENGINEER DEGREE IN CHEMICAL ENGINEERING

Applicants for admission to this program must hold a master's degree (or equivalent) comparable to that of the department. This must include at least the equivalent of courses in transport phenomena, thermodynamics, chemical process kinetics, and process dynamics and control as a subset of the overall prerequisite of the master's degree. Applicants lacking academic backgrounds in these courses are obliged to satisfy these deficiencies before enrollment in the engineering program.

Candidates for the degree of engineer in chemical engineering plan their programs with the following required courses:

No.	Required Subjects	Units
CH 851	Process Design and Synthesis I	3
Chemical Engineering electives—chosen from CH 641, CH 721, CH 752, CH 766, CH 782, CH 815, CH 819, CH 852		15
Electives (should include at least 3 units in applied mathematics)		9
CH 998	Chemical Engineering Design Project	9

CH 991-992   Seminar   0

    36

All electives are to be chosen in conference with the graduate adviser.

Upon completion of the design project the candidate must take an oral examination before a faculty committee. The examination focuses on the subject of the project; its scope is not limited, and the candidate is examined in the broadest sense.

REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN CHEMICAL ENGINEERING

Programs of study are planned individually with each candidate by members of the Department of Chemical Engineering. Systematic study toward a doctor's degree is carried out under a guidance committee appointed by the Office of Research and Graduate Studies. The program is planned to give the student thorough chemical engineering background accompanied by study of a minor field chosen by the candidate. The student must pass a comprehensive qualifying examination in chemical engineering and present a doctoral dissertation.

Each candidate for the doctorate must complete a minimum of 90 units of academic work past the bachelor's degree, including a minimum of 30 units of dissertation research. Although the student may elect to take more than 30 units of Ph.D. thesis, only 30 units of Ph.D. thesis can be counted in the required 90 units past the bachelor's degree, and these must be taken at Polytechnic. Once the student has started the dissertation, registration must be continuous, excluding summer sessions, until it is completed and accepted. Of the 90 units, a minimum of 30 units must be taken at Polytechnic. A minimum of 48 graduate units beyond the bachelor's degree (not including Ph.D. thesis) in chemical engineering subjects are required, of which at least 18 units must be taken at Polytechnic. A minor is required within a science or engineering department and should consist of at least 12 credits. Attendance is required at chemical engineering seminars for at least four semesters. All students must maintain overall B averages in those courses submitted for the doctoral degree.

For a degree in chemical engineering, the following courses are required and may be used to complete the 48 graduate units required in chemical engineering subjects:

No.	Required Subjects	Units
CH 631-632	Transport Phenomena I, II	6
CH 771-772	Chemical Engineering Thermodynamics I, II	6
CH 781	Chemical Reactor Design I	3
CH 782	Chemical Reactor Design II	3
CH 821	Process Dynamics and Control	3
		21

Students interested in the Ph.D. program should obtain information outlining procedures and requirements, which is available from the office of the department head.

UNDERGRADUATE COURSES

CH 123   Chemical Process Analysis I   2:0:2
Introduction to chemical processes, synthesis and design. Flow sheets. Material balances. Recycle. Properties of materials. Modern computer methods. Prerequisite: Knowledge of programming.

CH 124   Chemical Process Analysis II   2:0:2
Continuation of studies of material and energy balances. Elementary thermodynamics and energy balances. Heats of reaction, solution and mixing. Combined energy and material balances. Computer methods. Prerequisite: CH 123.

CH 220   Transfer Operations I   4:0:4
Introduction to transport processes from the standpoint of the laws of conservation, rate phenomena and natural and imposed constraints. Unit operations; distributed versus lumped-parameter systems. Momentum transport and fluid flow operations in laminar and turbulent flow. Prerequisites: CH 124 and MA 104 or adviser's approval.

CH 221   Transfer Operations II   4:0:4
Continuation of theory of transfer operations with applications to chemical engineering systems. Energy and mass transport; heat transfer and diffusional mass transfer operations. Prerequisite: CH 220.

CH 251   Chemical Engineering Thermodynamics   4:0:4
First and second laws of thermodynamics, open and closed systems, thermodynamic properties of materials; generalized correlations for real fluids and multicomponent systems. Chemical potentials and their uses in phase and chemical reaction equilibria. Prerequisites: CM 161 and CH 124, or adviser's approval.

CH 261   Multistage Separation Processes   3:0:3
Unified treatment of separation processes utilizing the multi-stage model and mass and energy balances, e.g., absorption, extraction, distillation. Equilibrium stages, stage efficiencies, reflux and system parameters. Graphical, analytical and digital computer techniques of modeling stressed. Prerequisites: CH 220 and CH 251, or adviser's approval.

CH 301-302   Chemical Engineering Laboratory I, II   each 0:6:2
Experimental studies in chemical engineering. Unit operations, transport processes, thermodynamics, reaction kinetics, process instrumentation, process dynamics and controls. Design and conduct of experiments, interpretations of results, preparation of engineering reports. Data analyses done with computers. CH 301 prerequisites: CH 261 and CH 221. CH 302 prerequisites: CH 301, CH 322 and CH 351.

CH 322   Chemical Reactor Engineering   3:0:3
Application of thermodynamics and chemical kinetics to analysis and design of chemical reactors and reactor systems. Homogeneous and heterogeneous reactors of various types, uncatalyzed and catalyzed. Design of single and cascaded industrial reactors. Prerequisites: CH 221, CH 251 or instructor's permission.

CH 351   Process Dynamics and Control   3:0:3
Simulation dynamics, instrumentation and control of chemical processes. Unsteady state behavior of processes and modeling; control theories. Process systems analyses via transient and frequency response methods; control systems design. Analog computer simulations. Prerequisites: CH 221, CH 261, MA 104, or adviser's approval.

CH 361   Process Design I   3:0:3
Syntheses and designs of chemical processes, with considerations of site and process selections process economics, materials of construction, data requirements and acquisition flowsheeting and subsystems. Computer utilized. Case studies. Prerequisite: CH 261 and Co/Prerequisite: CH 351.

CH 362 Process Design II 3:0:3
Designs of large chemical process systems, with special emphasis on more complex, integrated process schemes and systems optimization. Prerequisites: CH 322 and CH 361.

CH 371 Engineering Materials 3:0:3
Structures, properties and uses of polymers and metals as engineering materials. Crystal structures, defects, heat treatments, corrosion and its prevention. Manufacture and processing of polymers. Mechanical behavior of polymers and their thermal and electrical properties. Prerequisites: CM 162, CH 322, CM 123 and CM 124. **Also listed under MT 420.**

CH 380-381 Chemical Engineering Project variable credit to max. of 3 each
Independent work in areas of interest in chemical engineering selected by students and faculty supervisors. Not open to honors or senior thesis students. CH 380 only or both CH 380 and CH 381 may be taken. Prerequisite: department's approval.

CH 391-392 Bachelor's Thesis In Chemical Engineering variable credit
Original investigations of problems in chemical engineering. A thorough search of the literature required. Special apparatus constructed as required for experimental work.

CH 396 Chemical Engineering Internships , 3 credits
Supervised, creative engineering experiences of at least two months duration, typically taken during the summer, culminating in written and oral reports presented to the industrial and faculty supervisors. Faculty visitations and conferences during internships are arranged. Prerequisite: senior standing and adviser's approval.

CH 399 Senior Honors Work in Chemical Engineering credit to be arranged
Independent work undertaken by qualified honors students under faculty guidance.

GRADUATE COURSES

CH 611† Unit Processes of Chemical Technology 2½:0:3
Studies of the important chemical industries, their processes and products. Effects of process variables on end products and needs for variations in properties of products as determined by market demands. Interlocking chemical industries. Product planning and marketing. Prerequisite: instructor's permission.

CH 612 Chemical Processes and Project Evaluations 2½:0:3
Analyses of designs and operations of chemical process plants and their individual components, with attention directed to the integrated and consistent use of technical and economic information. Special consideration given to optimizing designs of chemical plant pumping, process piping insulation heat transfer and recovery systems, as well as various mass transfer operations such as distillation, gas absorption, stripping and liquid extraction. Prerequisite: CH 361 or equivalent.

CH 615 Applied Mathematics in Chemical Engineering 2½:0:3
Mathematical formulation of chemical engineering problems in terms of ordinary, partial differential and difference equations. Solutions of boundary and initial value problems using Green's functions and other techniques. Characterization of second-order partial differential equations and properties of their solutions. Asymptotic methods, numerical techniques. Prerequisite: MA 260 or MA 531 or instructor's permission.

CH 625 Design of Clean Rooms 2½:0:3
Critical nature of purity; starting purity, during processing. Starting materials; etchants, solvents, photoliths, gases. Piping and monitoring; circulation, inert gases. Clean room; interlocks, temperature, humidity, ambient light. Cascading of solvents and etchants. Deionized water; containers, generation and monitoring. Safety of handling. Waste disposal. Toxicity. Vacuum systems; inert atmosphere. Clean room fatigue; dress, human factors.

CH 631-632 Transport Phenomena I, II each 2½:0:3
Fundamental concepts of momentum, energy and mass transport; transport in stationary and flowing systems, steady-state and transient conditions. Elementary Cartesian vector and tensor analyses; conservation equations for general cases and in macroscopic form; rate expressions. Fluid dynamics, energy transfer and diffusion; turbulent transport; transport coefficients; analogies; dimensional analysis; boundary layers, high rates of mass transport. Applications to chemical engineering systems stressed. CH 631 prerequisites: CH 220 and CH 221, or equivalent. CH 632 prerequisite: CH 631.

CH 641 Particle Transport Processes* 2½:0:3
Fundamentals of particle-fluid systems. Momentum, heat and mass transport in two-phase systems. Fluidization. Particulate removal. Analyses of particle size distributions and concentrations. Fluid-solid reaction kinetics and designs. Prerequisite: MA 531 or equivalent.

CH 672 Fundamentals of Biochemical Engineering 2½:0:3
Kinetics of enzymatic reactions. Transport phenomena in microbial systems. Designs and analyses of biochemical reactors. Principles of natural product isolations. Genetic engineering, and chemical processes. Prerequiste: instructor's permission.

CH 721 Mass Transfer Operations* 2½:0:3
Unified treatments of mass transfer operations such as distillation, absorption and extraction. Phase equilibria and thermodynamic correlations for binary, multicomponent and complex systems. Engineering design methods of stagewise and differential contact operations, including machine computational techniques. Developments in these areas. Prerequisite: instructor's permission.

CH 752 Air Pollution Engineering Control* 2½:0:3
Pollutant emissions control; analysis of pollutant properties, concentrations and boundary conditions; absorptive and reactive recovery processes for moving and stationary sources; formation and removal of gaseous oxides (NO_x, SO_x, CO, etc.) and of aerosols and other particulates. Prerequisite: adviser's approval. **Also listed under CE 758.**

CH 766 Process Heat Transfer* 2½:0:3
Thermal designs of industrial heat exchangers, including condensers and forced and natural circulation reboilers; process design of fired heaters; optimum uses of extended surfaces; heat transfers and power requirements of agitated jacketed vessels. Prerequisite: instructor's permission.

CH 771 Chemical Engineering Thermodynamics I 2½:0:3
Laws of thermodynamics; conditions for themodynamic equilibria; use of equations of state and the principle of corresponding states to determine changes in thermodynamic properties for pure substances and mixutres. Chemical potentials, standard states, ideal solutions, introduction to chemical and phase equilibria. Prerequisite: CH 251 or equivalent.

CH 772 Chemical Engineering Thermodynamics II 2½:0:3
Advanced treatment of chemical and phase equilibria, phase rules, Gibbs-Dunham equation, non-ideal solutions; stability of thermodynamic systems, osmotic pressures, surface tensions, thermodynamic equilibria in potential fields; introduciton to irreversible thermodynamics. Prerequisite: CH 771 or equivalent.

CH 781   Chemical Reactor Design I   2½:0:3
Kinetics of complex homogeneous and heterogeneous reactions: determination of kinetic parameters; effects of transport processes; catalyst deactivation. Analysis and design of reactors: ideal reactors, effects of nonideal flow; fixed-bed, fluidized-bed and multiphase reactors. Prerequisite: CH 322.

CH 782   Chemical Reactor Design II   2½:0:3
Design techniques for industrially important reactor situations and advanced methodologies for complex reaction analysis.

CH 784   Heterogeneous Catalysis*   2½:0:3
Kinetics of elementary steps (adsoption, surface reaction, desorption) and overall catalytic reactions: uniform and nonuniform surfaces, structure sensitivity, metal-support interactions, transport effects. Characterization of catalysts: preparation methods, analytical techniques. Prerequisite: CH 781 or equivalent.

CH 791   Modern Electrochemistry   2½:0:3
Thermodynamics, kinetics and mass transport in electrochemical processes. Modern electrochemical techniques including pulse waveforms and micro-electrodes. Application of electrochemistry to corrosion and energy conversion (batteries and fuel cells). Prerequisite: CM 162 or equivalent.

CH 819   Machine Computations In
**   Chemical Engineering**   2½:0:3
Digital computer applications in chemical engineering. Topics include programming languages such as FORTRAN, analog simulation languages such as CSMP and general simulation techniques using GPSS. Applications to material and energy balances, designs and optimizing distillation processes, heat transfer apparatus, processing flow sheets, uses of matrix methods in formulating and solving chemical engineering problems. Prerequisite: CS 100 or equivalent.

CH 821   Process Dynamics and Controls   2½:0:3
Instrumentation and control of chemical processes from the viewpoint of systems engineering. Unsteady state behavior of chemical engineering systems. Analyses of closed-loop feeback systems for control of variables of chemical processes equipment. Prerequisite: CH 351 or equivalent.

CH 851-852   Process Design
**   and Synthesis I, II***   each 2½:0:3
Designing of complex chemical process plants. Uses of optimization techniques in design. Selections of design techniques and process alternatives. Evaluation and designing of projects in the light of uncertainties. Factors affecting design and erection of plants such as market, plant location, raw materials availabilites. CH 851 prerequisite: CH 781 or equivalent. CH 852 prerequisite: CH 851.

CH 862   Rheology of Non-Newtonian Fluids*   2½:0:3
Classifications of non-Newtonian viscoelastic fluids. Derivations of rheological equations of state from continuum mechanics points of view. Molecular viscoelastic theories: random-coil and network theories. Experimental characterizations of non-Newtonian fluids: steady and dynamic experiments, measurements of normal stress differences in shear flow. Engineering applications to polymer processing operations. Prerequisites: CH 631, MA 531 and MA 532 or equivalent.

CH 900-901   Selected Topics in
**   Chemical Engineering***   each 2½:0:3
Topics of special current interest in chemical engineering, as announced in advance of a particular semester offering. Prerequisite: adviser's approval.

CH 927   Energy Policy issues   2½:0:3
See Energy Program for details.

CH 928   Energy Resource Distribution and
**   Conversion Technology**   2½:0:3
See Energy Program for details.

CH 935   Engineering Projects Related to
**   Public Administration**   each 3 units
See Polytechnic's Cooperative Program with New York University's Graduate School of Public Administration for details.

POLYMER SCIENCE AND ENGINEERING

CH 917   Introduction to Polymeric Materials   2½:0:3
Principles of technological aspects of polymerization, compounding and processing of polymeric materials, their properties and applications. Thermoplastic materials such as polyethylene, polypropylene, polyvinyl chloride, polystyrene, acrylics and engineering plastics are discussed. Thermosetting materials to be covered include: phenolics, epoxies, unsaturated polyesters, aminoplastics, polyurethanes and silicones. Prerequisite: CM 123 or equivalent.

CH 921   Polymer Processing   2½:0:3
Applications of engineering principles of polymer processing. Studies of non-Newtonian polymetric systems. Extrusion theories and applications. Discussions and problem-solving in compression, transfer and injection molding, thermoforming and plasticization, as well as other polymer engineering processes. Prerequisites: CH 220 and CH 221 or instructor's permission.

CH 922   Polymer Processing Laboratory   0:4:3
Laboratory studies of engineering principles and processes involved in polymer processing and analyses. Experiments include injection molding, extrusion, thermoforming, mixing and compounding, melt theology, flat-and-blown-film extrusion, blow molding, etc. Prerequisite: CH 921.

CH 924   Polymerization Reaction Engineering   2½:0:3
Principles of polymerization reactions, such as chain polymerization and heterogeneous polymerization reactions, from the engineering point of view, including mixing and thermal effects. Mathematical modeling techniques for describing molecular weight moments, copolymer composition and sequence distribution. Principles of polymer reactor design. Model parameter estimations and reactor controls. Prerequisite: CH 781 or equivalent.

CH 926   Engineering Properties of Polymers   2½:0:3
Studies of mechanical properties and structures of solid polymers. Viscoelastic theories and responses of amorphous, crystalline and composite materials in stress-strain tests, creep, stress relaxation and dynamic tests. Effects of orientation, and previous history on mechanical behavior. Prerequisites: CH 915, CM 771.

CH 928   Polymar Composites   2½:0:3
Comprehensive coverage of production, properties and durability of polymer composities. Emphasis is on fiber-reinforced thermosets. Fundamentals of chemical compositions, cure kinetics, processing, viscoelasticity and fracture mechanics will be discussed. Behavior of composites in service will be analyzed in terms of their structures. Prerequisites: CH 921, CH 926.

CH 933   Coatings Technology   2½:0:3
Chemistry, manufacture and applications of organic film formers; solvents and solubility principles; mechanisms and methods of film applicaitons, formations, conversions. Chemistry manufacture and applications of pigments. Principles and methods of pigment dispersions and coatings preparations, including influences of reology and surface chemistry. Principles of formulation of important paints and clear coatings. Specifications and test methods for coatings. Prerequisite: CM 123 or equivalent.

CH 940-941   Selected Topics in Polymer Science
**   and Engineering I, II***   each 2½:0:3
Topics of special interest in polymeric materials as announced in advance of particular semester offering. Prerequisite: adviser's approval.

PROJECTS, THESES AND SEMINARS

**CH 902   Guided Studies in
              Chemical Engineering   6 units, each 2 units**
Selections, analyses, solutions, and presentations of engineering reports of problems in processes or equipment design, thermodynamic studies or correlations, or other fields of chemical engineering practices under supervision of staff member. Conferences scheduled. Master's degree candidates required to submit three unbound copies of typewritten reports to advisers one week before the last day of classes. Prerequisite: degree status.

**CH 930   Guided Studies in Polymer Science
              and Engineering   6 units, each 2 units**
Selections, analyses, solutions, and presentations of comprehensive reports of problems involving polymeric materials, such as polymer synthesis, processing, evaluations, and equipment design. Supervision by staff members. Conferences scheduled. Master's degree candidates required to submit three unbound copies of typewritten project reports to advisers one week before last day of classes. Prerequisite: degree status.

**CH 987   Thesis for Degree of
              Master of Science in Polymer
              Science and Engineering   9 units, each 3 units**
Theses for master's degree in polymer science and engineering should give results of original investigations of problems in the chemistry and chemical engineering of polymeric materials. Theses may involve experimental research, theoretical analyses, process designs or combinations thereof. Master's degree candidates required to submit four typewritten unbound thesis copies to advisers before or on the seventh Wednesday before commencement. Prerequisite: degree status.

**CH 989   Dissertation for Degree of Doctor of
              Philosophy in Polymer Science
              and Engineering   30 units, each 3 units**
See description for CH 999. A wide variety of problems may be selected from topics in polymer science and engineering. Prerequisite: see CH 999.

CH 991-992   Seminars in Chemical Engineering   nc
Recent developments in chemical engineering are presented through lectures given by engineers from industry, research and educational institutions, by staff members and by qualified graduate students. Required for two semesters of all graduate students seeking degrees.

**CH 997   Thesis for Degree of Master of Science
              in Chemical Engineering   9 units, each 3 units**
Theses for master's degree in chemical engineering should give results of original investigation of problems in chemical engineering or application of physical, chemical or other scientific principles to chemical engineering. Theses may involve experimental research, theoretical analyses or process designs or combinations thereof. Master's degree candidates required to submit four typewritten unbound thesis copies to advisers before or on the seventh Wednesday prior to commencement. Prerequisite: degree status.

**CH 998   Chemical Engineering
              Design Projects   9 units, each 3 units**
Engineering analyses, syntheses, optimization and design of processes or novel equipment. Projects require original individual work. Evaluation of results, use of engineering judgment and excellence in reporting emphasized. Supervision by staff members. Conferences scheduled. Engineer degree candidates required to submit four unbound typewritten project report copies to advisers before or on the seventh Wednesday prior to commencement. Prerequisite: degree status.

**CH 999   Dissertation for Degree of
              Doctor of Philosophy in
              Chemical Engineering   30 units, each 3 units**
Dissertations must give results of independent investigations of problems in chemical engineering and may involve experimental and/or theoretical work. Theses must show ability to do creative work and that original contributions have been made to chemical engineering, which are worthy of publication in recognized journals. Candidates required to take oral examinations on subjects of theses and related topics. Doctor's degree candidates required to submit five unbound thesis copies to advisers before or on the seventh Wednesday prior to commencement. Prerequisites: degree status and a qualifying examination on quantitative aspects of chemical engineering.

FACULTY

Allan S. Myerson, Professor and Head of Chemical Engineering
B.S., Columbia University; M.S., Ph.D., University of Virginia
Crystallization, mass transfer, biochemical engineering

Robert C. Ackerberg, Professor of Chemical Engineering
B.S., Massachusetts Institute of Technology; M.S.E., University of Michigan; M.A., Ph.D., Harvard University
Fluid Mechanics, applied mathematics, thermodynamics

Robert F. Benenati, Professor of Chemical Engineering
B.Ch.E., M.Ch.E., Ph.D., Polytechnic Institute of Brooklyn
Computer applications to process design, packed and fluidized beds, heat transfer

James J. Conti, Professor of Chemical Engineering and Vice President for Educational Development
B.Ch.E., M.Ch.E., D.Ch.E., Polytechnic Institute of Brooklyn
Transport processes, biomedical engineering

Chang Dae Han, Professor of Chemical Engineering and Director of Polymer Science and Engineering Program
B.S., Seoul National University; M.S., Sc. D., Massachusetts Institute of Technology; M.S., Newark College of Engineering; M.S., New York University
Rheology, polymer processing, process control

T.K. Kwei, Professor of Chemistry and Chemical Engineering
B.S., National Chiao-Tung University (China); M.S., University of Toronto; Ph.D., Polytechnic Institute of Brooklyn
Polymer-polymer miscibility, phase relationships in polymers

Eli M. Pearce, Professor of Polymer Chemistry and Chemical Engineering, and Dean of Arts and Sciences
B.S., Brooklyn College; M.S., New York University; Ph.D., Polytechnic Institute of Brooklyn
Polymer synthesis and degradation

Jovan Mijovic, Associate Professor of Chemical Engineering
B.S., University of Belgrade; M.S., Ph.D., University of Wisconsin (Madison)
Polymer morphology, fracture properties of polymers, adhesives and composites

Leonard I. Stiel, Associate Professor of Chemical
Engineering
B.S., Massachusetts Institute of Technology; M.S., Ph.D.,
Northwestern University
*Thermodynamic properties of mixtures, properties of polar
fluids*

Edward N. Ziegler, Associate Professor of Chemical
Engineering
B.Ch.E., CCNY; M.S., Ph.D., Northwestern University
Kinetics and reactor design, air pollution control, fluidization

Walter P. Zurawsky, Assistant Professor of Chemical
Engineering
B.A., Temple University; M.S., Ph.D., University of Illinois
Plasma polymerization, polymer adhesion

ADJUNCT FACULTY

Joseph W. Prane, Adjunct Professor of Chemical
Engineering
B.Ch.E., CCNY; M.S., Columbia University

EMERITUS FACULTY

Paul F. Bruins, Professor Emeritus of Chemical
Engineering
B.S., Central College, Iowa; M.S., Ph.D., Iowa State
University; D.Sc. (Hon.), Polytechnic Institute of New York
Plastics technology, electrochemistry, materials science

Donald F. Othmer, Professor Emeritus of Chemical
Engineering
B.Ch.E., D.Sc., University of Nebraska, M.Ch.E., Ph.D.,
University of Michigan; D. Eng. (Hon.), New Jersey Institute
of Technology
*Energy conversion processes, thermodynamics of phase
equilibria*

W. Fred Schurig, Professor Emeritus of Chemical
Engineering
B.Ch.E., M.Ch.E., D.Ch.E., Polytechnic Institute of Brooklyn,
Unit operations, laboratory information

CHEMICAL PHYSICS

GRADUATE DEGREE PROGRAMS

The chemical physics program at Polytechnic is designed to train students for careers in areas common to chemistry and physics. It provides, within the scope of a normal graduate program, an unusual overlap of studies in both departments, emphasizing aspects that are closely related to both fields.

Faculty members participating in the chemical physics program are currently engaged in research in the following areas:

- Atomic and molecular dynamics
- Imaging sciences
- Infrared and Raman spectroscopy
- Laser chemistry and spectroscopy
- Medical physics
- Microparticle photophysics
- Nonlinear optics
- Photoelectrochemistry
- Polymer photochemistry and photophysics
- Solid state chemistry
- Statistical mechanics
- Surface and condensed matter physics
- X-ray crystallography

Doctoral research in chemical physics involves working closely with a faculty member on a research project in areas such as those listed above.

Students normally enter the program with undergraduate degrees in chemistry, physics or mathematics. Students spend the first year in the program developing competence in those areas of chemistry, physics and mathematics that are outside their undergraduate training. Guided by the graduate adviser, students select a plan of study suited to their individual needs and interests; thus there are no formal specific course requirements for a master's or doctor's degree. Representative first-year programs for students entering graduate study in chemical physics are:

Representative Program for First-Year Students

No.	Subject	Units
CM 703	Chemical Physics I	4½
CM 704	Chemical Physics II	4½
MA 630	Complex Vairables	3
MA 839	Introduction to Functional Analysis	3
CM/PH 995-996	Seminar in Chemical Physics	3
CM 971-972	Chemistry Colloquium	0
or		
PH 901-902	Physics Colloquium	0

Students with baccalaureate degrees in chemistry:

MA 260	Vector analysis and Partial Diff. Eqs.	4
PH 373-374	Introduction to Theoretical Physics	6

Students with baccalaureate degrees in physics:

CM 161-162	Physical Chemistry I, II	6
CM 601	Inorganic Chemistry	4½

Thesis, project and/or electives chosen from chemistry, physics, mathematics 8-11

REQUIREMENTS FOR THE MASTER'S DEGREE

The program of study for the degree of master of science in chemical physics offers three options, each requiring 36 units. One option, including early formal research, consists of a 12-unit thesis and 24 units of required and elective courses. In another option, candidates with suitable experience may substitute a six-unit project and six additional electives for the 12-unit thesis. The project requires a literate and critical discussion of the current status of a specialized area of research and demonstration of the student's professional maturity. The project is completed by the submission of an acceptable written report and by its satisfactory defense in an examination.

The third option emphasizes a strong formal training in courses and is acceptable as well as advised only for students planning to proceed to the doctorate. The Ph.D. qualifying examination will generally serve as the M.S. final examination. A satisfactory pass is required.

No.	Required Subjects	Units
CM971-972	Chemistry Colloquium	0
or		
PH901-901	Physics Colloquium	0
CM/PH 995-996	Seminar in Chemical Physics or Chemistry or Physics (to be taken with either colloquium)	3

and one of the following:

CM998/ PH999	Thesis in Chemical Physics	12
Electives*		at least 21
or‡		
CM998 PH 999	Project in Chemical Physics	6
Electives*		at least 27
or‡		
Electives*		at least 33
		at least 36

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* To be chosen from approved courses in chemistry, mathematics and physics in consultation with adviser.

‡ Advised and allowed only for students intending to proceed to the doctorate.

REQUIREMENTS FOR THE DOCTOR'S DEGREE

The requirements for the doctorate conform to the general regulations given elsewhere in this catalog. Both the major and minor fields are generally chosen from the areas of chemical physics, chemistry, physics and mathematics. Students are expected to pass examinations which form part of those regularly given to graduate students in the Departments of Chemistry and Physics.

The most important requirement is the preparation of a dissertation embodying a substantial research contribution in chemical physics.

Students may apply for admission to the chemical physics program either when applying for admission to graduate school or later. Application forms, as well as additional information, are available from the Office of Research and Graduate Studies.

FACULTY INTERDEPARTMENTAL COMMITTEE

Bruce A. Garetz, Associate Professor of Chemistry; Chairman, Chemical Physics Committee

*Edward L. Wolf, Professor and Head of Physics

*William H. Starnes, Professor and Head of Chemistry

*Eli M. Pearce, Professor of Chemistry and Dean of Arts and Sciences

Ernest M. Loebl, Professor of Chemistry

*Ex officio

PARTICIPATING FACULTY

Stephen Arnold, Professor of Physics

Ephraim Banks, Professor Emeritus of Chemistry

Patrick T. Cahill, Professor of Physics

Richard Carlin, Assistant Professor of Chemistry

Lorcan Folan, Assistant Professor of Physics

Hellmut J. Juretschke, Professor of Physics

Norman C. Peterson, Professor of Chemistry

Arnost Reiser, Research Professor of Chemistry and Director of the Institute of Imaging Sciences

Donald M. Schleich, Associate Professor of Chemistry

CHEMISTRY

Chemistry is concerned with our knowledge of the structures, properties and reactions of matter and our evolving theories to explain our observations, predict chemical behavior and suggest experiments.

Classical divisions of chemistry were organic chemistry, dealing primarily with compounds of carbon; inorganic chemistry, concerned with all other compounds; analytical chemistry, concerned with qualitative determinations of composition; and physical chemistry, which seeks understanding of matter, including chemical bonds and molecular interactions. These classical fields have overlapped increasingly, and several inter-disciplinary fields are now of great importance: biochemistry, electrochemistry, photochemistry, polymer chemistry, solid state chemistry, and chemical physics.

Polytechnic's Department of Chemistry offers a full complement of undergraduate and graduate courses in all aspects of modern chemistry. Graduates are prepared for positions with educational institutions, research institutes, industrial organizations and government laboratories.

Staff members conduct and supervise research at undergraduate, graduate, and postdoctorate levels. This research is combined with teaching so that courses at all levels are taught by chemists who are highly competent in their respective fields.

Participation of undergraduates in optional research activities provides them with both stimuli and good preparation for graduate school or professional positions.

The department offers programs leading to degrees of bachelor of science, master of science and doctor of philosophy in chemistry, and the degree of master of science in industrial chemistry.

The department also offers joint programs with the Departments of Physics and Chemical Engineering.

CHEMICAL PHYSICS

Chemical physics is an interdisciplinary program designed to train students for careers in those areas common to chemistry and physics. Administered jointly by the Departments of Chemistry and Physics, it provides, within the scope of a normal graduate program, flexible courses of study in both departments. The program leads to degrees of master of science and doctor of philosophy. (For details, see special listing.)

POLYMER SCIENCE AND ENGINEERING

Polymer science and engineering is an interdisciplinary program, administered jointly by the Departments of Chemistry and Chemical Engineering, leading to degrees of master of science and doctor of philosophy. (For details, see special listing.)

UNDERGRADUATE PROGRAMS

For students majoring in chemistry, the Department of Chemistry provides curricula which go beyond the requirements of the American Chemical Society for professional training. Courses offered are designed to prepare students for graduate studies or work in industry. Students may elect the thesis option or the no-thesis option in either chemistry or the biochemistry option (see detailed curricula).

Bachelor of science degrees in chemistry are certified by the American Chemical Society, and graduates are immediately eligible for membership.

Requirements for the Degree of Bachelor of Science

	Credits
CM 101, 102, 108, 109, 111, 112, 118-120, 122-125, 161, 162, 175, 501, 504,	45
Advanced Chemistry	3
*Thesis Research (CM 390-394)	10
CS 100	2
MA 101-104	14
PH 104-106, 115-116	10

The minimum of 128 credits required for the degree of bachelor of science in chemistry includes a minimum of 30 credits in humanities and social sciences.

At least two semesters of a foreign language (French, German or Russian) are strongly recommended.

*Students electing thesis research are required to submit a written thesis prior to graduation. Students may elect a no-thesis option and select ten credits of advanced chemistry courses in consultation with an advisor.

Curriculum for the Bachelor of Science Degree in Chemistry

Freshman Year

First Semester			Hours/Week			Second Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.	No.		Subject	Cl.	Lab.	Cr.
CM	101	General Chemistry I	2½	0	2½	CM	102	General Chemistry II	2½	0	2½
CM	111	General Chemistry Lab I	0	1½	½	CM	112	General Chemistry Lab II	0	1½	½
CS	100	Introduction to Computer-	2	0	2			Hum./Soc. Sci. elective	6	0	6
		Programming				*MA	102	Calculus II or MA 110	4	0	4
		Hum./Soc. Sci. electives	6	0	6	PH	104	Introductory Physics I	3	0	3
*MA	101	Calculus I or MA 100	4	0	4	PE	102	Physical Education	0	2	0
SL	101	Student Survival	0	1	0						16
PE	101	Physical Education	0	2	0						
					15						

Sophomore Year

CM	122	Organic Chemistry I	3	0	3	CH	123	Organic Chemistry II	3	0	3
CM	124	Organic Chemistry Lab I	3/10	5	2	CM	125	Organic Chemistry Lab II	3/10	5	2
		Hum./Soc. Sci. electives	6	0	6			Hum./Soc. Sci. electives	3	0	3
MA	103	Calculus III	3	0	3	CM	161	Physical Chemistry I	3	0	3
PH	105	Introductory Physics II	3½	0	3½	MA	104	Applied Diff. Equations	3	0	3
PH	115	Physics Laboratory I	0	1½	½	PE	104	Physical Education	0	2	0
PE	103	Physical Education	0	2	0	PH	106	Introductory Physics III	2½	0	2½
					18	PH	116	Physics Laboratory II	0	1½	½
											17

Junior Year

CM	118	Chemical Equilibria	2-3/10	5	4	CM	108	Inorganic Chemistry	3	0	3
CM	162	Physical Chemistry II	3	0	3	CM	119	Analytical Chemistry	3	0	3
CM	504	Chemical Laboratory Safety	1	0	1	CM	120	Analytical Chemistry Lab	0	6	2
		Hum./Soc. Sci. electives	3	0	3	CM	177	Physical Chemistry Lab	3/10	5	2
		Techn. elective			3	CM	501	Chemical Literature	1	0	1
		Elective			3			Hum./Soc/ Sci electives	3	0	3
					17			Electives	3	0	3
											17

Senior Year

CM	109	Inorganic Chemistry Lab	0	3	1			Advanced Chemistry	3	0	3
CM	175	Adv. Physical Chemistry	4	0	4	CM	392-				
CM	390-	Bachelor's Thesis			4		394	Thesis			6
	391							Electives			4
		Hum./Soc. Sci. elective	3	0	3						13
		Elective			3						
					15						

Total credits required for graduation: 128

*Placement into MA 101 and MA 102 or MA 100 and MA 110 is based on an entrance examination.

BIOCHEMISTRY OPTION

Freshman and sophomore courses as above.

Junior Year

First Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
LS	105	Biology I	3	0	3
LS	115	General Biology Lab I	1	3	2
CM	118	Chemical Equilibria	2-3/10	5	4
CM	162	Physical Chemistry II	3	0	3
CM	201	Biochemistry I	3	0	3
CM	504	Chemical Laboratory Safety	1	0	1
					16

Second Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
LS	106	Biology II	3	0	3
LS	116	General Biology Lab II	1	3	2
CM	177	Physical Chemistry Lab	3/10	5	2
CM	202	Biochemistry II	3	0	3
CM	204	Biochemistry Lab	3/10	5	2
CM	501	Chemical Literature	1	0	1
CM	108	Inorganic Chemistry	3	0	3
					16

Senior Year

CM	109	Inorganic Chemistry Lab.	0	3	1
		Hum./Soc. Sci. electives	6	0	6
CM	390-391	Bachelor's Thesis			4
		Electives			3
					14

CM	119	Analytical Chemistry	3	0	3
CM	120	Analytical Chemistry Lab	0	6	2
CM	392-394	Thesis			6
		Hum./Soc. Sci. electives			3
		Electives			2
					16

Total credits required for graduation: 128

In humanities and social sciences, students must take HU 101 and either HU 200 and SS 104 or IS 140 and IS 141. Students who are placed in HU 103 on the basis of the English Composition Placement Test administered at Polytechnic to all incoming students may substitute HU 103 for HU 101. Students placed in HU 008 or HU 009 must complete this noncredit writing course before taking HU 101 (or HU 103).

Students are strongly urged to select areas of concentration (such as literature, communications, the arts or philosophy in the Department of Humanities, or political science, economics, history, anthropology or psychology in the Department of Social Sciences) and to elect two or three courses in these concentrations in consultation with departmental advisers. Modern languages are recommended as suitable concentrations, but students without prior knowledge of languages must plan to devote at least 12 credit hours to each one. A minimum of two semesters of French, German or Russian is recommended.

For remaining humanities/social sciences requirements, students should select course in areas other than that of their concentrations. Additional courses in humanities and social sciences may be taken as free electives.

Students are strongly encouraged to take technical writing courses prior to their senior year.

CM 201, CM 502 or a graduate course may be used as advanced chemistry courses. Students with strong interests in mathematics may substitute MA 111-114 for MA 101-104.

Students with special interests in biochemistry may eliminate CM 175 and the technical elective but must include the following: LS 105-106, LS 115-116, CM 201-202 and CM 204. It is recommended that LS 105-106, LS 115-116 be taken in the junior year by deferring the necessary credits of humanities/social sciences. Requirements for advanced chemistry courses are waived for students taking the biochemistry thesis option.

All laboratory courses in chemistry require a breakage deposit.

The department does not usually grant transfer credits to students who, while registered at Polytechnic, take chemistry courses at other schools.

Curriculum for the Degree of Bachelor of Science in Engineering Chemistry

Engineering Chemistry is a degree program in chemistry with a concentration in engineering principles and techniques associated with chemical processes. This degree allows students to enter industrial employment with advantages over a pure science degree and at the same time allows pursuit of M.S. or Ph.D. degrees in chemistry or chemical engineering.

Chemistry Curriculum
Engineering Chemistry Options

Freshman Year

First Semester			Hours/Week			Second Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.	No.		Subject	Cl.	Lab.	Cr.
CM	101	General Chemistry I	2½	0	2½	CM	102	General Chemistry II	2½	0	2½
CM	111	General Chemistry Lab I	0	1½	½	CM	112	General Chemistry Lab II	0	1½	½
		Hum./Soc. Sci. electives*	9	0	9			Hum./Soc. Sci. elective*	3	0	3
MA	101	Calculus I or MA 100**	4	0	4	MA	102	Calculus II or MA 110**	4	0	4
PE	101	Physical Education	0	2	0	PH	104	Introductory Physics I	3	0	3
CS	100	Introduction to Computer						Technical elective	3	0	3
		Programming	2	0	2	PE	102	Physical Education	0	2	0
SL	101	Student Survival	0	1	0						16
					18						

Sophomore Year

			Cl.	Lab.	Cr.				Cl.	Lab.	Cr.
CH	123	Chemical Process Analysis I	2	0	2	CH	124	Chemical Process Analysis II	2	0	2
CM	122	Organic Chemistry I	3	0	3	MA	104	Applied Diff. Equations	3	0	3
CM	124	Organic Chemistry Lab I	3/10	5	2	CM	123	Organic Chemistry II	3	0	3
		Hum./Soc. Sci. elective*	3	0	3	CM	125	Organic Chemistry Lab II	3/10	5	2
MA	103	Calculus III	3	0	3			Hum./Soc. Sci. electives*	3	0	3
PH	105	Introductory Physics II	3½	0	3½	CM	161	Physical Chemistry I	3	0	3
PH	115	Physics Laboratory I	0	1½	½	PH	106	Introductory Physics III	2½	0	2½
PE	103	Physical Education	0	2	0	PH	116	Physics Laboratory II	0	1½	½
					17	PE	104	Physical Education	0	2	0
											19

Junior Year

			Cl.	Lab.	Cr.				Cl.	Lab.	Cr.
CH	251	Chemical Eng. Therm.	4	0	4	CH	221	Transfer Operations II	4	0	4
CH	220	Transfer Operations I	4	0	4	CH	271	Engineering Materials	3	0	3
CM	118	Chemical Equilibria	2-3/10	5	4	CM	119	Analytical Chemistry	3	0	3
CM	162	Physical Chemistry II	3	0	3	CM	120	Analytical Chemistry Lab	0	6	2
		Hum./Soc. Sci. elective*	3	0	3			Hum./Soc. Sci. elective*	3	0	3
					18			elective***			3
											18

Senior Year

			Cl.	Lab.	Cr.				Cl.	Lab.	Cr.
CM	175	Physical Chemistry III	4	0	4	CH	241	Multistage Separation Processes	3	0	3
		Bachelor's Thesis			4			Engineering elective			3
CM	108	Inorganic Chemistry	3	0	3			Bachelor's Thesis			6
		Hum./Soc. Sci. electives*	3	0	3			Hum./Soc. Sci. electives*	3	0	3
		elective***			3						15
					17						

Total credits required for graduation: 138
(CH Total credits for graduation 136)
(CM Total credits for graduation 128)

*A minimum of two semesters of a foreign language (German, French or Russian) is strongly recommended. The corresponding courses should be chosen in consultation with advisers.

**Placement into MA 101 and MA 102 or MA 100 and MA 101 is based on an entrance examination.

***Engineering option courses should total at least 6 credits between junior and senior years. Engineering options must be selected from the following list. Students planning studies in Chemical Engineering should be certain to include the following courses:

CH	322	Chemical Reactor Engineering	3	0	3
CH	351	Process Dynamics and Controls	3	0	3
CH	361	Process Design I	3	0	3
CH	362	Process Design II	3	0	3

Honors Curricula in Chemistry for B.S. and Ph.D. Degrees

Honors Curricula are designed for the talented and motivated student with good scholastic preparation and a serious interest in chemistry. Students can complete B.S. and Ph.D. degrees in only six years. These accelerated curricula satisfy the normal requirements for both degrees.

While rewarding careers in chemistry can certainly begin with B.S. degrees, Ph.D. chemists have more opportunities, more responsibilities, higher salaries and greater potential for advancement in industry, government or academia. Many chemistry students begin college with the B.S. as their goal, only to realize in their junior year that they should aim for graduate school.

Graduate school in chemistry seems distant, forbidding and expensive to high school juniors and seniors, but need not be. This program enables students to complete requirements for Bachelor of Science degrees (certified by the American Chemical Society) after three years, at which time they also have begun graduate level courses. In the fourth year, students hold full graduate status, are no longer required to pay tuition, and are paid graduate Teaching Assistant stipends. Support as a Teaching or Research Assistant continues until the Ph.D. is completed.

Besides the equivalency credits required before matriculation, a B average must be maintained throughout the program, and a minimum B grade is required in chemistry courses during the first two years. Applications should be made to Polytechnic, and the student interested in this program should contact the chemistry department advisers. Formal application to the graduate program is made in the fall of the third year. The B.S. degree is awarded at the first regularly scheduled commencement after the third summer, and the Ph.D. degree is conferred after the doctoral dissertation is defended and deposited.

Equivalency work required prior to matriculation:*

		Credits
CM 101	General Chemistry Lecture I	2½
CM 111	General Chemistry Laboratory I	½
CM 102	General Chemistry Lecture II	2½
CM 112	General Chemistry Laboratory II	½
PH 104	Introductory Physics I	3
MA 101	Calculus I	4
Humanities/Social Science** (e.g. language, history. Two courses)		6
	Total	19

*Equivalency certification may vary from department to department. Please check with individual departments or chemistry advisers for details.
**A second language in addition to English is strongly recommended, e.g., French, German or Russian; courses can be selected with the aid of advisers, or equivalency credits may be established. A technical writing course is also strongly recommended.

First Year

First Semester			Hours/Week		
No		Subject	Cl.	Lab.	Cr.
CM	122	Organic Chemistry Lectures	3	0	3
CM	124	Organic Chemistry Laboratory	3/10	5	2
PH	105	Introductory Physics II	3½	0	3½
PH	115	Physics Laboratory I	0	1½	½
MA	102	Calculus II	4	0	4
PE	101	Physical Education	0	2	0
SL	101	Student Survival	0	1	0
CM	504	Chemical Laboratory Safety	1	0	1
Humanities/Social Science elective**			3	0	3
					17

First Summer Session				
CM	161	Physical Chemistry I	3	0	3
Humanities/Social Science elective**		3	0	3
				6

Second Semester			Hours/Week		
No		Subject	Cl.	Lab.	Cr.
CM	123	Organic Chemistry Lectures	3	0	3
CM	125	Organic Chemistry Laboratory	3/10	5	2
CS	100	Introduction to Computer Programming	2	0	2
PH	106	Introductory Physics III	2½	0	2½
PH	116	Physics Laboratory II	0	1½	½
MA	103	Calculus III	3	0	3
PE	102	Physical Education	0	2	0
Humanities/Social Science elective**			3	0	3
					16

Second Summer Session				
CM	162	Physical Chemistry II	3	0	3
Humanities/Social Science elective**		3	0	3
				6

Total credits: 45

Second Year

			Cl.	Lab.	Cr.
CM	118	Chemical Equilibria	2-3/10	5	4
CM	175	Advanced Physical Chemistry	4	0	4
PE	103	Physical Education	0	2	0
Technical elective					3
Electives (two)					6
					17

First Summer Session				
Humanities/Social Science electives (two)	6	0	6

			Cl.	Lab.	Cr.
CM	108	Inorganic Chemistry	3	0	3
CM	119	Analytical Chemistry Lecture	3	0	3
CM	120	Analytical Chemistry Laboratory	0	6	2
CM	177	Physical Chemistry Laboratory	3/10	5	2
CM	501	Chemical Literature	1	0	1
CM	871	Guided Studies	3	0	3
PE	104	Physical Education	0	2	0
		Elective			3
					17

Second Summer Session				
Humanities/Social Science electives (two)	6	0	6

Total credits: 46

Third Year

CM	109	Inorganic Chemistry Laboratory	0	3	1
CM	703	Advanced Physical Chemistry I	3¾	0	4½
CM	903	Advanced Organic Chemistry I	3¾	0	4½
CM	971	Colloquium in Chemistry	0	0	0
CM	973	Seminars in Chemistry	1	0	1½
		and either †			
CM	907	Spectroscopy of Organic Molecules	3¾	0	4½
		or †			
CM	872	Guided Studies	TBA	TBA	4½
					16

During this semester, the student shall make formal application to the Graduate Program in Chemistry.

Summer Session (either first, second or both)
Undergraduate Electives (two)   6

Total credits: 40

CM	704	Advanced Physical Chemistry II	3¾	0	4½
CM	904	Advanced Organic Chemistry II	3¾	0	4½
CM	972	Colloquium in Chemistry	0	0	0
CM	974	Seminar in Chemistry	1	0	1½
	Elective				3
		and either †			
CM	872	Guided Studies	TBA	TBA	4½
		or †			
CM	802	Applied Spectroscopy	3¾	0	4½
					18

At this point, the student has completed all requirements for the B.S. degree in chemistry, and amassed 21 credits toward the Ph.D. B.S. degrees are conferred at the next scheduled commencement. In the fourth year, students are considered full-fledged graduate students, and are supported by teaching or research assistantships.

† For these two options, students choose either the first in both semesters, or the second in both semesters, depending upon interests.

Fourth Year

| First Semester | | | | Hours/Week | |
No		Subject	Cl.	Lab.	Cr.
CM	601	Advanced Inorganic Chemistry	3¾	0	4½
CM	971	Colloquium in Chemistry	0	0	0
CM	975	Seminar in Chemistry	1	0	1½
CM	991	Special Experimental Techniques	TBA	TBA	3
		Advanced Chemistry Course			3
					12

| Second Semester | | | | Hours/Week | |
No		Subject	Cl.	Lab.	Cr.
CM	972	Colloquium in Chemistry	0	0	0
CM	976	Seminar in Chemistry	1	0	1½
CM	992	Special Experimental Techniques	TBA	TBA	3
CM	998	Research in Chemistry	TBA	TBA	7
		Advanced Chemistry Courses (two)			6
					17½

Total credits: 29½

Fifth Year

CM	971	Colloquium in Chemistry	0
CM	999	Research in Chemistry	15
		Advanced Chemistry Course	3
			18

CM	972	Colloquium in Chemistry	0
CM	999	Research in Chemistry	18
			18

Year's Total credits: 36

Sixth Year

CM	971	Colloquium in Chemistry	0
CM	999	Research in Chemistry	18
			18

CM	972	Colloquium in Chemistry	0
CM	999	Research in Chemistry	18
			18

Year's Total credits: 36

CHEMISTRY

Advanced chemistry courses are selected from the following list, which appears in the catalog under appropriate interest areas.

INORGANIC CHEMISTRY

CM 614-619 Special Topics in Inorganic Chemistry

PHYSICAL CHEMISTRY

CM 715-717 Advanced Topics in Physical Chemistry: Kinetics of Chemical Reactions, Valence and Molecular Structures, Electrochemistry
CM 721 Quantum Mechanics for Chemists
CM 722 Statistical Mechanics for Chemists
CM 730-731 Group Theory and Applications I & II
CM 750 Special Topics in Physical Chemistry
CM 760 Minicomputer Instrumentation for Scientific Research

POLYMER CHEMISTRY

CM 771 Introductory Polymer Chemistry
CM 722 Synthesis of High Polymers
CM 781 Solution Properties of High Polymers
CM 782 Macromolecules in the Solid State
CM 783 Laboratory Methods in Polymer Chemistry
CM 785 Special Topics in Polymer Chemistry
CM 790 Biopolymers

ORGANIC CHEMISTRY

CM 915 Topics in Physical Organic Chemistry
CM 920 Current Aspects of Organic Synthesis
CM 921-933 Advanced Topics in Organic Chemistry
CM 940 Special Topics in Organic Chemistry

BIOCHEMISTRY

CM 941-942 Biochemistry I & II
CM 943-946 Advanced Topics in Biochemistry
CM 947 Biochemical Techniques

With adviser's approval, courses in other departments may be taken instead of the advanced chemistry courses, such as courses in Physics, Metallurgy, Computer Sciences, Chemical Engineering and Bioengineering.

There are four major areas in chemistry for the Ph.D. Degree, and there are individual requirements in each area:

INORGANIC CHEMISTRY REQUIREMENTS

CM 601; CM 703; CM 802 or CM 907; CM 903 or CM 904; at least 6 units of advanced topics in inorganic chemistry (CM 614-CM 619).

ORGANIC CHEMISTRY

CM 601; CM 703 or CM 704; CM 903; CM 904; CM 907; and CM 920.

PHYSICAL CHEMISTRY

CM 601; CM 703; CM 704; CM 802; CM 903 or CM 904; either CM 721 and CM 722 or 9 units selected from PH 663, PH 664, PH 667 or PH 668; and CM 995 (Seminar in Chemical Physics).

POLYMER CHEMISTRY

CM 601; CM 703 or CM 704; CM 903 or CM 904; CM 802 or CM 907; CM 771; CM 772; CM 781; CM 782; CM 783.

There are also minor requirements. The Chemistry Department offers minors in biochemistry, inorganic chemistry, organic chemistry, physical chemistry and polymer chemistry. A faculty adviser in the minor area will advise students in selecting two courses to satisfy minor requirements.

By the end of the second year, students have earned 110 credits (including equivalency credit) towards the B.S. degree. In the third year, the student accumulates 19 credits toward the B.S. degree, e.g., CM 109 (1 credit), either CM 704 or CM 904 (4½ credits, as an advanced chemistry course), CM 872 (4½ credits, guided studies, reading), and a total of three electives (3 credits each, for a total of 9) in the second semester and in summer sessions. Total credits earned towards the B.S. degree by the end of the third year are 129; by this time the student has earned 21 credits towards the Ph.D. (remaining credits for the third year). If a student decides not to continue, he/she would receive a B.S. degree at the next regularly scheduled commencement. Formal application is made to Graduate School in the third year.

During the fourth, fifth and sixth years, students take advanced chemistry courses, colloquia, seminars, and research credits. At the end of the sixth year, students have accumulated 46½ credits of advanced degree work (including core courses, major requirements, minor requirements, seminars and colloquium registration) and 69 credits of research to be presented in a dissertation, which is in excess of the credits of research required for Ph.D. degrees (45).

Major differences between the Honors Curriculum and the standard one, aside from the acceleration of course work, are: advanced preparation and equivalency credit for more than a semester's course-work; substitution of courses for bachelor's thesis (since the student prepares a doctoral dissertation); and the combination of lower level and upper level courses in the third year.

In the fourth year, the student begins duties as a teaching assistant, supervising undergraduate laboratories and grading exams. Then, the student is supported financially by the department as a Teaching Fellow. Depending upon these duties and the availability of necessary advanced courses, course loads may be redistributed slightly, and the student may take courses in a semester different from those described above.

Selection of an advisor and a dissertation committee and the scheduling of examinations are described under the graduate program.

Academic policy for the graduate program in chemistry requires that a B average be maintained. Similarly, a B

average exclusive of research or guided studies is required for a student to remain in the Honors Program. B minimum grades in chemistry courses must be maintained during the first two years of study.

GRADUATE STUDIES

Admission to graduate studies in chemistry requires a sound foundation in mathematics, physics and chemistry. College preparation should include at least four semesters of mathematics, two semesters of physics and chemistry (analytical, inorganic, organic and physical). In addition, it is desirable for students to have had differential equations, atomic and nuclear physics, and two years of German, Russian or French. All applicants are required to take the Graduate Record Examination (General and Chemistry). Applicants whose native language is other than English must score at least 550 on the TOEFL. All teaching assistants must pass HU 521 or an oral examination given by the Chemistry Department. Chemistry graduate students cannot take CM 500 level courses for graduate credit, except for M.S. degree candidates in Industrial Chemistry.

REQUIREMENTS FOR THE MASTER'S DEGREE

Chemistry

A total of 36 units past the bachelor's degree is required with an overall grade point average of B (3.0) or better in all courses (exclusive of thesis research or guided studies) submitted for a master's degree. Programs must include the following core courses:

No.	Subject	Units
CM 601	Inorganic Chemistry	4½
CM 703	Chemical Physics I	4½
	or	
CM 704	Chemical Physics II	
CM 802	Applied Spectroscopy	4½
	or	
CM 907	Organic Spectroscopy	
CM 903	Advanced Organic Chemistry I	4½
	or	
CM 904	Advanced Organic Chemistry II	

Students may elect research and a thesis (12 units). The oral defense of the thesis is held after the typed thesis has been submitted. A grade of A or B in thesis research is required.

Students not electing theses are required to take 3-6 units of guided studies (CM 871-872) with the submission of a written report.

Students in the master's program must participate in seminars for two semesters (CM 973-974); those electing no thesis must present at least one lecture to the seminar group.

Students must be in continuous attendance at departmental colloquia.

All master's students must take CM 504, Chemical Laboratory Safety. Students are *strongly* encouraged to take CM 501, Chemical Literature.

Industrial Chemistry

The Department of Chemistry offers a master of science degree in industrial chemistry. Students electing this program are required to take the following courses:

No.	Subject	Units
CM 950-951	Industrial and Engineering Chemistry I, II	6
MG 600	Management Process	3
MG 865	Research, Development and Management of Innovation	3
	either	
CM 760	Minicomputer Instrumentation for Scientific Research	3
	or	
MA 531	Applied Mathematics for Engineers	
CM 955	Project in Industrial Chemistry	3-6
CM 504	Chemical Laboratory Safety	0
		18-21

At least 12-15 units must be taken from graduate courses in chemistry numbered above 600.
Remaining units are chosen from the following list and from other graduate courses in chemistry:

SS 672	Technological Forecasting	3
CH 915-916	Introduction to Polymeric Materials I, II	each 3
CH 921	Polymer Processing	3
HU 605	Technical Writing	3
CM 502	Environmental Chemistry	3

REQUIREMENTS FOR THE DOCTOR'S DEGREE

The student selects a research advisor after interviewing a minimum of five faculty members. The student must take the Written Preliminary Examination during the second year. Two attempts are allowed. (After a second failure, the student is dropped from the doctoral program). The student then selects a dissertation committee including the research adviser, major advisers, a minor adviser and at least one other faculty member who monitors the progress of the student through the rest of the program. Approximately six months after the Written Preliminary Examination, an Oral Preliminary Examination is scheduled, where students will present plans and possibly results from specific areas of thesis research for evaluation by the committee. When all thesis research is completed, the student schedules an Oral Defense of the Thesis. Final judgment on awarding a Ph.D. is made by the dissertation committee.

A total of 90 units past the baccalaureate degree level is required. A grade point average of B or better is mandatory in all courses (not including dissertation research) submitted for the Ph.D. degree and a grade of A or B is required for the dissertation.

Currently the Chemistry Department offers the Ph.D. degree with majors in inorganic, organic, physical or polymer chemistry. Minors are also required and may be in any of these areas other than the major and, additionally, in biochemistry or other departments or areas such as polymer science and engineering. The program includes

the following courses, for which students must maintain at least a B average.

1. Required Courses
In the doctoral curriculum, required courses are listed below.

Course	Title	Units
CM 601	Inorganic Chemistry	4½
CM 703	Chemical Physics I	
	or	4½
CM 704	Chemical Physics II	
CM 802	Applied Spectroscopy	
	or	4½
CM 907	Organic Spectroscopy	
CM 903	Organic Chemistry I	.
	or	4½
CM 904	Organic Chemistry II	

These courses are offered in two consecutive terms so that full-time students entering in the fall term can complete the sequence in two terms. In addition to the 18 credits of required courses listed, Ph.D. students must take a one-credit course in laboratory safety, CM 504, and fulfill the seminar and other requirements described in the catalog. Course requirements are explicitly defined below.

2. Required Courses for Chemistry Majors
Listed below are required courses for the four major areas in chemistry, i.e., inorganic, organic, physical and polymer.

Inorganic Chemistry: CM 601, CM 903 or CM 904, CM 802 or CM 907. CM 703 and at least six units of advanced topics in inorganic chemistry (CM 614-619).

Organic Chemistry: CM 601, CM 703 or 704, CM 903, CM 904, CM 907 and CM 920.

Physical Chemistry: CM 601; CM 703, CM 704, CM 802; CM 903 or CM 904; either CM 721 and CM 722 or 9 credits selected from PH 663, PH 664, PH 667, or PH 668; and CM 995.

Polymer Chemistry: CM 601, CM 703 or 704, CM 802 or 907, CM 903 or 904, CM 771, CM 772, CM 781, CM 782, and CM 783.

3. Minor Requirements
The Chemistry Department offers a minor concentration in biochemistry, inorganic, organic, physical and polymer chemistry. Students may elect a minor in areas of concentration offered by other departments. In all cases a faculty adviser from the minor area will be a member of the guidance committee. The student shall select courses to fulfill minors in consultation with the minor adviser.

4. Participation in seminar for four semesters, twice as a lecturer.

5. Research presented in a dissertation.

6. All doctoral students must take CM504, Chemical Laboratory Safety, prior to registering for thesis research.

7. Students are *strongly* encouraged to take CM501, Chemical Literature.

8. Students must be in continuous attendance at departmental colloquia for the duration of research.

9. The final oral examination will take place after members of the guidance committee have read the dissertation in typed, unbound form.

All students in the doctoral program are granted master of science degrees upon satisfactory completion with a B average of course requirements and 12 units of research toward doctoral dissertations, as certified by the chairman of the guidance committee. On application to the Office of Research and Graduate Studies and after completion of preliminary examinations, the student is certified as having earned a master of science degree.

All students should consult the current departmental bulletin, *Information for Chemistry Graduate Students*, for most recent guidelines for Ph.D. students.

UNDERGRADUATE COURSES

CM 101   General Chemistry I   2½:0:2½
Chemical equations; chemical conservation laws; stoichiometry; thermochemistry; properties of gases; atomic structure; periodic table; chemical bonding and molecular structure. This class meets four hours per week for lectures, recitations, tutorials and examinations. Co-requisite: MA 101 or MA 100.

CM 102   General Chemistry II   2½:0:2½
States of matter; chemical thermodynamics and chemical equilibria; kinetics; acid-base chemistry; descriptive inorganic chemistry; introduction to organic chemistry. This class meets four hours per week for lectures, recitations, tutorials and examinations. Not open to students who take CM 103. Prerequisites: CM 101; CM 111; MA 101, or MA 100. Co-requisites: MA 102 or MA 110; CM 112.

CM 103   Chemistry for Engineers   1½:0:1½
States of matter; chemical thermodynamics and chemical equilibria; kinetics; electrochemistry; organic molecules; polymers; types of materials; electronic and magnetic materials. This class meets three hours per week for lectures, recitations, tutorials and examinations. Not open to students who take CM 102. Prerequisites: CM 101, CM 111; MA 101 or MA 100. Co-requisites: MA 102 or 110; CM 113. Open only to EE undergraduates.

CM 108   Inorganic Chemistry   3:0:3
Atomic structures of elements as basis for periodic classification. Descriptive chemistry of elements and their compounds. Theories of chemical bonds and introduction to coordination chemistry. Prerequisites: CM 102, CM 112 and CM 161.

CM 109   Inorganic Chemistry Laboratory   0:3:1
Laboratory experiments introducing techniques employed in preparation and characterization of inorganic substances. Lab fee required. Prerequisite: CM 102, CM 112 and CM 161.

CM 111   General Chemistry Laboratory I   0:1½:½
Introduction to chemical laboratory procedures. Laboratory associated with lecture courses CM 101. Lab fee required.

CM 112   General Chemistry Laboratory II   0:1½:½
Laboratory experiments are coordinated with CM 102. Lab fee required. Prerequisites: CM 101, CM 111.

CM 113   Chemistry for Engineers Laboratory   0:1½:½
Laboratory experiments in the chemistry of materials, taken in conjunction with CM 103. Not open to students who take CM 112. Prerequisites: CM 101, CM 111. Co-requisite: CM 103. Open only to EE undergraduates.

CM 118   Chemical Equilibria   2⅓:5:4
Equilibria in homogeneous and heterogeneous chemical processes. Applications of equilibrium concepts and data to analytical and physical chemistry. Theory of titrations and other analytical processes. Thermodynamic and chemical interpretations of equilibirium data. Separation techniques. Lab fee required. Prerequisites: CM 161-162.

**CM 119   Instrumental Methods in
          Analytical Chemistry   3:0:3**
Theories and applications of instrumental techniques in modern analytical chemistry, including chromatography, spectroscopy (absorption, fluorescence, infrared, Raman, nuclear magnetic resonance, electron spin resonance, atomic absorption, and emission); x-ray absorption, fluorescence and diffraction; mass spectrometry; thermal methods, etc. Prerequisites: CM 161-162.

CM 120   Analytical Chemistry Laboratory   0:6:2
Techniques described in CM 119 applied to various chemical problems stressing physiochemical interpretation of data obtained. Lab fee required. Prerequisites: CM 118 and CM 161-162. Co/Prerequisite: CM 119.

CM 122   Organic Chemistry I   3:0:3
Chemistry of organic molecules: structure, nomenclature, properties and reactions of carbon compounds with emphasis on aliphatic compounds. Introduction to reaction, mechanisms, and stereochemistry. Prerequisites: CM 102 and CM 112.

CM 123   Organic Chemistry II   3:0:3
Continuation of CM 122 with emphasis on spectroscopic methods, aromatic chemistry, condensation reactions, carbohydrates, amino acids, and synthetic polymers. Prerequisite: CM 122.

CM 124   Organic Chemistry Laboratory I   ⅓:5:2
Laboratory methods for preparation, isolation and purification of typical organic compounds. Experiments chosen to illustrate basic techniques. Lab fee required. Co/Prerequisite: CM 122.

CM 125   Organic Chemistry Laboratory II   ⅓:5:2
Laboratory methods for preparation, purification, characterization and identification of organic compounds by chemical and physical means. Introduction to instrumental methods of analysis and identification. Lab fee required. Prerequisite: CM 124. Co/Prerequisite: CM 123.

CM 161   Physical Chemistry I   3:0:3
Chemical thermodynamics (macroscopic and molecular approach) with applications to solutions, phase and chemical equilibria. Kinetic theory. Prerequisites: CM 102, CM 112, MA 103 and PH 103.

CM 162   Physical Chemistry II   3:0:3
Electrochemistry; ionic solutions. Solids, liquids, surfaces, high polymers. Chemical kinetics. Relation of bulk properties of matter to atomic and molecular properties. Prerequisite: CM 161.

CM 175   Physical Chemistry III   4:0:4
Atomic and molecular aspects of physical chemistry. Quantum chemical statistical description of matter with applications to molecular spectroscopy, binding and structure. Prerequisite: MA 104. Co/Prerequisite: CM 162.

CM 177   Physical Chemistry Laboratory   ⅓:5:2
Experimental methods of physical chemistry. Chemical kinetics; thermodynamics, electrochemistry, molecular spectroscopy, high vacuum, instrumental techniques. Computer analysis of experimental data. Report writing. Lab fee required. Prerequisites: CM 118 and CM 162.

CM 201   Biochemistry I   3:0:3
Survey of modern biochemistry with emphasis on current areas of research. Structure-function relationships in proteins. Enzymes and their mechanisms of action. Bioenergetic principles and energy production. Biochemical theories and techniques. Prerequisites: CM 123, CM 125 and CM 161, or instructor's permission.

CM 202   Biochemistry II   3:0:3
Continuation of Biochemistry I. Principles of intermediary metabolism, energetics, membrane structure and transport; structure and function of DNA and RNA, principles of molecular biology, the immune system, hormonal regulation, cancer.
Prerequisites: CM 201 and CM 162, or instructor's permission.

CM 204   Biochemistry Laboratory   ⅓:5:2
Laboratory experiments illustrating techniques for isolating and characterizing biological macromolecules, analyzing enzyme kinetics and elucidating metabolic pathways. Lab fee required. Co/Prerequisite: CM 201.

**CM 390-394   Bachelor's Thesis in
              Chemistry   each 2 credits**
Original investigations by student under guidance of staff members. Careful literature search required before inception of laboratory work; continued reference to chemical literature expected, and active participation in conferences and seminars scheduled as work progresses. A written thesis must be approved by at least two members of the department. Full-time students are expected to register for 10 credits of thesis during senior year. Research (lab) fee required. Co/Prerequisites: CM 501 and CM 504.

SPECIAL LISTINGS:

Undergraduate and Graduate

CM 501   Chemical Literature   1:0:1
Programs of lectures, exercises and discussion designed to familiarize students with the chemical literature. Undergraduate students may emphasize topics related to the bachelor's thesis. Prerequisites: CM 123, CM 125 and CM 162.

CM 502   Environmental Chemistry   3:0:3
Chemical properties of pollutants in air, water, soil and hazardous wastes. Effects of chemical pollutants on health. Prerequisites: CM 122, CM 124 and CM 161 or CM 164 or instructor's permission. This course does not fulfill requirements for the regular M.S. or Ph.D. degrees in chemistry. M.S. candidates in Industrial Chemistry may select this course to meet degree requirements.

CM 504   Chemical Laboratory Safety   1:0:1
Discussions of problems of health and safety arising in chemical laboratories. How to work safely with dangerous chemicals. *This course must be completed by both graduate and undergraduate chemistry students before they undertake laboratory research.*

CM 515   Polymer Organic Chemistry   2½:0:3
Review of basic organic chemistry. Synthesis, characterization and applications to polymeric materials. May not be taken for credit by undergraduates to substitute for CM 122-123. May not be taken for graduate credit by graduate students in Chemistry or Polymer Science and Engineering. Prerequisite: CM 101, 102 or consent of instructor.

GRADUATE COURSES

INORGANIC CHEMISTRY

CM 601　Inorganic Chemistry　　　　3¾:0:4½
Theories of bonding of inorganic compounds. Introduction to group theory as applied to molecular orbital and ligand field theories. Spectra of inorganic compounds. Nonaqueous solvents. Introduction to transition metal chemistry. *Required of all candidates for Ph.D. degree in chemistry.*

CM 614-619　Advanced Topics in Inorganic
**　　　　　　Chemistry　　　each 2½:0:3**
Selections from following topics may be offered: physical and synthetic methods in inorganic chemistry, organometallic chemistry, chemistry of the solid state, chemistry of coordination compounds, mechanisms of inorganic reactions, chemistry of non-metals, inorganic polymers, chemistry of representative elements, bonding theories. Prerequisite: CM 601 and adviser's approval.

PHYSICAL CHEMISTRY

CM 703　Chemical Physics I　　　　3¾:0:4½
Quantum structures of molecules. Fundamental ideas of quantum mechanics. Applications to atomic and molecular structures and bonding. Approximation methods. Interactions of light and matter. Prerequisites: undergraduate physical chemistry and physics.

CM 704　Chemical Physics II　　　　3¾:0:4½
Chemical kinetics and thermodynamics. Fundamental ideas of statistical mechanics. Development of relationships of various bulk properties of matter to molecular structures and interactions. Applications to solutions, polymers. Prerequisites: Undergraduate physical chemistry and physics.

CM 715-717　Advanced Topics in Physical Chemistry 2½:0:3
Selections from the following topics may be offered at regular intervals: Kinetics of Chemical Reactions, Valence and Molecular Structure, Electrochemistry. May be offered at irregular intervals.

CM 721　Quantum Mechanics for Chemists　　3¾:0:4½
Principles of quantum mechanics quantitatively developed. Comparison of various approaches. Most important approximation methods useful for applications of theory to many problems in chemistry and physics. Detailed discussions of several applications to some basic problems. *Required of all Ph.D. candidates with major in physical chemistry.* Prerequisites: CM 704, PH 601 and PH 602. May be offered at irregular intervals.

CM 722　Statistical Mechanics for Chemists　　3¾:0:4½
Classical and quantum statistical mechanics systematically developed and applied to calculations of thermodynamic properties of various states of matter from knowledge of structure of atoms and molecules and their forces of interaction. *Required of all Ph.D. candidates with major in physical chemistry.* Prerequisite: CM 721. May be offered at irregular intervals.

CM 730-731　Group Theory and its
**　　　　　　Applications I, II　　each 2½:0:3**
Group theory and its application to various problems in chemistry and physics. Abstract group theory; group representations; finite and continuous groups. Applications to crystallography; valence theory; interpretation of atomic and molecular spectra; crystal field theories; energy band theories of solids; crystal symmetry and physical properties. CM 730 prerequisite: instructor's permission. CM 731 prerequisite: CM 730. May be offered at irregular intervals.

CM 750　Special Topics in Physical
**　　　　Chemistry　　　　　　2½:0:3**
Advanced or specialized topics in physical chemistry presented at irregular intervals.

CM 760　Minicomputer Instrumentation
**　　　　for Scientific Research　　1¼:2:3**
Fundamentals of digital electronics and minicomputers; computer-automated laboratory instrumentation; programming and interfacing required for data acquisition and control in scientific research. Experiments with minicomputers and with laboratory apparatus interfaced directly to minicomputers. Lab fee required. Prerequisite: instructor's permission. Offered in alternate years.
Also listed under PH 612 and BE 623.

POLYMER CHEMISTRY

CM 771　Introductory Polymer Chemistry　　2½:0:3
Syntheses of polymers by step-reaction and addition polymerization; copolymerization; formation of three dimensional networks; block and graft polymers; polymer degradation; characterization of polymers in solution; rubber elasticity; polymer crystallization; spectroscopic techniques for polymer study; properties of commercial polymers. Prerequisites: CM 123, CM 125 and CM 162.

CM 772　Synthesis of High Polymers　　2½:0:3
Organic aspects. Chemistry of monomer and polymer formations. Modern mechanistic analyses of reactions. Stereochemistry of polymer structures and forces of stereoregulation. Condensation; free radical (bulk, suspension, emulsion, solution); ionic, ring-opening and nonclassical polymerization reactions.

CM 781　Solution Properties of High Polymers　　2½:0:3
Application of osmometry, light scattering, equilibrium ultracentrifugation, electrophoresis, viscosity, diffusion, ultracentrifugal sedimentation, flow birefringence, polarimetry, spectroscopy, and other techniques to the characterization of dissolved macromolecules. Properties of polyelectrolytes, association in solutions containing macromolecules and reaction kinetics in macromolecular solutions also are discussed. The course is designed to cover both synthetic and biological macromolecules. Prerequisites: CM 161, CM 162 and CM 772 or CM 783.

CM 782　Macromolecules in Solid States　　2½:0:3
Crystalline-amorphous systems, thermodynamics of crystallization, defect structures, morphology of polymer crystals, characterization of polymeric solids by X-ray and electron diffraction, potential energy calculations, electron microscopy, absorption spectroscopy, and nuclear magnetic resonance. Electrical and optical properties of polymer solids. Prerequisite: CM 771.

CM 783　Laboratory Methods in Polymer Chemistry　　0:4:3
Experiments on free-radical and ionic polymerizations, copolymerization; UV/VIS and NMR spectroscopy, intrinsic viscosity, light scattering, gel permeation chromatography, X-ray diffraction, thermogravimetric analysis, differential scanning calorimetry, dilatometry, concentrated solution viscosity, and other aspects of polymer synthesis and characterization. Lab fee required. Prerequisite: CM 771.

CM 785　Special Topics in Polymer Chemistry　　2½:0:3
Presentation at intervals of various advanced or specialized topics in polymer chemistry.

CM 790　Biopolymers　　　　　　2½:0:3
Structure and properties of important biological macromolecules including proteins, nucleic acids and polysaccharides, membranes and macromolecular complexes; applications of X-ray diffraction, NMR, vibrational and CD spectroscopy to the analysis of structure. Biopolymers may be used to satisfy major field requirements in polymers or minor field requirements in biochemistry. Offered in alternate years. Pre/Corequisite: CM 941 or consent of instructor.

ANALYTICAL CHEMISTRY

CM 802   Applied Spectroscopy   3¾:0:4½
Solving chemical problems using spectroscopic methods. Vibrational, electronic, nuclear magnetic resonance spectroscopy and mass spectrometry. Discussion of physical principles, instrumentation, interpretation of spectra, applications to molecular and physical problems. Prerequisite: CM 703.

ORGANIC CHEMISTRY

CM 903   Organic Chemistry I   3¾:0:4½
Molecular structure and bonding. Stereochemical and conformational principles. Theories of bonding and the physical parameters of stable and reactive molecular states. Applications in biochemistry and polymer chemistry. Prerequisites: undergraduate physical chemistry and organic chemistry.

CM 904   Organic Chemistry II   3¾:0:4½
Reactivity of molecules. The methods of mechanistic study of reaction pathways. Important reactions of organic and organometallic chemistry. Introduction to synthesis and applications in living systems and in polymer reactions. Suggested prerequisite: CM 903 or consent of instructor.

CM 907   Organic Spectroscopy   3¾:0:4½
Structure elucidation by joint applications of spectroscopic techniques such as proton and carbon-13 magnetic resonance, infrared and mass spectroscopy, and other methods. Prerequisite: CM 903 or CM 904 or consent of instructor.

CM 915   Topics in Physical Organic Chemistry   2½:0:3
Quantitative aspects of structural, electronic and medium effects in organic reactions; theoretical approaches to organic mechanisms; stereochemistry. Prerequisite: CM 903 or CM 904. May be offered at irregular intervals.

CM 920   Current Aspects of Organic Synthesis   2½:0:3
Approaches to syntheses of organic molecules. Stereoselective and stereospecific reactions. Examples drawn from naturally occurring and theoretically interesting molecules. Prerequisite: CM 903 or CM 904. May be offered at irregular intervals.

CM 921-933   Advanced Topics in Organic Chemistry   2½:0:3
Selections from the following topics will be offered at irregular intervals: organometallic chemistry, photochemistry, heteroatom chemistry, and natural products. Prerequisite: CM 903 or CM 904.

CM 940   Special Topics in Organic Chemistry   2½:0:3
Topics selected from current research or literature, and approaches to problem solving. Co/Prerequisite: CM 903 or CM 904.

BIOCHEMISTRY

CM 941-942   Biochemistry I, II   each 2½:0:3
In-depth studies of biochemistry. Structure and function of biological macromolecules: proteins, nucleic acids, polysaccharides. Enzyme kinetics, mechanism and control. Membrane structure and function. Energy production, transformation and utilization. Regulation of biochemical systems. Replication, transcription and translation of DNA. Mutagenesis and carcinogenesis. Immune system. Prerequisites: LS 106, LS 116 and CM 202, or consent of instructor.

CM 943-946   Advanced Topics in Biochemistry   2½:0:3
Selections from the following topics offered at irregular intervals: protein and nucleic acid chemistry; intermediary metabolism; and metabolic regulation. Prerequisite: CM 941 or consent of instructor.

CM 947   Biochemical Techniques   ⅓:5:3½
Laboratory procedures illustrating new techniques for isolation, fractionation and characterization of biological macromolecules. Enzyme kinetics. Lab fee required. Prerequisites: CM 123, CM 125, CM 202, CM 162, LS 106, LS 116. Co/Prerequisites: CM 941-942.

INDUSTRIAL CHEMISTRY

CM 950-951   Industrial and Engineering Chemistry I, II   each 2½:0:3
Discussions of the chemical process industries, emphasizing basic chemical and physical principles, as well as economic feasibility of individual processes, to provide chemical engineering backgrounds for chemists. Emphasis on stoichiometry, thermodynamic considerations, and unit operations such as absorption, extraction and distillation, as well as fluid dynamics and heat transfer. Natural resource analyses and recycling. Stagewise and continuous contact equipment and flow sheet analyses. Chemical plant design and chemical economics. Individual reading and discussion of selected papers in chemical process technology. Prerequisite: B.S. degree in chemistry or allied field or permission of instructor.

CM 955   Projects in Industrial Chemistry   as arranged
Directed studies or supervised reading and/or experimental work in advanced areas of chemistry and chemical technologies. Conferences scheduled. Candidates for M.S. degree program required to submit four unbound copies of typewritten project reports and present oral summary to advisers on or before the seventh Wednesday prior to graduation. Prerequisite: B.S. in chemistry or allied field or permission of instructor.

GENERAL COURSES

CM 871-872   Guided Studies in Chemistry   as arranged
Directed studies or supervised readings in advanced areas of chemistry. Registration by consent of department head.

CM 971-972   Chemical Colloquium   0
Meetings of the members of the department staff, invited guests and qualified students to study recent developments in chemistry. Required each year of all students in graduate degree status majoring in chemistry and for two years of doctoral matriculants in other departments with minor in any field of chemistry. Seminar fee required.

CM 973-976   Seminar in Chemistry   each 1½ units
Chemical topics of current interest presented by participating students, staff, outside lecturers. Two semesters required of all master's candidates and four semesters of all doctoral candidates.

CM 991-992   Special Techniques in Experimental Chemistry I, II   each 0:6:3
Specialized techniques and processes of modern experimental chemistry. Depending upon requirements of thesis students and recommendations of advisors, advanced laboratory skills in X-ray diffraction, solid state synthesis, measurements of magnetic moments and susceptibilities, spectroscopic techniques, chromatographic techniques, thermal analyses, relaxation kinetics, electrochemistry, etc. Emphasis on intensive training in students' research activities. May be taken for a maximum of two semesters. Prerequisite: Concurrent thesis registration and permission of advisor and course director.

CM 995-996   Seminar in Chemical Physics   each 1½ units
Topical subjects, problems, current research in chemical physics presented by participants, staff, outside lecturers. Required of all master's and doctoral candidates in chemical physics.

CHEMISTRY

CM 998   Research in Chemistry   3 units
Original research, which serves as basis for master's degrees. To be taken by Ph.D. candidates before completion of Ph.D. preliminary examinations in chemistry. Minimum research registration requirements for the master's degree: 12 units. Registration for research required each semester consecutively until students have completed adequate research projects and acceptable theses and passed required oral examinations. Research credits registered for each semester reflect realistically time devoted to research. A maximum of 6 units may be counted towards a Ph.D in chemistry. Research charge. Prerequisites: for M.S. candidates, degree status and consent of graduate adviser and thesis director and CM 504.

CM 999   Research in Chemistry   3 units
Original experimental or theoretical research (undertaken under guidance of a chemistry faculty member), which may serve as basis for degree of doctor of philosophy. Chemical physics majors with thesis advisers in Department of Physics should register for pH 791-796 and PH 981-993. Minimum research registration requirements for degree for holders of M.S. based on research and thesis acceptable to department, 33 units; for other students, 45 units. Registration for research required each semester consecutively until students have completed adequate research projects and acceptable theses and passed required oral examinations. Number of research credits registered for each semester must reflect realistically time devoted to research. Research fees required. Prerequisites: completion of Ph.D. preliminary examination in chemistry, consent of thesis director and CM 504.

LIFE SCIENCES COURSES

In recent years, Polytechnic has developed life sciences courses which complement those in its teaching and research programs in engineering and physical sciences. Undergraduate students with specific interests in the areas of biology, biochemistry, environmental sciences, bioengineering, premedicine and laboratory techniques may elect life science courses to fulfill specific B.S. program requirements or to serve as technical or free electives.

Biology is concerned with the study of life in all manifestations—from the simple to the complex, from the invisible to the macroscopic, from the virus to the human. To move beyond definitions of life to understanding life's fundamental nature, characteristics of living systems must be examined, including growth, heredity and reproduction, metabolism, energy production and utilization, responsiveness, and locomotion. Structures and function of living matter at the molecular, cellular and organismal levels must be probed. Biology, chemistry and physics contribute to understanding of living systems.

UNDERGRADUATE COURSES

LS 105-106   General Biology I, II   each 3:0:3
Fundamentals of biology. Physical, chemical, biochemical bases of life on various organizational levels. Cellular morphology, complementarity of form and function. Reproduction, development, genetics. Homeostasis, regulation, integration, coordination. LS 105 prerequisite: high school chemistry. LS 106 prerequisite: LS 105 or instructor's consent.

LS 115-116   General Biology Laboratory I, II   1:3:2
Recitations in relationship to laboratory experiments include discussions of such topics as: cell structure and function; chemical and physical characteristics of living things; unity and diversity of living things; genetics, development, homeostasis, integration and coordination; adaptation, evolution, ecology and the biological bases of behavior. Lab fee required. LS 115 Co/Prerequisite: LS 105. LS 116 Co/Prerequisite: LS 106.

LS 103-200   Topics in Biology   Credit as arranged
From time to time courses may be offered in the following areas: Developmental Biology, Fundamentals of Genetics, Microbiology, Physiology, Cell Physiology, Cell Biology, Techniques and Instrumentation, Histological Techniques, and others.

LS 305-307   Projects in Life Sciences   each 2 credits
Investigations of problems in biology under supervision of faculty members. Library research, experimental studies, written reports required. Lab fee required. Prerequisite: senior status or adviser's consent.

LS 308   Life Science Internship   2 credits
Supervised projects carried out in hospital, community or industrial settings. Evaluated on basis of written and oral reports presented to faculty and outside project co-sponsors. Faculty conferences and visits required. Open to senior students on approval of departmental adviser. Preplanned experiences provide students with significant exposure to relationships between theoretical information and practical applications. Prerequisite: senior status or adviser's consent.

LS 310   Seminar in Biology   1 credit
Selected topics of current interest presented by participating students, staff and outside lecturers. Prerequisites: LS 105 and LS 106.

GRADUATE COURSES

LS 561-702   Advanced Topics in Biology   Credit as arranged
From time to time, graduate level courses may be offered in Bioethics, Electron Microscopy, Environmental Biology, Neurophysiology, Topics in Neurosciences, and Cytology.

LS 900   Selected Topics in Biology   2½:0:3
Presentation of significant topics in biology or related interdisciplinary areas. Topics may vary from year to year.

FACULTY

Donald M. Schleich, Associate Professor of Inorganic Chemistry and Head, Department of Chemistry
B.S., SUNY (Fredonia); Ph.D., Brown University
Photoelectrochemistry, intercalation and materials studies

William Braunlin, Assistant Professor of Polymer Chemistry
B.S., Antioch College; Ph.D., University of Wisconsin (Madison)
Biophysical chemistry, biological polyelectrolytes, multinuclear NMR, ions in biology, ion-DNA interactions.

Richard Carlin, Assistant Professor of Inorganic Chemistry
B.S., University of Alabama; Ph.D., Iowa State University
Electrochemistry of inorganic complexes in molten salts, catalytic reactions in molten salts, solid-state electrochemistry, high-temperature superconducting metal oxides.

Mary K. Cowman, Associate Professor of Biochemistry
B.S., M.S., Ohio University; Ph.D., Case Western Reserve
Solution conformation and interactions of complex carbohydrate polymers; circular dichroism and nuclear magnetic resonance spectroscopy; biochemistry of extracellular matrix components.

Frederick Eirich, Distinguished Professor of Polymer
Chemistry
Ph.D., University of Vienna
Mechanical behavior of polymers, rheology, colloid chemistry, chemical evolution, biopolymers

Bruce A. Garetz, Associate Professor of Physical
Chemistry
A.B., Harvard College; Ph.D., Massachusetts Institute of
Technology
Laser spectroscopy, nonlinear optics and multiphoton processes, molecular dynamics

Mark M. Green, Professor of Organic Chemistry
B.S., CCNY; Ph.D., Princeton University
Stereochemistry of reactive intermediates, macromolecular stereochemistry, isolation of bio-active plant substances

T.K. Kwei, Professor of Polymer Chemistry
M.S., National Chiao-Tung University (China); M.S., University of Toronto; Ph.D., Polytechnic Institute of Brooklyn
Polymer-polymer miscibility, segmented polyurethanes and unsaturated polyesters, phase relationships in polymer blends, interactions in composites

Ernest M. Loebl, Professor of Physical Chemistry
M.S., Hebrew University; Ph.D., Columbia University
Theoretical chemistry, quantum statistical mechanics

Shirley M. Motzkin, Professor of Biology
B.S., Brooklyn College; A.M., Columbia University; Ph.D.,
New York University
Development mechanisms, teratology and skeletal development, radiation effects

Yoshiyuki Okamoto, Professor of Organic and Polymer
Chemistry
B.S., Osaka University of Science and Engineering (Japan);
Ph.D., Purdue University
Organic and polymer synthesis, characterizations and applications

Eli M. Pearce, Professor of Polymer Chemistry and Dean of
Arts and Sciences.
B.S., Brooklyn College; M.S., New York University; Ph.D.,
Polytechnic Institute of Brooklyn
Polymer synthesis and degradation

Norman C. Peterson, Professor of Physical Chemistry
B.S., Massachusetts Institute of Technology; Ph.D., Iowa
State University
Molecular beam scattering, laser chemistry, reaction kinetics

Sergio Petrucci, Professor of Physical Chemistry
Ph.D, University of Rome
Relaxation kinetics, ligand substitution in non-aqueous media, microwave and diffusional rotational relaxation

Arnost Reiser, Research Professor of Chemistry
Dr. Ing. (Prague); D.Sc. (London)
Polymer photochemistry, photoresists, image science

William H. Starnes, Professor of Organic and Polymer
Chemistry
B.S., Virginia Polytechnic Institute; Ph.D., Georgia Institute
of Technology
Polymer degradation, stabilization, and microstructure; mechanisms of organic reactions.

Matthew Schlecht, Assistant Professor of Organic
Chemistry
B.S., University of Wisconsin; M.A., Ph.D., Columbia
University
Synthetic methods; total synthesis of natural products; organometallic reactions, medicinal chemistry.

Giuliana Tesoro, Research Professor of Polymer
Chemistry
Ph.D., Yale University
Applied polymer science, fiber science, thermal dehydration and flammability of polymers, composites, and polymers for electronics applications

Nancy M. Tooney, Associate Professor of Biochemistry
and acting Associate Dean of Arts and Sciences
B.S., M.S., SUNY (Albany); Ph.D., Brandeis University
Structure and function of proteins and other biopolymers, blood clotting system, fibronectin structure and function, environmental chemistry

Otto Vogl, Herman F. Mark Professor of Polymer Chemistry
Ph.D., University of Vienna
Polymer synthesis, polymer stabilizers, polymer drugs

EMERITUS FACULTY

Ephraim Banks, Professor Emeritus of Inorganic Chemistry
B.S., CCNY; Ph.D., Polytechnic Institute of Brooklyn
Chemistry and physics of crystals, solid state reactions and phase transitions

Herman F. Mark, Professor Emeritus of Polymer Chemistry
and Dean Emeritus
B.S., Ph.D., University of Vienna
Synthesis, characterization, and properties of natural and synthetic polymers

Herbert Morawetz, Institute Professor, Professor Emeritus
of Polymer Chemistry
B.S.Sc., M.S.Sc., University of Toronto; Ph.D., Polytechnic
Institute of Brooklyn
Polymer reactions, hindered rotation in polymer systems, properties of polymer gels, and polymer compatibility

CIVIL AND ENVIRONMENTAL ENGINEERING

Civil engineers build the structures and infrastructures of modern society. They design and supervise the construction of buildings, bridges, roads, airports, dams, irrigation systems, harbors, wastewater and water supply plants, tunnels and offshore platforms. The wide spectrum of the civil engineering profession is reflected by the technical divisions of the American Society of Civil Engineers—aerospace, air transport, construction, energy, engineering management, engineering mechanics, environmental engineering, geotechnical engineering, highway, hydraulics, irrigation and drainage, materials engineering, pipeline, structural, surveying engineering, urban planning and development, urban transportation, water resources planning and management, waterway, port, coastal and ocean engineering.

Many civil engineers, as licensed professionals, are in private practice as consultants or are employed by corporations, governmental agencies, architects and others that require their expertise. Others are with construction companies or manage fabrication operations. Civil engineers act as city and regional engineers, interacting with planning officials, political authorities and the public to develop and maintain the nation's vital transportation links, public services and shelter.

Environmental engineering is closely linked to civil engineering but goes beyond the "design and build" function to examine problems of scarce natural resources, pollution control and waste disposal. Environmental scientists perform vital functions in quality monitoring, environmental impact studies and research and development.

Many civil engineers continue beyond the bachelor's degree to advanced studies and research at the master's, engineer's, and doctoral levels. Others branch out into law, management, planning, and other fields.

The undergraduate program is accredited by the Accreditation Board for Engineering and Technology, in which the American Society of Civil Engineers is a participant.

UNDERGRADUATE PROGRAM

The fundamental sciences of mathematics, physics and chemistry are presented first, together with additional subjects such as English, history, languages and economics designed to broaden the student's intellectual horizons. The program then introduces the basic engineering sciences, including properties of materials, fluids, soils, electricity, thermodynamics and stress analysis. In the last phase of the program, professional applications—such as highways, environmental engineering and detailed design of structures—are studied. The emphasis is on preparing

students broadly in all major areas of civil and environmental engineering so that graduates can be immediately employed in the profession.

Technical Electives

To allow students to broaden their technical knowledge, the curriculum provides 12 elective credits of appropriate coursework. Approved technical electives are indicated below; senior courses in other departments as well as graduate courses (for example, CE 590, CE 601, CE 780, CE 781, CE 854) may be chosen, but they require the approval of a departmental adviser. A minimum of 6 technical elective credits, carrying civil engineering designation must be completed at Polytechnic; only one course may be in mathematics.

No.	Technical Electives	Credits
CE 272	Construction Engineering	3
CE 336	Timber and Masonry Structures	3
CE 345	Hydraulic Engineering	3
ME 331	Computational Methods in Computer Aided Design	3
IE 300	Engineering Economy	3
MA 153	Elements of Linear Algebra	3
MA 217	Complex Variables	3
MA 223	Introduction to Probability	3
MA 260	Vector Analysis and Partial Differential Equations	4
TR 360	Traffic Planning and Operations	3
TR 361	Transportation Demand Models	3
TR 362	Public Transportation	3

ROTC students should note that freshmen and sophomores may substitute zero-credit military science courses for PE 101-104 (physical education); juniors and seniors may substitute three of the two-credit courses MS 301, 303, 401 and 403 for six credits of technical electives.

Humanities and Social Science Requirements

Elective courses are chosen in consultation with a civil engineering undergraduate adviser according to the following university and departmental guidelines:

In humanities and social sciences, students must take HU 101, HU 110, HU 200, and SS 104 (total 12 credits). Students placed in HU 103 on the basis of the English Composition Placement Test administered at Polytechnic to all incoming students may substitute HU 103 for HU 101. Students placed in HU 008 or HU 009 must complete this noncredit course before taking HU 101 (or HU 103). All students must elect 12 additional credits in humanities and social sciences to bring to 24, the total of such credits.

At least 18 of the credits students select in the humanities and social sciences must meet the requirements of the Accreditation Board for Engineering and Technology (ABET). These credits may not include skills-oriented courses such as college composition, technical writing, public speaking, or English as a second language. Courses in literature, foreign languages, history, economics, and related areas are acceptable. Students should consult their advisers to ensure that these criteria are met. Management courses and ROTC courses may not be used.

For further information, students should refer to the section of this catalog entitled Humanities and Social Sciences Requirements for Engineering and Computer Science Majors.

TRANSFER STUDENTS (Undergraduate)

Potential transfer students should refer to the University guidelines as shown elsewhere in this catalog. The faculty of the Civil and Environmental Engineering Department has established its own additional requirements and interpreted the University guidelines as follows:

The 136-credit curriculum approved by ABET is fulfilled through a combination of transfer credits, credits by examination and course credits completed at Polytechnic. Transfer credits for courses in mathematics, physics, chemistry, the humanities and social sciences are evaluated by the Admissions Office with the guidance of the faculty of the individual departments.

The length of time for a transfer student to complete the degree requirements will depend on the following factors:

   a) the number of transfer credits awarded
   b) the particular courses required to complete the degree requirements
   c) enrollment status, ie. full-time or part-time

In general, as part of the 136 credit curriculum, students from accredited schools must complete a minimum of 24

credits at Polytechnic with a civil engineering designation as indicated below:

Junior Year (Day)		Senior Year (Day)	
CE 322	1st term	CE 252	1st term
		CE 317	
CE 323	2nd term	CE 332	2nd term
CE 331		CE 342	
CE 340			

Because of the sequential nature of these courses, four *successive* semesters are usually required. Additional credits may be required, as determined by the transfer credit evaluation, to complete the bachelor's degree requirements. International students holding degrees from schools in their own countries are required to fulfill these requirements to earn a Polytechnic bachelor's degree.

Transfer students from schools with 2-year AAS degree programs in Engineering Science can normally expect to complete the bachelor's degree requirements within two years, with appropriate summer school coursework immediately before the junior year.

Students from 2-year technology programs are granted transfer credits according to the schools from which they come. With careful planning, it is generally possible to complete the necessary work in three years, including summer school coursework.

PART-TIME STUDENTS (Undergraduate)

Prospective students planning to earn a degree on a part-time evening basis should contact an undergraduate adviser for details about this plan before enrolling. Most upper-level evening courses will be offered on an alternate-year basis and may be integrated with the day program using a late afternoon schedule. Sample programs are shown for both full-time and part-time study.

Course of Study for the Bachelor of Science
Degree in Civil Engineering

Freshman Year

First Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
MA	101	Calculus I (or MA 100)	4	0	4
CM	101	General Chemistry I	2½	0	2½
CM	111	General Chemistry Lab I	0	1½	½
SS	104	Main Themes in Contemporary World History	3	0	3
HU	101	Writing and the Humanities I	3	0	3
CS	100	Intro. to Computer Prog.	2	0	2
SL	101	Student Survival	0	1	0
PE	101	Physical Education	0	2	0
					15

Second Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
MA	102	Calculus II (or MA 110)	4	0	4
CM	102	General Chemistry II	2½	0	2½
CM	112	General Chemistry Lab II	0	1½	½
PH	104	Introductory Physics I	3	0	3
HU	110	Basic Report Writing I	3	0	3
ME	101	Graphics	1	3	2
PE	102	Physical Education	0	2	0
					15

Summer camp (2-week session)

CE	150	Surveying Fieldwork			2

Sophomore Year

MA	103	Calculus III	3	0	3
PH	105	Introductory Physics II	3½	0	3½
PH	115	Physics Lab I	0	1½	½
CE	111	Engineering Mechanics I	2	0	2
CE	151	Surveying	3	3	4
HU	200	Writing and the Humanities II	3	0	3
PE	103	Physical Education	0	2	0
					16

MA	104	Applied Differential Equations	3	0	3
CE	112	Engineering Mechanics II	2	0	2
CE	202	Mechanics of Materials	3	0	3
CE	303	Nature & Prop. Struct. Matls.	1	3	2
EE	370	Principles of E.E.	3	0	3
PH	106	Introductory Physics III	2½	0	2½
PH	116	Physics Lab II	0	1½	½
PE	104	Physical Education	0	2	0
					16

Junior Year

CE	214	Computer Techniques in Engineering	2	3	3
CE	222	Fluid Mechanics	3	3	4
CE	322	Theory of Structures I	3	0	3
CE	351	Highway & Transportation Engrg. (Second Semester in Farmingdale)	2	3	3
ME	201	Thermodynamics I	3	0	3
		Hum./Soc. Sci. elective	3	0	3
					19

CE	232	Soil Mechanics	2	3	3
CE	323	Theory of Structures II	3	0	3
CE	331	Steel Structures	2	3	3
CE	340	Water Resources & Hydr. Engrg.	3	0	3
		Hum./Soc. Sci. elective	3	0	3
*		Mathematics elective*	3	0	3
		(First Semester in Farmingdale)			
					18

Senior Year

CE	252	Reinforced Concrete Structures	3	0	3
CE	317	Foundations	2	3	3
CE	341	Environmental Engineering I	2	3	3
		Hum./Soc. Sci. elective	3	0	3
		Technical electives			6
					18

CE	305	Engineering Contracts & Specifications.	2	0	2
CE	332	Design of Structural Systems	2	3	3
CE	342	Environmental Engineering II	2	3	3
		Hum./Soc. Sci. elective	3	0	3
		Technical electives			6
					17

Minimum total credits required for graduation: 136
A minimum GPA of 2.0 also is required.

*This elective shall be of college level material beyond MA 102

Sample Eight-Year Program Leading
to the Bachelor of Science Degree in Civil Engineering

First Year

First Semester			Hours/Week			Second Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.	No.		Subject	Cl.	Lab.	Cr.
MA	101	Calculus I (or MA 100)	4	0	4	MA	102	Calculus II (or MA 110)	4	0	4
HU	101	Writing and the Humanities I	3	0	3	PH	104	Introductory Physics I	3	0	3
					7	SS	104	Main themes in Contemporary World History	3	0	3
											10

Second Year

No.		Subject	Cl.	Lab.	Cr.	No.		Subject	Cl.	Lab.	Cr.
MA	103	Calculus III	3	0	3	MA	104	Applied Differential Equations	3	0	3
PH	105	Introductory Physics II	3½	0	3½	PH	106	Introductory Physics III	2½	0	2½
PH	115	Physics Lab I	0	1½	½	PH	116	Physics Lab II	0	1½	½
HU	110	Basic Report Writing I	3	0	3	ME	101	Graphics (1989-1990, 1991-1992) or	1	3	2
					10	CS	100	Introduction to Computer Programming (1988-1989, 1990-1991)	2	0	2
											8

Third Year

No.		Subject	Cl.	Lab.	Cr.	No.		Subject	Cl.	Lab.	Cr.
CE	111	Engineering Mechanics I	2	0	2	CE	112	Engineering Mechanics II	2	0	2
CM	101	General Chemistry I	2½	0	2½	CM	102	General Chemistry II	2½	0	2½
CM	111	General Chemistry Lab I	0	1½	½	CM	112	General Chemistry Lab II	0	1½	½
***		Mathematics elective	3	0	3	ME	101	Graphics (1989-1990, 1991-1992) or	1	3	2
					8	CS	100	Intro. to Programming (1988-1989, 1990-1991)	2	0	2
											7
						CE	150	Surveying Fieldwork*			2

Fourth Year

No.		Subject	Cl.	Lab.	Cr.	No.		Subject	Cl.	Lab.	Cr.
CE	202	Mechanics of Materials	3	0	3	CE	222	Fluid Mechanics	3	3	4
EE	370	Principles of E.E.*†	3	0	3	CE	322	Theory of Structures I	3	0	3
					6	HU	200	Writing and the Humanities II	3	0	3
											10

Fifth Year*†

No.		Subject	Cl.	Lab.	Cr.	No.		Subject	Cl.	Lab.	Cr.
CE	214	Computer Techniques in Engineering	2	3	3	CE	232	Soil Mechanics	2	3	3
ME	201	Thermodynamics I	3	0	3	CE	303	Nature & Prop. Struc. Matls.	1	3	2
		Hum./Soc. Sci. elective	3	0	3	CE	340	Water Resources & Hydr. Engrg.	3	0	3
					9						8

Sixth Year**

No.		Subject	Cl.	Lab.	Cr.	No.		Subject	Cl.	Lab.	Cr.
CE	151	Surveying	3	3	4	CE	323	Theory of Structures II	3	0	3
		Hum./Soc. Sci. elective	3	0	3	CE	331	Steel Structures	2	3	3
					7			Hum./Soc. Sci. elective	3	0	3
											9

Seventh Year*†

No.		Subject	Cl.	Lab.	Cr.	No.		Subject	Cl.	Lab.	Cr.
CE	341	Environmental Engineering I	2	3	3	CE	342	Environmental Engineering II	2	3	3
CE	351	Highway & Transportation Engrg.	2	3	3			Technical elective	3	0	3
		Technical elective	3	0	3			Hum./Soc. Sci. elective	3	0	3
					9						9

Eighth Year**

No.		Subject	Cl.	Lab.	Cr.	No.		Subject	Cl.	Lab.	Cr.
CE	252	Reinforced Concrete Structures	3	0	3	CE	305	Eng. Contr. & Specs.	2	0	2
CE	317	Foundations	2	3	3	CE	332	Design of Struc. Systems	2	3	3
		Technical elective	3	0	3			Technical elective	3	0	3
					9						8

Minimum total credits required for graduation: 136
A minimum GPA of 2.0 also is required.

* This 2-week course is offered every May during the day.
*† Offered in alternate odd years, i.e., 1989-1990, 1991-1992. (The fifth and sixth years are interchangeable.)

** Offered in alternate even years, i.e., 1988-1989, 1990-1991. (The seventh and eighth years are interchangeable.)

GRADUATE STUDIES

Programs of study are offered leading to degrees of master of science in civil engineering, master of science in environmental health science master of science in environmental engineering, engineer in civil engineering, doctor of philosophy in civil engineering, and doctor of philosophy in environmental health science.

Requirements for the master's degree include prescribed courses and approved elective courses. A project must be completed; a thesis may be substituted for elective courses. A minimum of 36 units is required for the degree.

Engineer degrees are oriented toward civil engineers who wish to study advanced engineering techniques beyond the master's degree. A minimum of 24 units of approved graduate courses and a minimum of 12 units of design project are required.

Ph.D. degrees require advanced study beyond the master's degree level in the field of civil engineering. A thesis characterized by originality must be written and defended.

Computer literacy is a requirement for all areas of specialization. In some cases, an undergraduate or graduate course may be included in the program of study to overcome deficiencies.

Students interested in graduate programs are advised to refer to the *Graduate Manual* (available from the department office) for information on degree requirements and the latest revisions of curricula and courses.

REQUIREMENTS FOR THE MASTER'S DEGREE

Students pursuing the M.S. in civil engineering generally have undergraduate preparation in engineering. Students pursuing this degree, who have undergraduate or graduate degrees in other fields may qualify for this program by completing additional undergraduate engineering courses. When a student pursues both the B.S. and M.S. degrees simultaneously at Polytechnic, the bachelor's degree requirements must be completed first. Two programs in environmental engineering and science are offered, in addition to the M.S. in civil engineering. Students pursuing the M.S. in environmental health science or the M.S. in environmental engineering generally have undergraduate or graduate preparation in the sciences, although the programs leading to these degrees may also be taken by students with engineering preparation.

Courses in some areas of specialization are not offered on a regular basis. Students should consult with the department advisers to determine the expected scheduling of such courses.

M.S. PROGRAMS IN CIVIL ENGINEERING

M.S. programs are offered with majors in the following specialty areas: structural engineering, water resources and hydraulic engineering, water quality engineering, geotechnical engineering, highway engineering, and construction engineering and management.

Departmental Requirements

No.	Course	Units
CE 780	Analysis of Uncertainty in Civil Engineering	3
CE 996	Project for the Degree of Master of Science	3
		6

Required Major Courses
Five courses in one of the majors: structural engineering, water resources and hydraulic engineering, water quality engineering, geotechnical engineering, highway engineering, or construction engineering & management. At least three of these courses must be selected from the Core Courses for the major. **15**

Department Electives
Three approved courses in civil and environmental engineering, in field(s) other than the major. **9**

Other Approved Electives
At Least 6 units of approved graduate courses **6**

TOTAL **36**

CORE COURSES

Structural Engineering

CE 601	Theory of Structural Analysis and Design	3
CE 609	Matrix Methods of Structural Analysis	3
CE 614	Metal Structures	3
CE 625	Structural Dynamics	3
CE 641	Reinforced Concrete Structures	3
		15

Water Resources and Hydraulic Engineering

CE 715	Open Channel Hydraulics	3
CE 716	Applied Hydraulics	3
CE 722	Hydrology	3
CE 725	Water Resources Mathematical Modeling	3
CE 781	Formulation & Analysis of Public Works Projects	3
		15

Water Quality Engineering

CE 737	Environmental Chem & Microb I	3
CE 739	Environmental Chem & Microb II	3
CE 742	Water & Wastewater Treatment I	3
CE 743	Water & Wastewater Treatment II	3
CE 747	Analysis of Stream & Estuary Pollution	3
		15

Highway Engineering
(in cooperation with the Transportation Program)

CE 781	Formulation & Analysis of Public Works Projects	3
CE 796	Highway Pavement Design	3
CE 797	Design and Management of Highway Structures and Materials	3
CE 805	Traffic Engineering I	3
CE 807	Traffic Engineering II	3
		15

Construction Engineering and Management
(in cooperation with the Division of Management)

CE 781	Formulation & Analysis of Public Works Projects	3
CE 825	Construction Administration	3
CE 826	Construction Estimates & Costs	3
CE 827	Specifications & Contracts	3
CE 828	Project Planning & Control	3
		15

Geotechnical Engineering

CE 851	Earth Pressure & Retaining Structures	3
CE 861	Soil Mechanics I	3
CE 862	Soil Mechanics II	3
CE 863	Experimental Soil Mechanics	3
CE 871	Foundation Engineering	3
		15

M.S. PROGRAM IN ENVIRONMENTAL HEALTH SCIENCE

No.	Course	Units
Departmental Requirement		
CE 996	Project for the Degree of Master of Science	3
		3

Environmental Health Science Requirements

CE 737	Environmental Chemistry & Microb. I	3
CE 739	Environmental Chemistry & Microb. II	3
CE 742	Water & Wastewater Treatment I	3
CE 743	Water & Wastewater Treatment II	3
CE 751	Environmental Health Engineering	3
CE 752	Air Pollution	3
CE 770	Solid Waste Management	3
		21

Approved Electives

At least 12 units of approved graduate courses		12
	Minimum Total Units	36

M.S. PROGRAM IN ENVIRONMENTAL ENGINEERING

No.	Course	Units
Departmental Requirement		
CE 996	Project for the Degree of Master of Science	3
		3

Environmental Engineering Graduate Course Requirements

CE 715	Open Channel Hydraulics	3
CE 722	Hydrology	3
CE 737	Environmental Chemistry & Microb. I	3
CE 739	Environmental Chemistry & Microb. II	3
CE 742	Water & Wastewater Treatment I	3
CE 743	Water & Wastewater Treatment II	3
CE 747	Analysis of Stream & Estuary Pollution	3
		21

Approved Graduate Electives

At least 12 units of approved graduate courses		12
	Minimum Total Units Graduate Studies	36

Required Additional Undergraduate Work

Minimum background in science should include one year of chemistry and physics, and in mathematics should include basic courses in calculus and differential equations. In addition, a minimum of 15 credits of additional undergraduate makeup or prerequisite courses are required. Transfer credit for undergraduate and non-engineering graduate courses from other institutions will not normally be allowed. Individual programs will depend on previous preparation of student, and may be approved by a Department Committee. Students with a Bachelor's degree in engineering may have the requirements partially or fully waived.

REQUIREMENTS FOR THE ENGINEER DEGREE

A master's degree in civil engineering meeting the specialization requirements for the Polytechnic master's degree is generally required for admission. Applicants with master's degrees in other engineering disciplines may be admitted with deficiencies as evaluated by the departmental adviser. A minimum of 36 units of work beyond the master's degree is required, of which at least 27 units must be completed at Polytechnic. This work must include a 12-unit design project. Engineer degrees may be earned in any area of specialization except environmental health science. The program follows:

No.	Required Subjects	Units
CE 998	Project for the Degree of Engineer	12
	An approved elective in applied mathematics, or operations research	3
	Nine units of courses in areas of specialization selected with the consent of the adviser	9
	Required units	24
	Minimum elective units	12
	Minimum total units	36

REQUIREMENTS FOR THE DOCTOR'S DEGREE

Students with exceptional scholastic ability may pursue a doctorate in civil engineering or environmental science. An applicant for a doctorate in civil engineering, must hold a master's degree in civil engineering. For a doctorate in environmental health science, a master's degree in science is a prerequisite. Applicants with degrees in other fields may be admitted with deficiencies as evaluated by a departmental graduate adviser.

All doctoral students must complete a minimum of 90 units of work beyond the bachelor's degree or a minimum of 66 units beyond the master's degree. Of the units taken at Polytechnic, at least 27 must be formal course work (not including guided readings, seminars or projects). Ph.D. students must select a major field and two minor fields in consultation with the advisers.

To qualify as Ph.D. candidates, students must pass written and oral qualifying examinations. Registration for a minimum of 30 units of dissertation research is required. Registration should be continuous, until the dissertation has been completed and accepted.

UNDERGRADUATE COURSES

CE 111   Engineering Mechanics I   2:0:2
Three-dimensional vector treatment of the static equilibrium of particles and rigid bodies. Equivalent force and couple systems. Static analyses of trusses, frames, and machines. Friction, impending motion. Prerequisite: PH 104. Co/Prerequisite: MA 102.
Also listed under ME 116.

CE 112   Engineering Mechanics II   2:0:2
Three-dimensional vector treatment of the kinematics and kinetics of particles using various coordinate systems. Newton's laws, work, energy, impulse, momentum, conservative force fields, impact. Prerequisite: CE 111.
Also listed under ME 117.

CE 150   Surveying Fieldwork   2 credits
Field exercises involving the principles of elementary surveying, route surveying and geodetic surveying given at summer camp (two weeks). Prerequisite: MA 101 or MA 100.

CE 151   Surveying   3:3:4
Modern methods and computations for engineering surveys. Fundamental theory of photogrammetry with laboratory exercises. Prerequisites: CE 150 and ME 101.

CE 202   Mechanics of Materials   3:0:3
Basic principles of stresses and strains of members subjected to direct force, torsion and bending. Deflections of beams. Statically determinate and indeterminate problems. Column stability. Prerequisite: CE 111.
Also listed under ME 121.

CE 214   Computer Techniques in Engineering   2:3:3
Use of higher-level computer languages and techniques in engineering. Use of computer for numerical methods involving differentiation, integration and solution of systems of equations. Computer graphics in engineering. Evaluation of one commercial software package and its applications to civil engineering. Prerequisites: CS 100 and MA 104.

CE 222   Fluid Mechanics   3:3:4
Fluid-flow concepts including continuity, energy and momentum equations, laminar and turbulent flow, boundary layer drag, dimensional analysis. Euler's equation and two-dimensional ideal fluid flow. Hydrostatics. Pipe flow, pumps, turbines, fluid measurements. Prerequisites: CE 111 and CE 112.

CE 232   Soil Mechanics   2:3:3
Geological soil-forming processes and physical and mechanical properties of soils. Plasticity, capillarity, permeability, stress distribution in soil masses, consolidation theory, settlement of structures. Laboratory studies of physical and mechanical properties of soils. Prerequisites: CE 222 and CE 202.

CE 252   Reinforced Concrete Structures   3:0:3
Fundamentals of analysis and design of reinforced concrete beams, columns, slabs. Prerequisite: CE 322.

CE 272   Construction Engineering   3:0:3
Construction methods and management. Planning of construction operations, including cost estimating, bid preparation, time scheduling and economic evaluation of alternatives. Project planning and resource allocation utilizing the critical path method and PERT. Prerequisite: senior status.

**CE 303   Nature and Properties of
              Structural Materials   1:3:2**
Physical and mechanical properties of concrete, metals, plastics and asphaltic materials related to structure. Experimental investigation of mechanical properties of select structural materials and physical properties of cement and concrete mixes. Jointly developed and taught by civil and metallurgical engineering departments.
Also listed under MT 303.

**CE 305   Engineering Contracts and
              Specifications   2:0:2**
The preparation of contracts and technical specifications for engineering projects. Prerequisite: CE 202.

CE 317   Foundations   2:3:3
Site explorations and soil sampling; planning boring programs and interpretation of boring logs. Bearing capacities of footings and mats for granular soils and clays. Settlement of structures. Lateral earth pressure and proportions of retaining walls. Pile foundations. Prerequisite: CE 232 and Co/Prerequisite: CE 252.

CE 322   Theory of Structures I   3:0:3
Analysis of statically determinate beams, frames and trusses. Deflection calculations using energy methods. Analysis of indeterminate structures using superposition. Determinate and indeterminate influence lines. Slope deflection. Prerequisite: CE 202.

CE 323   Theory of Structures II   3:0:3
Analysis of statically indeterminate linear frames by moment distribution. Matrix analysis of structures using force and stiffness methods. Computer applications. Prerequisite: CE 322.

CE 331   Steel Structures   2:3:3
Design of steel beams and girders, tension members, columns. Bolted, riveted and welded connections. Prerequisite: CE 322.

CE 332   Design of Structural Systems   2:3:3
Structural design of buildings, frames and bridges in steel and reinforced concrete. Selection of framing systems and design of multistory structures. Composite and prestressed construction. Prerequisites: CE 322, CE 252, CE 317 and CE 331.

CE 336   Timber and Masonry Structures   3:0:3
Properties and classification of structural lumber. Design of timber connectors. Design and erection of residential and industrial timber buildings. Beams, frames, columns and trusses of sawn lumber and glued-laminated construction. Manufacture and properties of concrete masonry units. Properties of mortar and grout. Design and construction of load-bearing reinforced and unreinforced masonry structural elements. Prerequisite: CE 322.

**CE 340   Water Resources and
              Hydraulic Engineering   3:0:3**
Hydrologic techniques. Surface water and ground water supplies. Open channel flow. Water transmission and distribution. Wastewater and storm water drainage. Dam and reservoir projects. Development of water resources for multi-purpose projects. Prerequisite: CE 222.

CE 341   Environmental Engineering I   2:3:3
Water and wastewater quantities. Water quality. Water and wastewater treatment, stream assimilation, public health and environmental problems. Laboratory analyses of water and wastewater samples, treatment process tests. Prerequisites: CE 222 and CE 340

CE 342   Environmental Engineering II   2:3:3
Integrated lecture and design periods covering water distribution systems, water filtration units and principal components of wastewater treatment plants for small communities. Introduction to air quality and solid waste problems. Prerequisites: CE 341 and CE 340.

CE 345   Hydraulic Engineering   3:0:3
Pumping systems, hydroelectric developments, nonuniform flow in open channels. Overflow, siphon and shaft spillways. Flow meters for open and closed conduits. Prerequisite: CE 222.

CE 351   Highway and Transportation Engineering   2:3:3
Fundamentals of highway and transportation engineering including land, urban, air and water transportation. Geometric design, capacity intersection design, drainage, economic analysis and finance, rigid and flexible pavements, velocity profile and performance, evaluation, future developments. Prerequisite: CE 151.

CE 391-392 Bachelor's Thesis in Civil Engineering   each 2 credits
Original research, design or plan for an approved engineering project. Thesis gives students the opportunity to apply knowledge and training gained in courses by approaching and successfully solving comprehensive problems. Conferences held regularly with an appointed member of the faculty. Thesis registration required each semester. Students must reregister for thesis until completed. Prerequisite: senior status.

CE 396 Civil Engineering Internship   2:0:2
Supervised, creative civil engineering work of at least two months' performance judged on the basis of written and oral reports presented to industrial and faculty supervisors. Regular faculty visitations and conferences arranged during internships. Open to students who have completed their junior year and have departmental approval prior to beginning the internship experience. Prerequisite: department head's approval.

CE 398 Project in Civil Engineering   2 or 3 credits as arranged
Solution to civil engineering problem or detailed study of an advanced area of civil engineering under close supervision of an adviser. Before undertaking the project, interested students must submit a detailed written proposal of the problem they intend to investigate to the course director, along with the number of credits for which they wish to register. Results of the project must be submitted to the department as a formal report.

GRADUATE COURSES

GENERAL

CE 590 System Analysis for Civil Engineers   2½:0:3
Review of optimization techniques and simulation and optimization models used to make policy decisions for civil engineering systems. Computer applications including facilities location, project sequencing and scheduling, capacity expansion, land use planning, and districting and scheduling of municipal services, optimal sewer system design, and reservoir operation.

CE 598-599 Special Topics in Civil Engineering   2½:0:3
Specialized current topics of interest of an interdisciplinary nature. Offered at irregular intervals. Advance announcements include course description and prerequisites.

CE 780 Analysis of Uncertainty in Civil Engineering   2½:0:3
Brief review of basic concepts including problem indentification, definitions of statistical parameters and principles of probability. Applications utilizing techniques of frequency distribution, regression and correlation, time series analysis, significance testing, elementary decision theory, sensitivity and risk analysis, reliability assessments. All topics emphasize applications to civil engineering practice and research, and include problem solving in such areas as hydrology, structures, geotechnical, transportation, and environmental engineering. Student specialty areas will be considered in selection of problems for study.

CE 781 Formulation and Analysis of Public Works Projects   2½:0:3
Methods for the identification, formulation, preliminary appraisal, and detailed analysis of individual projects and systems of civil engineering projects. Different approaches appropriate for government agencies, public utilities, industrial firms, and private entrepreneurs. Planning considers projects that satisfy single and multiple purposes and objectives, meet local and regional needs, and take advantage of opportunities for development. Financial and economic analyses, including sensitivity and risk analysis. Mathematical models for evaluation of alternatives and optimization. Impacts of projects: environmental, social, regional economic growth, legal and institutional, and public involvement.
Also listed under MG 830.

CE 790 Fire Protection Engineering   2½:0:3
Overview of fire problems in the United States. Statistics, trends and fire experiences of interest to engineers. Chemistry and physics of fire phenomena, including ignition, flammability, heat transfer, products of combustion and modes of fire growth and extension. Properties and behavior of materials at elevated temperatures. Performance of structures exposed to fire and failure mode analysis. Laboratory and full-scale testing of construction materials, components, assemblies and structures. Building codes, fire codes and standards. Measures for fire protection: detection, alarm and communication systems and systems for fire suppression and smoke control.

CE 791 Infrastructure Systems Analysis   2½:0:3
Methodologies and procedures for macro-level analysis of engineered infrastructure systems. Introduction to computer-based techniques for optimization of design, operation and maintenance of infrastructure subsystems. Demographic, system loading and capacity analyses for water distribution, wastewater collection and disposal, solid wastes collection, street sweeping, snow removal and other municipal service systems. Infrastructure financing and capital budget process. Life cycle and benefit-cost analyses applied to infrastructure renewal. Prerequisite: CE 214 or equivalent.

STRUCTURAL ENGINEERING

Prerequisites for all courses: MA 104, CE 323

CE 601 Theory of Structural Analysis and Design   2½:0:3
Theories of structural action, including elastic and plastic behavior and their relationship to design. Classical structural mechanics, matrix procedures and numerical methods of analysis as well as their interrelationships. Influence lines, elastic supports, settlement and rotation of supports. Applications to statically indeterminate frames and trusses. Prerequisite: CE 252 and CE 331.

CE 603-604 Special Topics in Structural Analysis I, II   2½:0:3
Specialized current topics of interest offered at irregular intervals by advance announcement. Graduate advisers may approve repeated registration for different topics. Prerequisite: CE 601.

CE 605 Plate and Shell Structures   2½:0:3
Analysis of plate and shell structures with particular emphasis on civil engineering applications of shells. Analysis of plates by finite differences. Membrane solution of shells of revolution, cylinders, elliptic and hyperbolic paraboloids. Asymptotic solution for symmetrically loaded shells of revolution. Folded plates.

CE 609 Matrix Methods of Structural Analysis   2½:0:3
Basic concepts of matrix methods in structural analysis. Flexibility and stiffness matrix of structural elements. Force and displacement transformations. Flexibility and stiffness of complete structures. Complete solutions of structural problems by chain matrix operations.

CE 611 Limit Design of Metal and Concrete Structures   2½:0:3
Application of plastic theory of structural behavior to design of civil engineering structures. Particular emphasis on steel and reinforced concrete beams and frames. Co/Prerequisite: CE 601.

CE 613 Stability of Structures   2½:0:3
Critical loads of elastic members and frameworks from characteristic-value problem formulations, considering lateral and torsional displacements. Stability of inelastic members, including initially strained steel shapes. Solutions by numerical methods. Behavior of members and frames with initial geometrical imperfections and transverse loading. Ultimate load of plate girders. Prerequisite: CE 601.

CE 614   Metal Structures   2½:0:3
Current developments in design of metal structures, including design of light-gauge, cold formed members, orthotropic bridge decks and structural applications of aluminum. Co/Prerequisite: CE 601.

CE 616   Finite Element Analysis of
**   Structural Systems**   2½:0:3
Relationship between the finite element method and the Rayleigh-Ritz method. Derivation of element stiffness matrices. Construction of general stiffness matrices in global coordinates. Problems in plane stress, plates and shells under static and dynamic loads. Prerequisite: CE 609.
Also listed under ME 621.

CE 617   Introduction to Modern Concepts
**   of Structural Safety**   2½:0:3
Introduction to modern concepts of structural safety limit states designs based on reliability analysis. Design code formats. Risk analysis. Semi-probabilism. Safety index analysis. Code optimization. Single load stochastic models; extreme value and holding time analysis. Combined load analysis; scalars, vectors. Basic system reliability. Conditional analysis, modeling errors and engineering judgment. Prerequisite: CE 780.

CE 621   Advanced Mechanics of Material   2½:0:3
Unsymmetrical bending of elastic bars, shear center for members of thin-walled open cross section, curved beams, beams on elastic foundations, membrane and bending stresses in shells.
Also listed under ME 611.

CE 625   Structural Dynamics   2½:0:3
Dynamic response of single degree of freedom systems. Theory of vibration of finite degree of freedom systems. Influence coefficient method. Analytical and numerical solution of dynamic response problems. Nonlinear analysis of single degree of freedom system. Emphasis on computer analysis of large complex systems. Prerequisite: CE 609.
Also listed under ME 661.

CE 626   Applied Structural Dynamics   2½:0:3
Review of classical structural dynamics. Introduction to linear random vibrations. Power spectra, auto- and cross-correlation functions. Wind loads, galloping, flutter, buffeting, vortex shedding. Response of civil engineering structures to wind effects. Seismic loads. Linear and nonlinear response spectra. Ductility. Simplified seismic analysis and design of structures. Prerequisite: CE 625.

CE 641   Reinforced Concrete Structures   2½:0:3
Elastic and ultimate strength design of reinforced concrete members. Shear and torsion effects on beams. Analysis and design of prestressed concrete structures. Prerequisite: CE 252 and Co/Prerequisite: CE 601.

CE 643   Prestressed Concrete   2½:0:3
Design of prestressed and post-tensioned beams, columns and slabs; principles and materials; losses, cracking and deflections. Prerequisite: CE 641.

WATER RESOURCES AND HYDRAULIC ENGINEERING

Prerequisite for all courses: MA 104, CE 222

CE 712   Water Resources Projects   2½:0:3
Feasibility-level planning and design studies for water resources projects, including water conveyance works; concrete dams and associated waterways; pumping stations; hydroelectric, irrigation, navigation, and flood mitigation projects. Subjects considered include layouts, dimensions and capacity of facilities, hydraulic and structural forces, and stability analyses. Co/Prerequisite: CE 340 or CE 715, or permission of instructor.

CE 715   Open Channel Hydraulics   2½:0:3
Theory and computations for uniform flow, gradually varied flow, rapidly varied flow, unsteady flow in prismatic and non-prismatic channels.

CE 716   Hydraulic Problems   2½:0:3
Similarity, dimensional analysis and modeling techniques as applied to hydraulic systems. Pumping systems including hydraulic transients and flow of air, liquids, sludge. Cavitation. Co/Prerequisite: CE 340 or CE 715.

CE 717   Hydrodynamics for Civil Engineers   2½:0:3
Applications of basic concepts of fluid kinetics and dynamics to problems in turbulent diffusion, density currents, stratified flows and other problems of special interest to civil engineers.

CE 722   Hydrology   2½:0:3
Hydrologic cycle. Meteorological considerations. Analyses of precipitation, runoff, unit hydrograph, flood routing and reservoir storage. Principles of groundwater hydrology. Introduction to frequency analysis of floods and droughts. Prerequisite: undergraduate degree in engineering or science.

CE 723   Groundwater Hydrology and Pollution 2½:0:3
Characteristics of confined and unconfined flow of water through porous media, groundwater and well hydraulics; quality of ground water; environmental influences; groundwater pollution; management aspects of groundwater; and groundwater modeling. Prerequisite: CE 340 or instructor's permission.

CE 725   Water Resources Mathematical
**   Modeling**   2½:0:3
Studies of hydraulic, hydrologic, water quality and systems models as applied to rivers and streams, embayments, estuaries and basins. Review of basic equations of flow applicable to these models. Appropriate modeling techniques using computer-based solutions reviewed with emphasis on time-varying boundary conditions and problems of calibration and verification. One-, two- and three-dimensional models considered. Stormwater models and water resource systems modeling. Prerequisite: course in computer programming and Co/Prerequisite: CE 715.

CE 732   Coastal Engineering   2½:0:3
Basic concepts of wind-wave induced phenomena in near shore areas as associated with problems of shoreline protection. Water-wave dynamics as applied to coastal structures, including effect of hurricanes on maximum storm tides, wave heights, pressures.

CE 735-736   Special Topics in Water Resources
**   and Hydraulic Engineering I, II** 2½:0:3
Topics in water resources and hydraulic engineering such as hydroeconomic models; finite difference and finite element models; synthetic hydrology; conjunctive use of surface water and groundwater; desalinized and recycled water; thermohydrologic and hydrometeorological problems; flushing of estuaries; hydrodynamics of oil pollution, sludge dumping, and sediment movement; environmental design of hydraulic structures; problems of macro projects. Prerequisite: permission of instructor.

ENVIRONMENTAL SCIENCE AND ENGINEERING

CE 737   Environmental Chemistry & Microbiology I   1:2:3
Introduction to the chemistry and microbiology of polluted and natural waters, including applications of principles developed.

CE 739   Environmental Chemistry & Microbiology II   1:2:3
Advanced topics in chemistry and microbiology of polluted and natural wastewater treatment.

CE 742   Water and Wastewater Treatment I   2½:0:3
Physical, chemical and biological principles involved in process design and treatment of water and wastewater. Topics include aeration, filtration, softening, chemical treatment, coagulation, flocculation, desalinization, taste and odor control. Co/Prerequisite: CE 737.

CE 743   Water and Wastewater Treatment II   2½:0:3
Continuation of CE 742. Topics include sedimentation, adsorption, aerobic and anaerobic biological treatment, sludge treatment and disposal. Co/Prerequisite: CE 739.

CE 745   Water and Wastewater Treatment
**   Laboratory   1:2:3**
Laboratory processes in water and wastewater engineering dealing with physical, chemical and biological methods and principles. Processes include disinfection, softening, sedimentation, oxygen transfer, coagulation, adsorption, filtration, aerobic and anaerobic biologial treatment systems. Warburg analysis of waste. Co/Prerequisite: CE 743.

CE 746   Industrial Waste Treatment   2½:0:3
Sources of industrial wastewaters and their treatability by physical, chemical and biological processes. Problems and solutions involved in combining municipal and industrial waste treatment. Status of government regulations imposed on industries in prevention of water pollution.

CE 747   Analysis of Stream and Estuary Pollution   2½:0:3
Dispersal and decay of contaminants introduced into lakes, streams, estuaries, oceans. Effects of pollutants on chemical quality and ecology of receiving waters.

CE 748   Sanitary Engineering Design   1:2:3
Design of water supply and wastewater treatment systems. Topics of special interest. Co/Prerequisite: CE 743.

CE 751   Environmental Health Engineering   2½:0:3
Theory, methodology and instrumentation associated with environmental health. Topics include epidemiology, food vectors, radiation, pest control, heating, ventilation, noise, illumination, hazards of home and community environment, other subjects which affect public health.

CE 752   Air Pollution   2½:0:3
Causes and effects of air pollution. Methods of sampling. Interpretation of data. Meteorological aspects. Methods of air pollution control.

CE 753   Hazardous/Toxic Waste Management   2½:0:3
Methods in the management of hazardous/toxic waste sites. Topics covered include health and safety, legal aspects, contamination of the environment, treatment processes, toxicology and risk assessment.

CE 758   Air Pollution Engineering Control   2½:0:3
Pollutant emissions control; analysis of pollutant properties, concentrations and boundary conditions; absorptive, and reactive recovery processes for moving and stationary sources; formation and removal of gaseous oxides (NO , SO , CO , etc.) and of aerosols and other particulates. Prerequisite: Instructor's permission.
Also listed under CH 752.

CE 767   Environmental Impact Evaluation   2½:0:3
An examination of legal and technical requirements in the preparation of environmental impact evaluations. Considerations include: legal and technical requirements, the procedure and the interdisciplinary nature of the analysis Topics include overall impact evaluation, problem definition, quantification of impact, methods used in analysis, field evaluations, mitigations, hearing procedures and management. Practical examples and case studies used.

CE 770   Solid Waste Management   2½:0:3
Engineering aspects of solid waste collection, transport and disposal, including incineration, sanitary landfill, composting, recovery and reutilization, economic evaluation of factors affecting selection of disposal methods.

CE 771-772   Special Topics in
**   Environmental Engineering I, II   2½:0:3**
Current topics including nitrification in natural and treated waters, hazardous and toxic wastes, organic removal from water supplies, water reuse, specialized aspects of biological wastewater treatment, environmental health, solids disposal, and modeling natural waters and treatment systems. Prerequisite: permission of the instructor.

HIGHWAY ENGINEERING

Prerequisites for all courses: MA 104, CE 351

CE 796   Highway Pavement Design   2½:0:3
Design, construction, maintenance and rehabilition of flexible and rigid pavements.
Also listed under TR 722.

CE 797   Design and Management of Highway
**   Structures and Materials   2½:0:3**
Structures for highways, rural roads and airports. Special problems of construction. Management of pavement systems.
Also listed under TR 723.

CE 804   Travel Demand Forecasting   2½:0:3
Theory and application of travel forecasting methods to predict the amount and nature of travel on transportation systems. Co/Prerequisite: TR 600 or equivalent.
Also listed under TR 601.

CE 805   Traffic Engineering I   1:3:3
First course in a two-semester sequence covering the basic aspects of traffic engineering. Driver, roadway, vehicle, and traffic stream characteristics, and their influence on operations, controls, and design. Traffic studies and data analysis: volume, speed, delay, density, accidents, etc. Concepts of traffic capacity and level of service analysis. Capacity and level of service analysis of limited access facilities: freeways, freeway components, two-lane rural highways, multilane highways. Laboratories emphasize the use of spreadsheets in data analysis and the use of computer packages for capacity and level of service analysis.
Also listed under TR 701.

CE 807   Traffic Engineering II   1:3:3
Second course in a two-semester sequence covering the basis of traffic engineering. Traffic control, operations, and management. Characteristics of signs, signals, and markings. The "Manual on Uniform Traffic Control Devices" and its use. Intersection control. Signal systems and coordination. Pretimed and actuated control. Design of street hardware. Traffic flow regulations and their implementation. Intersection and arterial analysis.
Also listed under TR 702.

CE 812   Transportation Economics and Finance   2½:0:3
Basic principles of present worth, single payment and uniform series, sinking funds, annualized costs. Differences in the public and private sectors of transportation: profit, depreciation, return of capital. Benefit-cost analysis. Rate of return. Bond issues. Formulation and use of unit costs in highways, transit, and other modes. History of financing of road systems, transit, and trucking. Privatization. Balance sheets, financial control, cash flow. Preparing a private venture business plan
Also listed under TR 750.

CE 821   Design of Traffic Facilities   2½:0:3
Functional and preliminary design principles and analyses for freeways and arterials. Interchange design for freeway facilities and design of at-grade intersections, using principles of channelization. Design of parking garages and parking lots.
Also listed under TR 710.

CE 840   Planning and Design of Terminals   2½:0:3
Passenger and freight terminals with emphasis on system descriptions of these facilities. Land, marine and air terminals. Methods are discussed for determining the levels of service for pedestrian flows, TOFC and truck terminals are also covered.
Also listed under TR 670.

CE 841   Airport Planning and Design   2½:0:3
Techniques for forecasting air passenger traffic and aircraft operations at commercial and general aviation facilities. Principles and practices for planning and design of terminal facilities, ground transportation systems, parking facilities, runways and navigational aids. Airport site selection, configuration and economics.
Also listed under TR 671.

CONSTRUCTION ENGINEERING AND MANAGEMENT

**CE 798-799   Special Topics in Infrastructure
                        Systems and Construction I, II   2½:0:3**
Current topics of interest such as methodologies and procedures for analysis of existing infrastructure systems, geographic information data and management systems, photogrammetic and remote sensing techniques and utilization and design of infrastructure facilities and systems. Intelligent buildings and other modern constructed works. Temporary structures for construction and problems in construction engineering. New approaches in construction management.

CE 825   Construction Administration ·   2½:0:3
Management problems unique to the construction business including licensing, bonding, insurance, short-term financing, and employee relations.
Also listed under MG 825.

CE 826   Construction Estimates and Costs   2½:0:3
Estimates, costs from the viewpoint of contractor or construction engineer, details of estimating, emphasis on labor, material, equipment, overhead costs.
Also listed under MG 826.

CE 827   Specifications and Contracts   2½:0:3
Principles of contract law as applied to the construction industry; legal problems in preparing and administering construction contracts.
Also listed under MG 827.

CE 828   Project Planning and Control   2½:0:3
Network planning techniques for project management and resource allocation. Emphasis on PERT, LOB, CPM and probabilistic generalized networks. Heuristic models for multi-project scheduling and resource leveling. Network development, computer adaptation, progress reports and project monitoring. Prerequisite: knowledge of computer programming.
Also listed under MG 810 and IE 620.

GEOTECHNICAL ENGINEERING

Prerequisites for all courses: MA 104, CE 232, CE 317

**CE 851   Earth Pressures and Retaining
                        Structures   2½:0:3**
Conjugate stress relationships in infinite slopes in granular and cohesive soils. Studies of classical works of Rankine, Coulomb, Kerisel and others for determining pressure distributions on rigid structures retaining soil masses. Effects of ground water seepage, surcharge loading. Analysis and design of rigid-type retaining structures and sheet piles. Soil reinforcement applications for retaining structures.

CE 854   Engineering Geology   2½:0:3
Importance of geology to civil engineers, case studies, rock formations, types of rocks, weathering of rocks, folds, faults, landslides, earthquakes, geological explorations and mapping, applications of geology in civil engineering projects such as dams, reservoirs, highways, and tunnelling, rock mechanics.

CE 861   Soil Mechanics I   2½:0:3
Index properties of soils. Stress distribution in homogeneous and layered elastic half-space due to surface loading. Permeability, capillarity, absorption and soil-water tension. Flow networks. Theory of wells and use of well data in field measurement of permeability. Consolidation of soils. Strength of soils.

CE 862   Soil Mechanics II   2½:0:3
Strength of soils, laboratory tests, effective strength parameters, total and effective stress paths. Applications of soil strength in stability analysis of embankments. Critical state soil mechanics, constitutive relations for soils. Prerequisite: CE 861.

CE 863   Experimental Soil Mechanics   1:2¼:3
Critical evaluation of standard testing procedures for identification and classification tests. Detailed examinations of permeability, capillarity and seepage phenomena using soil samples and electric analogs. One-dimensional consolidation test. Treatment of shear strength and the static triaxial compression test and its several variations. Special tests. Prerequisite: CE 861.

CE 871   Foundation Engineering   2½:0:3
Soil sampling and exploration procedures. Analytical procedures for determining bearing capacity as a function of stability and settlements. Plate-loading test shallow footing design. Analysis and design of mat footings Design of deep foundations; piles, piers and caissons.

**CE 881-882   Special Topics in Geotechnical Engineering
                        and Foundation Engineering I, II   2½:0:3**
Current topics of interest such as theoretical determination of pile capacities, sheet pile bulkheads and trench problems, stresses on tunnels, theoretical approaches to soil stability, refinements in settlement analysis, and soil reinforcement applications. Computer applications in foundation engineering. Soil structure interaction problems. Prerequisite: CE 851 or CE 861 or CE 871.

CE 892   Soil Dynamics and Earthquake Engineering   2½:0:3
Single- and multi-degrees of freedom systems. Wave propagation in homogeneous and layered half-spaces. Behavior of dynamically loaded soils. Basic concepts of seismology: earthquake distribution, type, magnitude, intensity, energy and seismic regionalization. Response spectrum. Effect of earthquakes on soil and response of structures to earthquakes as influenced by soil formation. Design of dynamically loaded foundations and earth structures. The liquefaction problem.
Prerequisite: CE 861.

**CE 893   Rock Mechanics and Underground
                        Structures   2½:0:3**
Intact rock and rock mass description and engineering properties; static ground-structure interaction, stability and wedge analysis, underground structures in rock and soft soil.

CE 894   Marine Geotechnology   2½:0:3
Geological nature of marine sediments and comparisons with terrestial soil deposits. Sampling techniques and problems of obtaining undisturbed samples and cores; in situ measurements of physical and mechanical properties of marine soils. Comparisons of stress-strain, strength and consolidation characteristics of terrestrial and marine soils. Stability of submerged slopes and slumping, bearing capacity, breakout resistance, marine anchors.

GUIDED READINGS, SEMINARS, PROJECTS AND THESES

Note: Students should obtain a copy of the University's "Regulations on Format, Duplication and Publication of Reports, Theses and Dissertations" at the Office of Research and Graduate Affairs.

CE 901   Guided Readings in Civil Engineering   3 units
Individual study of selected literature in civil engineering under guidance of a faculty adviser. Acceptable written report or successful completion of examination required. Only one registration permitted, except with department head's approval. Prerequisite: instructor's approval.

CE 952   Seminar in Civil Engineering   nc
Lectures on recent developments in civil engineering given by representatives from industry, other research and educational institutions, and Polytechnic graduate students and faculty.

CE 996   Project for Degree of Master of Science   3 units
Analytical, design or experimental studies in civil or environmental engineering under guidance of a faculty adviser. Written report required. Prerequisites: degree status and project adviser's approval.

CE 997   Thesis for the Degree of Master of Science
3 units
Original investigation or design in the student's principal field of study prepared under close supervision of a faculty adviser. Candidates must successfully defend thesis orally. Registration for a minimum total of twelve (12) units required. Maximum of 12 units counted toward degree. Allowable registration per semester 3-12 units. Prerequisite: degree status and thesis adviser's approval.

CE 998   Project for Degree of Engineer   3 units
Comprehensive planning and design of civil engineering project under guidance of a faculty adviser. Emphasis on current techniques. Written report in prescribed format to be submitted on completion of project. Oral examination on project subject must be passed. Registration for minimum total of 12 units required. Maximum of 12 units counted toward degree. Preferred registration per semester, 3-6 units; allowable registration 1-12 units with approval of department head. Prerequisites: degree status and project adviser's approval.

CE 999   Dissertation for Degree of
Doctor of Philosophy   6 units
Independent original investigation demonstrating creativity and scholarship worthy of publication in recognized engineering journals. Candidates must successfully defend their theses orally. Registration for minimum of 30 thesis units required prior to defense. Registration should be continuous. Preferred registration per semester, 6 units; allowable registration 1-18 units with approval of department head. Prerequisites: degree status, completion of qualifying examinations and thesis adviser's approval.

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COMPUTER SCIENCE

Computer science is the study of the theory and applications of computers. The field of study covers the design and analysis of algorithms for information processing, principles of programming languages and compilers, operating systems, software engineering, artificial intelligence, computer organization and architecture, computational mathematics, parallel processing and application areas including database systems, computer graphics, computer music, and image analysis and understanding.

The computer science program is administered by the Division of Computer Science of the Department of Electrical Engineering and Computer Science. Its faculty directs the degree programs in computer science and information systems engineering.

UNDERGRADUATE PROGRAM

This progam has been accredited by the Computer Science Accreditation Commission (CSAC) of the Computing Sciences Accreditation Board, Inc.

The program in computer science offers a curriculum that prepares students for a professional career as computer scientists, or graduate studies in computer science leading to research or teaching careers. The undergraduate program in computer science at Polytechnic is based on the principle that a well-rounded graduate should have a rigorous education in the fundamentals of computer science including a significant exposure to the design and operation of computers, a solid training in related mathematical and scientific disciplines, and a broad general education including the development of communication skills.

OVERVIEW OF THE UNDERGRADUATE CURRICULUM

This description of the curriculum is designed to give students an overview of the structure of the curriculum and to help them understand the reasons behind the design of the curriculum. Undergraduates in computer science at Polytechnic University have the advantage of being in a department with a strong graduate division. This means that undergraduate students study in a rich intellectual environment where many of their instructors are engaged in state-of-the-art research. This significantly contributes to the quality of education and provides highly motivated undergraduates with the opportunity to engage in advanced projects with first-rate researchers.

The Computer Science Component (47 credits)
One of the distinctive features of the computer science component is the balance of emphasis on subjects related to the design of computers and theoretical computer science. For example, students study switching and digital systems, computer organization and architecture, and take two computer laboratory courses, as well as study data structures, software development, and the principles of programming languages. The Department believes that this

balance of emphasis is important in preparing graduates for a professional or research career.

The Mathematics Component (20 credits)
Mathematics is essential to the CS curriculum. It forms the basis for understanding computer architecture and organization, principles of programming languages, algorithms, compilers, and operating systems. The mathematics sequence is designed to enhance the integration of mathematics with the computer science component. If students did not have a chance to learn high-school math well (as determined by the Polytechnic placement examination in mathematics), they will be given three extra hours a week of freshman mathematics, with no extra tuition charge. The physics sequence begins in the second term of the freshman year to take advantage of their preparation in mathematics.

Laboratory Sciences Component (13 credits)
These subjects are essential to a well-rounded education. Computer scientists find that their training in basic science plays an important role in their career. Although chemistry is no longer required, students are strongly recommended to take the sequence CM101/111-CM102/112 as electives. Students who have not had high school chemistry must take (as least) CM101/111.

General Education and Communication Skills Component (30 credits)
Courses in the humanities and social sciences are an important part of the curriculum. Career advancement is not only based on technical skills and knowledge. It is equally based on the ability to communicate effectively and apply the wisdom that results from a serious study and appreciation of the humanities and social sciences. Thus, in addition to basic humanities and social science courses, the Department requires students to take LA143 (Information, Communication & Society), HU110 (Report Writing), and 18 credits of humanities/social science electives.

For further details and descriptions see the section of this catalog entitled "Humanities and Social Sciences requirements for Engineering and Computer Science majors."

Opportunities to Explore—The Elective Component (18 credits)
It is important for students to have the opportunity to explore other subject areas or to delve into areas in more depth. This is the purpose of having 18 credits of electives. Of these 18 credits, 6 credits must be selected from either computer science or mathematics courses. Students may elect to minor in another discipline if they so choose. Every course is important, so students should talk over their alternatives with an adviser. Advanced students may also take some of the graduate computer science courses.

HONORS PROGRAM

Full-time students in computer science may be admitted into a BS/MS Honors program which leads to simultaneous award of the Bachelor's and Master's degree in computer science. Depending on the student's preparation and objectives, completion of the two degrees may come as early as the end of the fourth year of study. Admission into the program is normally made at the start of the freshman

other students individually with the departmental honors adviser. Acceleration may be achieved through Advanced Placement, through Credit by Examination, and through summer coursework or research participation. The program is intended for students with outstanding academic records.

TRANSFER STUDENTS

Transfer students are accepted into the computer science BS program on the same basis described in the catalog under admissions. In addition, the Division requires that at least 18 credits in computer science be taken at Polytechnic.

Graduates of technology programs may be able to fulfill the requirements for the bachelor's degree in computer science in two to three-and-one-half years, depending on the scope and level of their previous education. Consult an undergraduate adviser for details.

Transfer credits granted for graduates of programs at other schools are subject to frequent changes, based on reevaluation of content and level. Thus, students completing the same program, but in different years, may receive different amounts of transfer credit. Consult a computer science undergraduate adviser for current information. Transfer students must arrive and present their records for evaluation at least one week before the regular registration period for their first semester.

SENIOR HONOR STUDENTS

A full-time student whose performance in the first three years is outstanding will be named as a senior honor student and, in consultation with an adviser, is permitted to replace some of the required senior technical courses by other courses, usually more advanced, which are directed toward the student's professional goals.

DEPARTMENTAL STANDARDS AND PROBATION

To earn a BS degree in computer science, students must have a minimum C average (2.00 grade-point average) in the *major*. This requirement for a minimum *major technical* average is above and beyond the University BS degree requirement for a minimum 2.00 grade-point average *overall*. Students below average, or deficient in a subject, will be placed on departmental *probation* as a warning that

they are not acceptably progressing towards the degree. Continued inability to meet the conditions of probation may lead to academic *disqualification* from the BS(CS) degree program.

Probation action may be occasioned by a semester or cumulative major average less than 2.00; grades lower than C in important courses, particularly CS 112/204; failure to adhere to course prerequisites; and excessive or unauthorized course withdrawals. Students are strongly urged to take CS 204 immediately following their completion of CS 112. Students on probation may be required to reduce their course load or restrict their extracurricular activities; they may be required to postpone an advanced course or to undertake a remedial course program; or they may be made to *repeat* courses passed with a grade less than C. Almost without exception, students earning a grade lower than C in CS 112 or CS 204 will be asked to repeat the course. Likewise, a student with less than a C semester average, or with less than a C average in courses of a closely related sequence, may be asked to repeat courses in which grades were D+, D or I.

When a course is repeated, the second grade is required to be no lower than C. Failure to achieve this leads to disqualification from the program. Permission to try a course more than twice is granted only under exceptional conditions. The exclusion of the first grade of a repeated course in the computation of the *major* grade-point average applies for a maximum of four such courses. If additional courses are repeated, *all* grades count, including the first.

Students on probation are usually permitted to preregister for the next semester, but they are obliged to consult their advisers after grades are posted, *before* the start of classes. Students who undertake courses in violation of their probation face *deregistration* and possible disqualification.

INFORMATION

The *Undergraduate Student Manual*, issued to every student, contains further details on honors, probation, approved electives, typical examples of minors, projects, and other matters of interest. Curricula and prerequisite changes, new courses, special sections, and other last minute announcements are posted on the bulletin boards outside the computer science office in Brooklyn and the department office in Farmingdale. Each student is responsible for keeping informed.

Curriculum for the Bachelor of Science Degree
in Computer Science (for Freshmen entering 1988)

Freshman Year

First Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
CS	112	Programming in Pascal	3	0	3
MA	101	Calculus I	4	0	4
MA	341	Discrete Computational Structures	3	0	3
HU	101	Writing and the Humanities I	3	0	' 3
SS	104	Contemporary World History	3	0	3
SL	101	Student Survival	0	1	0
PE	101	Physical Education	0	2	0
					16

Second Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
CS	204	Data Structures and Algorithms	3	0	3
MA	102	Calculus II	4	0	4
PH	104	Introductory Physics I	3	0	3
HU	200	Writing and the Humanities II	3	0	3
		Hum./Soc. Sci. elective	3	0	3
PE	102	Physical Education	0	2	0
					16

Sophomore Year

			Cl.	Lab.	Cr.
CS	236	Switching Theory and Logic Design	3	0	3
MA	103	Calculus III	3	0	3
PH	105	Introductory Physics II	3½	0	3½
PH	115	Physics Laboratory I	0	1½	½
HU	110	Basic Report Writing I	3	0	3
		Hum./Soc. Sci. elective	3	0	3
PE	103	Physical Education	0	2	0
					16

			Cl.	Lab.	Cr.
CS	205	Assembly and Machine Languages	3	0	3
PH	106	Introductory Physics III	2½	0	2½
PH	116	Physics Laboratory II	0	1½	½
EE	377	Introduction to Electronics	2½	1½	3
LA	143	Information, Communication & Society	3	0	3
		Elective*	3	0	3
PE	104	Physical Education	0	2	0
					15

Junior Year

			Cl.	Lab.	Cr.
CS	212	Software Development	3	0	3
CS	337	Computer Architecture & Organization	3	0	3
MA	223	Introduction to Probability	3	0	3
		Hum./Soc. Sci. elective	3	0	3
		Elective*	3	0	3
					15

			Cl.	Lab.	Cr.
CS	275	Theory of Computation	3	0	3
CS	296	Computer Laboratory I	2	3	2
CS	312	Principles of Programming Languages	3	0	3
MA	224	Introduction to Mathematical Statistics	3	0	3
		Hum./Soc. Sci. elective	3	0	3
		Elective*	3	0	3
					17

Senior Year

			Cl.	Lab.	Cr.
CS	206	Compilers	3	0	3
CS	297	Computer Laboratory II	1	6	3
CS	306	Software Engineering	3	0	3
		Hum./Soc. Sci. elective	3	0	3
		Electives*	6	0	6
					18

			Cl.	Lab.	Cr.
CS	238	Operating Systems	3	0	3
CS	398	Sr. Project in CS	1	6	3
		Computer Science elective	3	0	3
		Hum./Soc. Sci. elective	3	0	3
		Elective*	3	0	3
					15

Total credits required for graduation: 128

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* There are 18 credits of electives. To pursue an area other than computer science in some depth, the student may elect up to 12 credits in an integrated, well defined area. This is chosen by the student in consultation with and with the approval of an academic adviser. Students not electing such a concentration may instead select courses in computer science, mathematics, chemistry, or engineering. The sequence CM101/111 and CM102/CM112 is strongly recommended. However, students who have not taken chemistry in high school must take at least CM101/CM111.

The remaining 6 credits must be selected in either computer science or mathematics.

An elective may neither duplicate material studied under another course number, nor be a programming course in another language, e.g. a course in FORTRAN or COBOL.

GRADUATE STUDY

The Division of Computer Science offers master's and doctor's degree programs in computer science, and a master's degree program in information systems engineering. See the section of this catalog on Information Systems Engineering for a description of this program.

The computer science master's program is intended to develop competence in basic areas such as information structures, programming languages, computer design and organization, compilers and translators, operating systems, artificial intelligence, interactive computer graphics, information retrieval, database management, switching theory, theory of computation, numerical analysis and software engineering.

The computer science master's degree program is specifically structured to enable the graduate to keep abreast of developments in the chosen discipline and to interact with other disciplines. Students may extend their studies into related areas such as operations research, mathematics, electrical engineering, management, statistics and economics, in accordance with individual interests.

Outstanding students are advised to apply for financial aid in the form of teaching fellowships or partial tuition remission.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE

Entrance Requirements—For entrance to the Master of Science degree programs, an undergraduate degree in computer science, mathematics, science or engineering, with a superior undergraduate record from an accredited institution, is required. Applicants having degrees in other fields will be considered for admission on an individual basis. Generally, entering students are expected to have a knowledge of mathematics through calculus. Additional entrance requirements for the two MS degree programs are as follows:

1. At least one year of university-level science;
2. A working knowledge of a higher-level programming language such as PL/I, ALGOL, Pascal, LISP, C, etc.;
3. A basic understanding of computer fundamentals such as computer organization and operations, data structures, assembly language programming, elements of logic and automata, computer architecture.

It is anticipated that entering students with BS degrees in computer science as well as students with degrees in technical areas from an accredited institution and strong minors in computer science will satisfy the entrance requirements for the MS degree programs.

Students having superior academic credentials but lacking sufficient background are admitted in conditional status pending satisfactory completion of additional preparatory courses as specified from undergraduate computer-science courses and/or from the series of six graduate orientation courses, CS 530, CS 540, CS 550, CS 560, CS 580, and CS 590. Successful completion of the preparatory courses with a B or better average grade in each course is a necessary condition for transfer to regular status.

The demonstrated ability to communicate in written and spoken English is an essential ingredient for success in pursuing graduate studies in computer science and information systems engineering and is required for regular status. Foreign students and others for whom English is a second language may be required to undertake preparatory work to improve their language skills before admission into the graduate program.

Admission with advanced standing is accepted in accordance with Polytechnic regulations published elsewhere in this catalog. A maximum of nine units may be applied to the MS degree for previous graduate work at an acceptable institution.

DEGREE REQUIREMENTS

To satisfy the requirements for the master's degree, the student must complete a total of 36 units as described below, with an overall average of B. In addition, a B average is required in specified groups of courses, as indicated below.

Students with a strong undergraduate computer science background may be allowed to replace required courses with more advanced electives. Permission of a graduate adviser is required.

MASTER OF SCIENCE (COMPUTER SCIENCE)

		UNITS
1. Core Requirements (B average required)		15
CS 603	Design and Analysis of Algorithms I	
CS 613	Computer Architecture I	
CS 623	Operating Systems I	
CS 637	Programming Languages	
CS 641	Compiler Design and Construction I	

2. One of the following three courses: 3
   CS 675   Theory of Computation
   MA 821   Numerical Analysis
   A course in modern algebra or other graduate-level mathematics course, as approved by an adviser.

3. Two one-year course sequences from the list: 6-12
   CS 603, CS 604   Design and Analysis of Algorithms I, II
   CS 606, CS 607   Software Engineering I, II
   CS 613, CS 614   Computer Architecture I, II
   CS 623, CS 624   Operating Systems I, II
   CS 641, CS 642   Compiler Design and Construction I, II
   CS 661, CS 662   Artificial Intelligence I, II
   or CS 665   Expert Systems & Knowledge Engineering
   CS 671, CS 672   Switching and Automata I, II

4. Approved elective courses of which a maximum of 6 units may be a thesis   6-12

Thesis - Exceptional students may elect to write a master's thesis, for which no more than 6 units may be earned toward the degree. Such students should find an appropriate adviser who has agreed to monitor the thesis research.

Such research need not be original, but should adequately demonstrate the student's proficiency in the subject material. A defense of the master's thesis with at least three professors in attendance is required.

MASTER OF SCIENCE (INFORMATION SYSTEMS ENGINEERING)

See separate section of catalog on Information Systems Engineering for this program.

REQUIREMENTS FOR THE DOCTOR'S DEGREE

Graduate students who have exhibited a high degree of scholastic proficiency and given evidence of ability for independent scholarly work may consider extending their goals toward the degree of doctor of philosophy. The requirements for admission to the program include the following:

1. A BS degree in science, engineering or management from an accredited school and a superior academic record.

2. An MS degree or one year of graduate work in an analytically-based area, and a superior academic record.

On admission to the program the student must submit for approval a plan of study consistent with the Ph.D. requirements shown below. Further details concerning procedure are contained in the "Guidance for Ph.D. Students" brochure available from the Division of Computer Science.

1. A mimimum of 90 units of graduate work beyond the BS degree, including 24 units of dissertation.

2. Qualitative rather than quantitative considerations will determine the final approval of the program of graduate study; however, the following should be included:

    a. The basic MS requirement in computer science;
    b. A major concentration in a computer science area;
    c. Supporting courses in noncomputer areas, for breadth;
    d. A minor concentration in an area other than computer science (a minimum of four courses).

Requirements b and c must be approved by the Division of Computer Science; requirement d must be approved by the Division of Computer Science or by a minor adviser.

3. Qualifying examinations consisting of four written examinations, generally covering topics corresponding to the MS requirements.

4. Presentation of an in-depth seminar talk on the subject of the dissertation, at such time as the thesis adviser deems appropriate.

5. Preparation and defense of a scholarly dissertation which embodies an original research contribution.

UNDERGRADUATE COURSES

Students are advised to consult the departmental *Undergraduate Student Manual* and the Schedule of Classes for changes in courses, course content and prerequisites in effect after publication of this catalog.

General Prerequisite: Students may not register for any junior- or senior-level courses until all freshmen requirements are completed.

CS 100 Introduction to Computer Programming 2:0:2
Introduction to computers to develop fundamental understanding of their use. Early use of computer permits immediate solutions to simple engineering problems. Development of more complex programming techniques for use in subsequent engineering and computer courses. FORTRAN language used. (Cannot be used to satisfy any degree requirements in computer science or in electrical engineering.)

CS 112 Programming in Pascal 3:0:3
Computers and programming; use of terminals; problem solving and program structure; control statements and procedures; data types. Functions. Arrays, records, sets and files. Recursion, searching and sorting. Pointers and dynamic data structures.

CS 204 Data Structures and Algorithms 3:0:3
Review of structured data types. Procedural and data abstraction. Stacks, queues. Sequential and linked representations. Recursion. Computational complexity. Trees, Graphs. Searching and sorting. Prerequisite: CS 112.

CS 205 Assembly Lanaguage and Systems Programming 3:0:3
Assembly language, machine language programming. Internal representation of numeric and character data. Assemblers and symbol tables. Stacks, subroutines and recursive programming. Macros. Position independent and re-entrant code. Introduction to linking and loading process. Traps and interrupts. Memory mapping. Prerequisite: CS 204.

CS 206 Compilers 3:0:3
Grammars, lexical analyses, parsing algorithms, intermediate languages, storage assignment, push-down stacks and run-time organizations. A large programming project is required. Prerequisite: CS 205.

CS 211 COBOL Programming 3:0:3
Computing using ANSI-COBOL for simple and complex business problems. Structured programming used throughout. Creating, using and updating sequential, indexed and relative data files on magnetic tapes and disks. Report writer and table handling modules in COBOL. Batch processing and time sharing processing. (Cannot be used to satisfy any degree requirements in computer science or in electrical engineering.)

CS 212 C, UNIX, and Software Development 3:0:3
Programming in C in the UNIX environment. Methodology of program design. Programming style, tools, environment, documentation. UNIX shell programming. Prerequisite: CS 112.

CS 236 Switching Theory and Logic Design 3:0:3
Introduction to concepts of switching theory and digital systems. Number representations, arithmetic operations, coding, Boolean algebra, combinational circuits, logical design, sequential machines, state diagrams/tables, clock mode and pulse mode systems, state reduction, machine synthesis. Prerequisite: CS 100 or CS 112 Recommended corequisite: PH 105 (PH 102).

COMPUTER SCIENCE

CS 237 Introduction to Computer Architecture 3:0:3

Introduction to machine language programming. Computer organization, arithmetic and logical operations, fixed and floating point systems. Registers, logical modules, memories, input-output devices. Introduction to a hardware specification language. Analysis of a complete digital computer employing hardwired and microprogrammed control. Prerequisite: CS 236. (Cannot get credit for both CS 237 and CS 337.) (Last offered Spring 1989.)

CS 238 Operating Systems 3:0:3

Overview of operating system facilities. Process structure, creation and context switching; system calls; process cooperation. Memory management in a multiprogramming environment; virtual memory. File structures and management. I/O management and interrupt handling. All concepts and facilities are illustrated by examining code for a small, real operating system. Prerequisites: CS 205 and either CS 237 or CS 337.

CS 240 Computer Music 3:0:3

Introduction to sound synthesis: frequency spectra, Fourier series and transforms, filtering, sampling, A/D and D/A conversion. Synthesis techniques: additive, subtractive, and FM synthesis; oscillators and envelope generators; computational requirements. Digital synthesizers and interfaces to microcomputers. Interactive composition languages; systems for sound file editing, mixing and playback. Control of musical microstructure; interaction via gesture; psychoacoustical effects. Composition on the Music II system. Prerequisites: MA 104, some knowledge of programming, interest in music.

CS 275 Theory of Computation

The concept of algorithms, foundational programming languages, computable functions, Godel numbering and Church's thesis, unsolvable programs, context-free grammars for formal languages, parsing, finite automata. Prerequisite: Junior standing and MA 341, or permission of instructor.

CS 296 Computer Laboratory I 2:3:2

A series of required experiments provides an introduction to small computers: digital and analog circuit techniques, small computer assembly language programming, minicomputer and microcomputer organization and operations. Lab fee required. Prerequisites: CS 205, CS 236; CS 237 or CS 337; EE 109 or EE 111 or EE 370 or EE 377; EE 195 or EE 374 or EE 377 lab.

CS 297 Computer Laboratory II 1:6:3

An introduction to the use of small computers as systems components: interrupt programming concepts, analog signal interfacing and real time, closed-loop systems. Independent learning and hands-on experience with different small computers are provided by projects involving such subjects as computer graphics, light intensity control and motor speed control. Lab fee required. May be used by EE majors as Senior Laboratory/Project. Replaces CS 299. Prerequisites: CS 296 or CS 298; CS 237 or CS 337; CS 205; for EE majors, all technical courses of the junior year.

CS 306 Software Design and Engineering 3:0:3

Introduces the techniques used to specify, design, test and document medium and large software systems. Design techniques include structured programming, defensive programming, program design language (PDL), and program complexity models. Path testing, exhaustive test models, and construction of test data. Software reliability models. Introduction to software tools and management techniques. Student term projects involve group software development. Prerequisite: CS 212.

CS 308 Introduction to Database Systems 3:0:3

The effective management and utilization of data. Objective of DBMS, data independence, integrity, security. Organization and access techniques, architecture, data definition and manipulation languages. Data models: hierarchical, network and relational structures. Practical applications of state-of-the-art techniques, foundations and underlying theories. Prerequisite: CS 204

CS 312 Principles of Programming Languages 3:0:3

Elucidation of principles and program styles associated with current conventional programming languages. Topics include lexical analysis; syntactical representation and analysis; processors; compilers, interpreters; data structures; control constructs; semantic considerations; distinctions among procedural, functional, and other language styles. Prerequisite: CS 212.

CS 316 Microprocessors 3:0:3

Block diagram description of the architecture of a typical microprocessor. Registers and ALU of the CPU. Interfacing components, bus structure, input-output techniques, priority interrupt schemes. Program techniques. Prerequisites: CS 205; CS 237 or CS 337

CS 337 Computer Architecture and Organization 3:0:3

Computer architecture: machine language instruction set design. Computer organization: logical modules, registers, memories, input/output devices. Arithmetic and logical operations, fixed and floating point systems. Introduction to a hardware description language. Design and analysis of a complete digital computer employing hardwired and microprogrammed control. Stack machines. Hierarchical memory organizations. Instruction lookahead and overlapping. Pipelining. Parallel computer systems. Prerequisites: CS 205 and CS 236.

CS 398 Senior Project in Computer Science 1:6:3

Term project. Several students work as a group with a staff member and graduate students on a topic of interest. Written report and presentation required. Prerequisite: CS 297 (or 299).

CS 480 Structure and Implementation of Computer Programs 3:0:3

Introduction to the Lisp language and compilation of Lisp programs. Data-directed programming, message passing style of programming, generic operators, streams. Introduction to logic programming. Storage management and garbage collection. Prerequisites: CS 205, CS 212, and CS 238.

ORIENTATION COURSES

The graduate courses listed in this section were formulated to accommodate the needs of students who wish to pursue graduate studies in computer science, but who lack sufficient undergraduate preparation. No credit will be allowed for any of these courses toward graduate degrees in computer science, information systems engineering or other degree programs administered by the Department of Electrical Engineering and Computer Science. Submission of substantial computer programming assignments is required in all these courses except CS 560.

CS 530 Introduction to Computer Science 2½:0:3

Computers and programming; use of terminals; problem solving and program structure; control statements and procedures; data types. Functions. Arrays, records, set and files. Recursion, searching and sorting. Pointers and dynamic data structures. Prerequisite: graduate status.

COMPUTER SCIENCE

CS 540 Data Structures and Algorithms 2½:0:3
Review of structured data types. Procedural and data abstraction. Stacks, queues. Sequential and linked representations. Recursion. Computational complexity. Trees. Graphs. Searching and sorting. Prerequisite: CS 530.

CS 550 Assembly Language and Systems Programming 2½:0:3
Assembly language, system organization. Internal representation of numeric and character data. Machine language programming; symbol tables and the assembler. Stacks, subroutines, recursion. Implementation of program environments, block structure. Position independent and re-entrant code. Linking, loading and memory mapping. I/O programming. Prerequisite: CS 530.

CS 560 Switching Theory and Logic Design 2½:0:3
Automata and switching theory, Boolean algebra, truth tables. Combinatorial circuits, logical design, gate realizations. Sequential machines, state diagrams/tables, state equivalence, machine synthesis. Prerequisite: graduate status.

CS 580 Computer Architecture and Organization 2½:0:3
Computer organization, arithmetic and logical operations, fixed and floating point systems. Registers, logical modules, memories, input/output devices. Introduction to a hardware specification language. Analysis of a complete digital computer employing hardwired and microprogrammed control. Stack machines. Instruction lookahead and overlapping. Pipelining. Prerequisites: CS 550 and CS 560.

CS 590 Introduction to Operating Systems 2½:0:3
Introduction to operating systems, memory management techniques, paging, virtual memory. Multiprogramming and time-sharing systems. Concurrency, interactive and real-time systems. Interrupts, file structures, and introduction to data bases; overview of practical systems for small and large machines. Prerequisites: CS 540, CS 550, and CS 580.

GRADUATE COURSES

Graduate courses in computer science are offered on each campus on a regular basis, annually, or in two-year or three-year cycles. The Computer Science Graduate Mailing, sent out to continuing students prior to each registration, contains the latest information on Selected Topics course offerings, curriculum and course revisions.

CS 531 Introduction to Digital Computing 2½:0:3
First course in computing concentrating on analysis of problems for computer solution. Organization of computers. Structure and properties of algorithms and programs, flow charting. Debugging and verification, documentation, data representation, numerical error analysis. FORTRAN IV language used. (No credit will be allowed toward graduate degrees in computer science, information systems engineering or other degree programs administered by the Department of Electrical Engineering and Computer Science.) Prerequisite: graduate status.

CS 603 Design and Analysis of Algorithms I 2½:0:3
Organization and processing of various types of information. Trees: traversals, scanning, heaps, binary search, height-balanced, B-trees. Tables: searches, hash, decision, symbol. Lists and strings. Advanced searching and sorting techniques. Prerequisite: CS 540.

CS 604 Design and Analysis of Algorithms II 2½:0:3
Analysis of computational complexity. Theory of NP-completeness and approaches to the exact and approximate solution of NP-complete problems. Linear and integer programming techniques. Dynamic programming. Combinatorial optimization. Prerequisite: CS 603.

CS 606 Software Engineering I 2½:0:3
Software development, modeling tools. Techniques: design estimation, testing, reliability, management. Design and analysis: top-down, modular structured. HIPO diagrams, cause-effect graphs. Probabilistic models: complexity, number of errors, exhaustive, regression. Management: costs, productivity, controls. Prerequisites: MA223 and one of the following: CS 603, CS 623, CS 641.

CS 607 Software Engineering II 2½:0:3
A continuation of material begun in CS 606 with emphasis on software development tools and the management of software projects including prediction, estimation, and control of software costs and program productivity. Students will be organized into project groups and will plan and design a software system using manual and computerized development tools. Class presentations, exams and term project. Prerequisite: CS 606.

CS 608 Principles of Database Systems 2½:0:3
Database management system overview. Data independence and abstraction. Physical database, organization, and access methods. Data models, entity relationships, network, hierarchical, and relational structures. Relational model design theory, functional multivalued dependencies, normalization, and query language optimization. Concurrent operation in centralized and distributed database systems. Prerequisite: CS 603.

CS 609 Information Analysis and System Design I 2½:0:3
Introduction to the system life cycles of a computer information system. System life cycle management. Basic analytic tools, determining system economics. Logical system design. Introduction to physical system design. Prerequisite: CS 530.

CS 610 Information Analysis and System Design II 2½:0:3
Basic design tools and objectives. Hardware/software selection and evaluation. Software design and software engineering. Database development. Program development. System development. Post-implementation analysis. Prerequisite: CS 609.

CS 613 Computer Architecture I 2½:0:3
CPU organization: control and arithmetic logic; bus interfaces and timing. Horizontal and vertical microprogrammed organizations. Instruction sets and data formats; interprocess synchronization; hardware/firmware/software trade-offs. Hardware organizations for support of virtual memory, high-level programming languages and operating system features. Knowledge of an assembly language is required. Prerequisite: CS 580.

CS 614 Computer Architecture II 2½:0:3
Further development of topics in machine organization and architecture. Memory hierarchies, virtual memory and cache memories. Pipelining. SIMD organizations; interconnection networks; parallelization of algorithms under various interconnection topologies. Systolic arrays; data flow organizations; MIMD organizations; performance evaluation considerations. Prerequisite: CS 613.

CS 616 Microprocessors 2½:0:3
Advanced microprocessor architectures and I/O techniques including multiprocessor systems, memory management, and real-time considerations. VLSI implementation, bit-slice microprogrammed systems. Prerequisite: CS 613.

CS 623 Operating Systems I   2½:0:3
Process management: process creation and switching; process synchronization and communication via semaphores, monitors and message passing; concurrent programming. Memory management: memory mapping and virtual memory architectures, I/O and file management. Deadlock detection, avoidance and recovery mechanisms. Prerequisite: CS 590.

CS 624 Operating Systems II   2½:0:3
Continuation of CS 623. Overall organization of multiprogramming operating systems, processor and management (scheduling), deadlock detention and avoidance, file system management. Prerequisite: CS 623.

CS 627 Performance Evaluation of Computer Systems   2½:0:3
Modeling and performance analysis of computer systems. Introdution to queuing network models and elements of queueing analysis. Exact and approximate analytic techniques, simulation and operational analysis. Examples in modeling multiprogramming operating systems, interactive systems, and flow control in computer networks. Prerequisite: EL 531 or MA 223 and instructor's permission.

CS 630 Input and Output Systems   2½:0:3
The theory, technique and technology of interaction between electronic digital information systems and the external environment from a systems perspective. Models of text, speech, and images useful for systems studies. The processes and devices to convert between text, speech, and image representations of information and electronic digital information systems. Prerequisite: CS 530.

CS 633 Information Retrieval and Natural Language Processing   2½:0:3
Characteristics of information retrieval systems. Search strategies, file organization, generalized database design. Automatic text processing methods. Automatic dictionary and thesaurus construction. Statistical and syntactic language analysis, automatic content analysis. Automatic information dissemination systems. Automatic question-answering systems. Examples and evaluation of information retrieval systems. Prerequisite: CS 603.

CS 637 Programming Languages   2:0:3
The structures, notations, and semantics of conventional programming languages. Introduction to analysis and design of user-oriented application languages. Advanced concepts of input and output. Prerequisites: CS 540 and CS 550.

CS 641 Compiler Design and Construction I   2½:0:3
Organization of compiler, symbol table organization, lexical analysis, syntax analysis, object code generation, introduction to code optimization techniques. Internal representations of parsed source program, Polish notation, triples, trees. Translation of arithmetic expressions and programming constructs. Prerequisites: CS 540, CS 550, and CS 560.

CS 642 Compiler Design and Construction II   2½:0:3
Further considerations of code optimization techniques. Formal languages and grammars. Introduction to translator systems. Prerequisite: CS 641.

CS 653 Interactive Computer Graphics   2½:0:3
Problems and objectives of interactive computer graphics. Interactive display devices and input devices. Transformations, construction of display file, and graphics languages. Windowing, perspective projection, hidden-line problems and shading. Curved surface generation. Prerequisites: CS 603 and CS 613.

CS 661 Artificial Intelligence I   2½:0:3
Automation of intellectual processes. Nature of machine intelligence and its limitations. Descriptions of cognitive processes. Heuristic vs. algorithmic methods of problem solutions and question-answering systems. Game-playing programs. Formula manipulation, symbolic integration, automation of programming. General problem solvers. Introduction to pattern recognition.

CS 662 Artificial Intelligence II   2½:0:3
Further study of automation of intellectual processes. Automatic theorem proving. Expert systems. Simulation of verbal learning behavior. Learning machines, adaptive systems, robots, decision-making problems. Adequacy of existing theoretical treatments. Prerequisite: CS 661.

CS 665 Expert Systems and Knowledge Engineering 2½:0:3
The purpose of an expert system is to disseminate the knowledge acquired by experts in their area to users using artificial intelligence techniques. The knowledge is formalized using various knowledge representation schema. This course will introduce students to various types of knowledge and their representation. The inference procedures, architecture and control used in expert systems will be discussed. An introduction to the rule-based programming language OPS5 will be given and a prototype expert system term project will be built based on it. Prerequisite: CS 661.

CS 671 Switching and Automata I   2½:0:3
Analysis and synthesis of combinational and sequential switching circuits. Boolean algebras, switching functions, minimization, single and multiple output networks, realization of functions. Finite-state sequential machines, state-transition diagrams, machine and state equivalence, incompletely specified machines, state reduction, machine realizations. Prerequisite: CS 560.

CS 672 Switching and Automata II   2½:0:3
Further development of theory of finite-state machines. State assignments, partitions with substitution property and partition pairs, machine decompositions, shift-register realizations, regular expressions, linear machines, information conservation, diagnosing and homing experiments, machine identification and testing. Prerequisite: CS 671.

CS 673 Formal Languages and Automata Theory   2½:0:3
Introduction to generative grammars, characteristics of regular, context-free, context-sensitive and type-zero grammars. Relationships between languages and machines. Finite-state machines, pushdown automata, Turing machines. The halting problem, solvable and unsolvable linguistic questions. Prerequsitie: CS 671.

CS 675 Theory of Computation   2½:0:3
Aspects of mathematical logic with emphasis on applications to computing machines. The Resolution Principle as applied to propositional and first-order logic. Theorem proving. Correctness of programs. Applications to computer architecture, algorithms, compilers, languages. Measures of program complexity. Prerequisites: CS 560, CS 580, CS 590 and mathematical maturity.

CS 676 Mathematical Techniques for Information Systems   2½:0:3
Basic results from queueing theory, data structures and graphs and network flows. Poisson processes, M/M/1, M/G/1 queues. Queueing networks. Linked lists, sorting, searching, dynamic storage management. Graphs and network flows, spanning trees; algorithmic complexity, linear programming, network flows, min-cut max-flow. Prerequisites: regular graduate status, EL 531, and MA 103.

CS 681   Information, Privacy and Security   2½:0:3
Introduction to security and privacy issues associated with information systems. Cost/risk tradeoffs. Technical, physical, and administrative methods of providing security. Control of access through technical and physical means. Identification and authentication. Encryption, including the Date Encryption Standard (DES) and public key systems. Management of encryption systems, including key protection and distribution. Privacy legislation and technical means of providing privacy. Prerequisite: graduate status.

**CS 901-912   Selected Topics in
Computer Science**   each 2½:0:3
Topics of current interest in computer science. Recent offerings include computer-aided design, fault-tolerant computing, automation techniques, software economics, parallel processing program methodology. Specific topics announced in advance. (See computer science graduate mailing for detailed description of each particular offering.) Prerequisite: specified when offered.

Courses in Selected Topics bearing the same numbers may be repeated for credit provided the topics are different, subject to adviser's approval.

**CS 941-942   Readings in Computer
Science I, II**   each 2½:0:3
Intended primarily for students who wish to study in a specialized area under the supervision of a faculty member. Courses are open only in unusual cases to outstanding students who have completed at least 30 credits of graduate study and who are available for weekly consultation with an adviser. An examination or term report is required. Prerequisite: regular status and permission of director of division.

**CS 996   Advanced Project in
Computer Science**   2½:0:3
This course permits the student to perform research in computer science somewhat less in scope than a master's thesis. The acceptance of a student by a faculty adviser is required before registration. An oral examination on the project report is required. Prerequisite: regular status.

**CS 997   Thesis for Degree of
Master of Science**   each 3 units
Exceptional students may elect to write a master's thesis for which no more than six units may be earned toward the degree. Such research should adequately demonstrate the student's proficiency in the subject material. Oral thesis defense with at least three professors in attendance plus a formal, bound thesis volume are required. Thesis registration must be continuous. Prerequisite: regular status and satisfactory grades in prescribed courses.

**CS 999   Dissertation for Degree of
Doctor of Philosophy**   each 3 units
Original investigation of computer science problem. Must demonstrate creativity and include features of originality and utility worthy of publication in a recognized journal. Candidate must successfully defend dissertation orally. Registration of 24 units required (continuous dissertation registration required). Prerequisite: passing of qualifying examination and approval of the computer science division.

FACULTY

Donald Hockney, Professor of Computer Science and Director of the Division of Computer Science
B.A., McMaster University; Ph.D., Cornell University
Logic, data base systems

Ivan T. Frisch, Professor of Electrical Engineering and Computer Science and Director of the Center for Advanced Technology in Telecommunications
B.S. (Physics), Queens College; B.S. (EE), M.S. (EE), Ph.D. (EE), Columbia University
Information systems, computer networks and network control

Aaron Kershenbaum, Professor of Computer Science
B.S., M.S., Polytechnic Institute of Brooklyn; Ph.D., Polytechnic Institute of New York
Computer communications, algorithms

Melvin Klerer, Professor of Computer Science
B.A., M.S., Ph.D., New York University
Programming systems, languages, and artificial intelligence

Arthur E. Laemmel, Professor of Electrical Engineering and Computer Science
B.E.E., Polytechnic Institute of Brooklyn
Computer architecture, coding, digital circuits

James T. LaTourrette, Professor of Electrical Engineering and Computer Science
B.S., California Institute of Technology; M.A., Ph.D., Harvard University
Quantum electronics; computer software

Paul F. Pickel, Professor of Mathematics and Computer Science
B.A. (Chemistry), Ph.D. (Math), Rice University
Mathematical programming, computer graphics, artificial intelligence

Stanley Preiser, Professor of Mathematics and Computer Science
B.S., City College of New York; M.S., Ph.D., New York University
Numerical analysis, theory of computation, applied mathematics, software engineering

Henry Ruston, Professor of Electrical Engineering and Computer Science
B.S.E. (Math), B.S.E. (EE), Ph.D., University of Michigan; M.S., Columbia University
Software engineering, programming, circuit theory

Martin L. Shooman, Professor of Electrical Engineering and Computer Science
S.B., S.M., Massachusetts Institute of Technology; D.E.E., Polytechnic Institute of Brooklyn
Software engineering, system reliability and safety

Richard Van Slyke, Professor of Electrical Engineering and Computer Science and Director of the Center for Advanced Technology in Telecommunications
B.S., Stanford University; Ph.D., University of California (Berkeley)
Computer communications, telecommunications

Roy S. Freedman, Associate Professor of Computer Science
B.S., M.S. (EE), M.S. (Math), Ph.D., Polytechnic Institute of New York
Artificial intelligence, expert systems

Andrew S. Noetzel, Associate Professor of Computer Science
B.E.E., City College of New York, Ph.D., University of Pennsylvania
Computer architecture, neural networks, operating systems, signal processing, computer music

Phyllis Frankl, Assistant Professior of Computer Science
B.A., Brandeis University; M.A. (Math), Columbia University; M.S. (CS), Ph.D., New York University
Software Engineering, theory of computation

Gad M. Landau, Assistant Professor of Computer Science
B.Sc. (Math, CS), M.S., Ph.D., Tel-Aviv University (Israel)
Algorithms

Michael J. Post, Assistant Professor of Computer Science
A.B., Columbia University; M.S., Ph.D., Polytechnic Institute of New York
Coding theory, operating systems, high-level architecture

Edward Kin-Ming Wong, Assistant Professor of Computer Science and Electrical Engineering
B.E. (EE), SUNY, Stony Brook; Sc.M. (EE), Brown University; Ph.D. (EE), Purdue University
Artificial intelligence, robotics

Linda Anne Grieco, Coordinator of Advising
B.A. (Math), Hofstra University; M.S. (CS) Polytechnic Institute of New York; Ph.D. (Math), Rutgers University
Programming and computer software

Witold Holubowicz, Visiting Professor of Computer Science
M.Sc. (EE), Ph.D. (EE), Technical University of Poznan (Poland)
Digital transmission techniques, communication theory, microprocessors

Kenneth R. Aupperle, Academic Associate in Computer Science
B.S., M.S., Polytechnic Institute of New York
Microprocessor architecture

Marian Corcoran, Academic Associate in Computer Science
B.A. (Phil), Long Island University; M.S. (CS), Polytechnic Institute of New York
Artifical intelligence, machine learning

Haldun Hadimioglu, Academic Associate in Computer Science
B.S.(EE), M.S.(EE), Middle East Technical University, (Turkey)
Concurrent computer systems, computer architecture and design, parallel computation, distributed operating systems

Hong Liu, Academic Associate in Computer Science
B.S., M.S. Hefei Polytechnical Unversity (People's Republic of China)
Compilers, optimization, network algorithms, computer graphics

Philippe Poisson, Academic Associate in Computer Science
Dipl.(EE) de l'Ecole Supérieure de Technologie Electrique (France); M.S., Polytechnic University
Compilers, programming languages

INDUSTRY PROFESSORS

Robert J. Flynn, Industry Professor of Computer Science
B.S. (Physics), Manhattan College; M.S. (Math), Ph.D. (Math), Polytechnic Institute of Brooklyn
Computer architecture, operating systems

Barry Jones, Industry Professor of Electrical Engineering and Computer Science
B.S. (EE), Cooper Union; M.S. (EE), Marist College
Electromechanical systems, real-time computer systems

Jack Machanik, Industry Professor and Director of the Center for Digital Systems
B.Sc. (Engr.), University of Witwatersrand (South Africa); M.S.E.E., Stanford University
Fault-tolerant architectures, distributed processing, system integration methodology

Joel B. Snyder, Industry Professor of Electrical Engineering and Computer Science
B.E.E., M.E.E., Polytechnic Institute of Brooklyn; P.E. (New York and Massachusetts)
Microprocessor systems, data acquisition and transmission, signal processing

Alexander A. Stepanov, Industry Professor of Computer Science
B.S., Moscow State University (U.S.S.R.); M.S., Moscow Institute of Education (U.S.S.R.)
Logic, artifical intelligence

ADJUNCT FACULTY

Maurice Karnaugh, Distinguished Adjunct Professor
B.S., City College of New York; M.S., Ph.D., Yale University

Ruven Brooks, Adjunct Professor
B.A., University of Michigan; M.S., Ph.D., (Psychology), Carnegie-Mellon University

Vincent Celeste, Adjunct Professor
B.S., (Physics), M.S. (Math), Ph.D. (Math), Polytechnic Institute of New York

David R. Doucette, Adjunct Professor
B.S., M.S., Ph.D., Polytechnic Institute of Brooklyn

Barry V. Gordon, Adjunct Professor
B.E.E., M.E.E., New York University

James H. Griesmer, Adjunct Professor
B.S. (Math), University of Notre Dame; Ph.D. (Math), Princeton University

Fred Grossman, Adjunct Professor
B.S. (Math), Polytechnic Institute of Brooklyn; M.S.(Math), Ph.D.(CS), New York University

Lewis Herzberg, Adjunct Professor
B.E.E., City College of New York; M.S., Ph.D., Polytechnic Institute of Brooklyn

COMPUTER SCIENCE

Edward Lancevich, Adjunct Professor
B.E.E., City College of New York, CUNY; M.S. (EE),
Columbia University; Ph.D. (EE), Polytechnic Institute of
New York

John P. O'Donohue, Adjunct Professor
B.E.E., Polytechnic Institute of Brooklyn; M.S.E., Union
College (Schenectady)

Dimitris A. Protopapas, Adjunct Professor
B.Sc., University of Athens (Greece); M.S. E.E., University of
Toronto (Canada); Ph.D., Polytechnic Institute of New York

Walter Vasilaky, Adjunct Professor
B.A., Rutgers University; M.A., University of Maryland;
Ph.D., New York University

Arthur Appel, Adjunct Associate Professor
B.M.E., M.M.E., City College of New York

Chidanand Apte, Adjunct Associate Professor
B. Tech. (EE) Indian Institute of Technology (Bombay, India);
M.S., Ph.D. (CS) Rutgers University

Charles J. Bontempo, Adjunct Associate Professor
B.S., M.S., University of Maryland

William Edelson, Adjunct Associate Professor
B.E.E., City College of New York, M.S., New York University;
Ph.D., Polytechnic Institute of New York

Donna Nagel, Adjunct Associate Professor
B.S., University of California (Irvine); M.S., Ph.D., Rutgers
University

Wang-Chuan Tsai, Adjunct Associate Professor
B.S., M.S., National Chiao-Tung University (Taiwan); Ph.D.,
University of Illinois

Paul Friedland, Adjunct Assistant Professor
B.S. (Math), M.S. (CS), Pennsylvania State University
Computer software, database systems

Bruce Martin, Adjunct Assistant Professor
B.S. (Applied Math), Polytechnic Institute of Brooklyn

Eleanor Boekman, Lecturer
B.S., New York University; M.S., Polytechnic Institute of
New York

Philip S. Brown, Lecturer
B.S., City College of New York; M.S., Engineer, Polytechnic
Institute of New York

William Chuang, Lecturer
B.S., Chung-Yun College (Taiwan); M.S., Ph.D., Polytechnic
Institute of New York

Joanne Di Marco, Lecturer
B.A. (Education), Queens College, CUNY; M.A. (Math),
SUNY, Stony Brook

Daniel Gill, Lecturer
B.A., New York University; M.S., Polytechnic Institute of
New York

Gennady Gorelik, Lecturer
B.A., M.S., New York University

Richard Gucciardo, Lecturer
B.E.E., SUNY, (Buffalo); M.B.A., New York Institute of
Technology

Amine G. Kandalaft, Lecturer
B.S., M.S., Polytechnic Institute of New York

Winston Park, Lecturer
B.S.E.E., Pratt Institute; M.S., Polytechnic Institute of New
York

Clement R. Pizzo, Lecturer
B.S., West Virginia Institute of Technology; M.S. (EE),
Engineer, Polytechnic Institute of New York

Jonathan Shopiro, Lecturer
B.A. (Math), M.A. (Math), Ph.D., University of Rochester

Fred Strauss, Lecturer
B.S., Arizona State University; M.S., Polytechnic Institute of
New York

David C. Willen, Lecturer
B.S., M.S., Polytechnic Institute of New York

RETIRED FACULTY

Edward J. Smith, Professor of Electrical Engineering
B.E.E., Cooper Union; M.E.E., D.E.E., Polytechnic Institute
of Brooklyn
Computer organization, switching and automata

CONTEMPORARY LIBERAL ARTS CORE CURRICULUM

The liberal arts have traditionally been associated with education for liberty or freedom.

In a world permeated by modern science and technology, individuals who fail to understand the basic character of scientific and technological thought and action are unable to exercise full human freedom.

Recognizing the need for education integrating science, technology and society (STS) studies, Polytechnic University has developed a unique program. This program constitutes a new vision of the liberal arts.

At the heart of this program is the Contemporary Liberal Arts Core Curriculum. Developed through a grant from the Andrew W. Mellon Foundation, the curriculum consists of a sequence of 48 semester credit hours. The sequence opens with a general presentation of the science-technology-society interaction and then moves on to three different sets of courses:

1. Basic introductions to mathematics, computers, and the physical, biological, and behavioral sciences.

2. Interdisciplinary courses in ethics and technology and STS interactions in the areas of materials, machines, energy, and information.

3. A senior seminar and thesis.

Besides this sequence, the Core Curriculum assumes the general University requirements of six credit of writing and the humanities, three credits of contemporary world history, and four semesters of physical education.

This core curriculum is based on the idea that a well-educated liberal arts graduate should be able to understand creativity from the fine arts to technology, and be able to appreciate the poetics of artificial as well as natural languages.

Students majoring in other disciplines are able to take the following courses from this curriculum to satisfy humanities and social science elective requirements:

LA 110   Technology and Society in Historical Perspective
LA 132   Introduction to Behavioral Science
LA 140   Ethics and Technology
LA 141   Materials and Social Issues
LA 142   The Cultures of Machines
LA 143   Computers, Cultures, and Society
LA 144   Energy Technology and Social Issues
LA 150   The Making of Connections

Typical Course of Study for the Bachelor of Science Degree in Humanities, Specialized Journalism, or Social Sciences

Freshman Year

No.		Subject	Credits
HU	101	Writing and the Humanities I	3
SS	104*	Main Themes in Contemporary World History	3
LA	110	Technology and Society in Historical Perspective	3
LA	120	Principles of Mathematics I	4
LA	125	Introduction to Computers	3
SL	101	Student Survival	0
PE	101	Physical Education I	0
			16

No.		Subject	Credits
HU	200*	Writing and the Humanities II	3
LA	121	Principles of Mathematics II	4
LA	130	Introduction to Physical Science	4
PE	102	Physical Education II	0
CS	or EL*		6
			17

Sophomore Year

LA	132	Introduction to Behavioral Science	4
PE	103	Physical Education III	0
CS	or EL*		12
			16

LA	131	Introduction to Biological Science	4
LA	140	Ethics and Technology	3
PE	104	Physical Education IV	0
CS	or EL*		9
			16

CONTEMPORARY LIBERAL ARTS CORE CURRICULUM

Junior Year

LA	141	Materials and Social Issues	3	LA	143	Computers, Cultures, and
LA	142	The Cultures of Machines	3			Society
CS		or EL*	9	LA	144	Energy Technology and Social

LA 141 Materials and Social Issues 3
LA 142 The Cultures of Machines 3
CS or EL* 9
15

LA 143 Computers, Cultures, and Society 3
LA 144 Energy Technology and Social Issues 3
CS or EL* 9
15

Senior Year

LA 150 The Making of Connections 3
CS or EL* 12
15

LA 160 Senior Seminar and Thesis 4
CS or EL* 12
16

*CS = Concentrated studies in major; EL = electives

Summary of Requirements

Institute requirements (HU 101, HU200*, SS104*)	9
Liberal arts core	48
Concentrated studies	33-42
Electives	
Humanities	6
Social Science	6
Free electives**	15-24
Total credits for graduation	126

*Students may elect to take IS 140 (Language and Communication) and IS 141 (The Self and Society) in place of HU 200 and SS 104.

**Students may elect to minor in a discipline other than their major. A minor may be in such fields as Information Management (12 credits), Computer Science (12 credits) or Life Sciences (14 credits).

COURSES

LA 110 Technology and Society in Historical Perspective 3:0:3
An examination of the role of secular and religious ideas in shaping technology, and the subsequent impact of technology on events and values. Psychological profiles of inventors and innovators. Invention, innovation, and diffusion of technology. The impact of the assembly line, telecommunications, computers, plastics, television and rockets. Emerging trends: miniaturization, robotics, biotechnology and space industrialization.

LA 120-121 Principles of Mathematics I & II each 4:0:4
An introduction to the principles of finite mathematics and calculus. Focus is on the mathematical concepts of the number system, units, integration, probability, statistics, derivatives, and matrices.

LA 125 Introduction to Computers 2:3:3
Introduction to the basic principles of computer and information processing for non-technical students. Survey of operating systems and programming languages. Heavy emphasis on personal computer applications for the liberal arts: application packages in word processing, database management, spreadsheets, communications, and graphics.

LA 130 Introduction to Physical Science 4:0:4
This course is designed to convey the excitement of the human experience called "physical science," and its connections with the issues that concern all men and women — the impact of science on technology and civilization, culture, and worldviews. Topics include: space-time, motion and force, work and energy, states of matter, the microscopic and macroscopic approach in the science of chemistry. Experiments are conducted at the discretion of the instructor.

LA 131 Introduction to Biological Science 3:3:4
An investigation of the origin of life and the characteristics of living things. Studies include an examination of evolution and its mechanisms which have resulted in the ecological diversity of the biosphere. Considers the effects of technology on ecology. Laboratory experiments and field trips are used to further elucidate these concepts.

LA 132 Introduction to Behavioral Science 3:3:4
An examination of psychological concepts and methodologies central to understanding behavior. Topics: sensation and perception, acquisition and maintenance of behavior, social behavior, abnormal behavior. Students conduct experiments in signal detection, verbal learning, and social conditioning of judgments.

LA 139 Engineering Ethics 2:0:2
An introduction to professional engineering ethics presented through the history of engineering, codes of conduct of the professional societies, contemporary case studies, and discussion of hypothetical situations. No essential duplication of HU 347 or IE 302. Prerequisites: HU 200 or IS 140; completion of at least 40 credits.

LA 140 Ethics and Technology 3:0:3
An examination of some basic ethical theories of human action and how these relate to technological making and using. Use is made of case studies representing various ethical problems as well as some classic ethical texts. Includes issues of professional engineering ethics.

LA 141 Materials and Social Issues 3:0:3
An examination of the origins, properties and uses of metals, polymers, and other materials. New frontiers in the development of materials. The impact of materials on contemporary society. Laboratory demonstrations throughout the course.

LA 142 The Cultures of Machines 3:0:3
An examination of machines in both their technical and human aspects. An analysis of work and power, and the use of machinery to duplicate and extend human dexterity and skill. Discussion of the human aspects includes the relation between machines and different social orders, and humanization vs. dehumanization by machines.

LA 143 Computers, Cultures and Society 3:0:3
Explores the nature of information, communications and their associated systems and technologies; introduction to information theory and information processing; cultural, economic, and political implications of the communications-computer revolutions.

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LA 144   Energy Technology and Social Issues   **3:0:3**
An integrated study of energy technologies and resources, their contemporary problems and future prospects. Review of basic physical principles; history of energy resources and technologies; contemporary energy technologies, with the social and ethical problems they pose; alternative technologies and social prospects for the future.

LA 150   The Making of Connections   **3:0:3**
An interdisciplinary seminar devoted to examining basic issues introduced by previous courses: questions concerning the relationships between machines and human nature, freedom and the individual in a technological society, science-technology and the imagination, social justice and technological limits. Explores probable futures and alternative social policies in light of rapid scientific and technological change. For each offering, the specific focus of this seminar is determined by the instructor.

**LA 160   Senior Seminar and
               Thesis**   **4:0:4**
An individual research project culminating in a substantial paper. Subject to be chosen by student in consultation with a thesis adviser.

FACULTY

William Blesser, Professor and Director of Bioengineering

George Bugliarello, President and Professor of Civil Engineering and Bioengineering

Edward Cassedy, Professor of Electrical Engineering

Carmine D'Antonio, Professor of Metallurgy

Duane DeVries, Head of Humanities & Communications and Associate Professor of English

Frederick Eirich, Distinguished Professor of Polymer Chemistry

Donald Hockney, Head of Computer Science and Professor of Computer Science and Humanities and Communications.

Pamela E. Kramer, Head of Social Sciences and Associate Professor of Psychology

Burton Lieberman, Associate Professor of Mathematics

Ernest M. Loebl, Professor of Physical Chemistry

Carl Mitcham, Director of Philosophy & Technology Studies Center and Associate Professor of Humanities

Shirley Motzkin, Professor of Biology

Jane Robinett, Assistant Professor of Humanities and Communications

Kurt Salzinger, Professor of Psychology

A. George Schillinger, Professor of Management and Operations Research

Romualdas Sviedrys, Associate Professor of History of Technology

COOPERATIVE EDUCATION PROGRAM

The Cooperative Education (Co-op) Program provides students with practical work experience in industry, government and public service agencies.

Co-op is normally a five year undergraduate program which enables students to combine the required number of classroom credits with approximately 20-24 months of work experience. The first and fifth years are spent on campus during the normal September to May academic schedule, while the middle years, including summers, are devoted to alternating periods of training in industry and study on campus.

For graduate students and undergraduate transfer students, the length of the program and sequence of alternation is determined through faculty recommendation.

Students accepted into the program start interviewing with participating Co-op companies during the semester prior to the first scheduled work period. The Cooperative Education Office is responsible for setting up interviews. In most cases, interviews determine whether students are hired as Co-op employees.

Co-op students will be given work directly related to their career goals and levels of academic experience. Student employees are paid salaries based on their experience and academic level.

The Cooperative Education Program is optional. Students participating in the program for at least three co-op field experiences receive co-op certificates upon graduation.

ELIGIBILITY

Before being given the initial Co-op work assignment, students must:

- Achieve and maintain a 2.5 grade point average;
- Complete at least 30 credits of academic work with no course deficiencies. These credits must include at least one technical course related to their major field.
- Participate in specialized Co-op seminars in career development (CP 101) and Technical Communications (CP 102); (Satisfactory completion of these seminars is required of all freshmen and sophomores before their first work assignment)
- Obtain advisor approval for program participation.

Transfer students are required to:

- Complete one semester of study at Polytechnic University before beginning their first work period;
- Attend one semester of the required Co-op seminar, either CP 101 or CP 102;
- Achieve a 2.5 grade point average;
- Obtain departmental approval for program participation.

Graduate students are eligible for participation at any time after scheduling work periods with their faculty adviser.

CO-OP SEMINARS

Co-op pre-employment seminars prepare students for entry into professional environments and are a pre-requisite to participation in the work experience sequence.

CP 101 examines methods of discovering fields which are most fulfilling. Topics include techniques of resume writing; interviewing; making contact with prospective employers; planning for advancement; and other issues which help to bridge the gap between education and work.

CP 102 assists students in the development of skills and the practice of oral and written communication. Rudiments of technical report writing and public speaking are presented.

CO-OP FIELD EXPERIENCES

Students entering industrial assignments after the freshman year normally complete five field experience courses, CP 201 through CP 401; students entering after the sophomore year might complete only three field experience courses. Types, complexities and challenges of field assignments vary depending on the student's academic preparation, ability, and interest. The initial field experience (CP 201) usually serves as an introduction to the technical work environment. Students are assigned work under supervisors, who are usually senior staff professionals. As students progress through subsequent field assignments, more complex tasks and duties are added.

COURSES

CP 101	Cooperative Education Seminar I Career Development	1:0:NC
CP 102	Cooperative Education Seminar II Technical Communication	1:0:NC
CP 201	First Co-op Field Assignment Prerequisite: CP 101, CP 102 or departmental approval	0:6:NC
CP 202	Second Co-op Field Assignment Prerequisite: CP 201	0:6:NC
CP 301	Third Co-op Field Assignment Prerequisite: CP 202	0:6:NC
CP 302	Fourth Co-op Field Assignment Prerequisite: CP 301	0:6:NC
CP 401	Fifth Co-op Field Assignment Prerequisite: CP 302	0:6:NC

Grades of (S) "satisfactory" or (U) "unsatisfactory" are recorded upon completion of each course. Courses will not

be computed in the grade point average (G.P.A.). These grades are based upon final reports and work evaluations written by students and evaluations submitted by supervisors.

Nominal registration fees are charged for each field assignment.

COORDINATORS

Ellen E. Dressner, Director of Student Development Programs
B.A., Queens College; M.S., St. John's University

Jeanette Grill, Assistant Director, Career Services and Cooperative Education, Long Island Campus.
B.A., Molloy College

Kathleen L. Kennedy, Assistant Director, Career Services and Cooperative Education.
B.S. Univ. of Dayton; M.S. Wright State University

Althea Foster, Coordinator of Job Development Program
B.S., Polytechnic University

ELECTRICAL ENGINEERING

The Department of Electrical Engineering and Computer Science administers a variety of degree programs summarized in the table below. From its beginnings in the 1880's the department has enjoyed national and international reputation based on the accomplishments of its alumni, on the research achievements of students and faculty, and on the textbooks written by faculty and alumni. This reputation has been confirmed periodically by surveys of members of the profession; the latest, the 1987 Gourman Report shows Polytechnic EE programs as best in the New York City area and high nationally, 12th for B.S. and 13th for M.S. The most recent American Society for Engineering Education list has the PhD (EE) 10th nationally, out of over 200 Electrical Engineering degree programs in the United States.

This section of the catalog describes the programs and courses in electrical engineering. Graduate programs in electrophysics and in system engineering are described in the appropriate catalog sections; however, the courses for these two programs (except for thesis) are located in the electrical engineering section. Programs and courses in computer science, and the graduate program in information systems engineering, are described in other sections of the catalog. The departmental faculty also participates in the graduate programs in energy, imaging sciences, and telecommunications management, described elsewhere in the catalog.

Degree Programs Administered by
the Department of Electrical Engineering
and Computer Science

UNDERGRADUATE

Electrical Engineering
Bachelor of Science

Computer Science
Bachelor of Science

GRADUATE

Electrical Engineering
Master of Science
Electrical Engineer
Doctor of Philosophy

Electrophysics
Master of Science
Doctor of Philosophy

Computer Science
Master of Science
Doctor of Philosophy

System Engineering
Master of Science
System Engineer
Doctor of Philosophy

**Information Systems
Engineering**
Master of Science

THE ELECTRICAL ENGINEERING PROFESSION

Electrical engineering is a rapidly growing profession which has evolved from its early beginnings in electric power generation and distribution through the development of radio to television and computers. More recently, it has contributed to man's pleasure, safety and health with automatic systems and devices used daily in medical and health care, high-speed transportation and satellite communication.

While undergraduate and graduate programs in electrical engineering are designed primarily to develop talents in these areas, graduates eventually apply their training to such diversified fields as bioengineering, city planning, astronautics, radio astronomy, system engineering, management and patent law. As students mature and realize their abilities, their professional lives may center on engineering, government, sales or education.

The electrical engineering faculty at Polytechnic covers a wide range of fields. Principal areas of teaching and research are micro-electronic devices and systems; computer engineering and computer science; telecommunications; speech and image processing; electro-optics and electro-acoustics; microwave engineering; power systems and energy conversion; plasma science and engineering; system and control engineering; quantum electronics; and materials science.

UNDERGRADUATE PROGRAM

The program for the degree of bachelor of science in electrical engineering gives students broad-based preparation for a career in electrical engineering in any of its specializations, and readies them for immediate employment in industry, business, and government, or for further graduate education. The program (both campuses), is accredited by the Accreditation Board for Engineering and Technology (ABET), on which the Institute of Electrical and Electronics Engineers (IEEE) is a participant.

Curriculum of Study for the Bachelor of Science Degree in Electrical Engineering (for Freshmen entering in 1988)

Freshman Year
Fall

First Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
CS	112	Programming in Pascal[9]	3	0	3
MA	101	Calculus I (or MA 100)[1][9]	4	0	4
CM	101	General Chemistry I[6]	2½	0	2½
CM	111	General Chemistry Lab I[6]	0	1½	½
HU	101	Writing&Human I (or HU 103)[2][4][9]	3	0	3
SS	104	Contemporary World History[2][3][4][5]	3	0	3
SL	101	Student Survival[13]	0	1	0
PE	10x	Physical Education[8]	0	2	0
CP	101	Coop Education I[7] (optional)	1	0	0
					16

Spring

Second Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
CS	204	Data Structure & Algorithms	3	0	3
MA	102	Calculus II (or MA 110)[1][9]	4	0	4
CM	103	Chemistry for Engineers	1½	0	1½
CM	113	Chem for Engineers Lab	0	1½	½
HU	200	Writing&Humanities II[2][3][4]	3	0	3
HU	119	Public Speaking (or HU 120)[2][4][5]	1½	1½	2
PH	104	Introductory Physics I[9]	3	0	3
PE	10x	Physical Education[8]	0	2	0
CP	102	Coop Education II[7] (optional)	1	0	0
					17

Sophomore Year
Fall

EE	101	Electric Circuits I[9]	3	0	3
CS	236	Switching Theory & Logic Design[9]	3	0	3
MA	104	Appl Differential Eqns	3	0	3
PH	105	Introductory Physics II[9]	3½	0	3½
PH	115	Physics Laboratory I	0	1½	½
HU	110	Report Writing I[4][5]	3	0	3
EE	193	Sophomore EE Lab I	½	1½	1
PE	10x	Physical Education[8]	0	2	0
					17

Spring

EE	102	Electric Circuits II[9]	3	0	3
CS	205	Assembly & Machine Lang	3	0	3
MA	103	Calculus III	3	0	3
PH	106	Introductory Physics III	2½	0	2½
PH	116	Physics Laboratory II	0	1½	½
PH	234	Intro to Modern Physics	2	0	2
LA	139	Engineering Ethics[4][5]	2	0	2
EE	194	Sophomore EE Lab II	½	1½	1
PE	10x	Physical Education[8]	0	2	0
					17

Junior Year
Fall

HU/SS Concentration (Non-Skill)[5]			3	0	3
ME	119	Dynamics (or AM 201)[10]	3	0	3
EE	109	Solid State Devices&Ccts I	4	0	4
EE	165	Fields and Waves I	3	0	3
CS	337	Computer Arch&Organization	3	0	3
EE	195	Junior EE Laboratory I	1	3	2
					18

Spring

HU/SS Concentration (Non-Skill)[5]			3	0	3
EE	103	Signals and Transforms	4	0	4
EE	110	Solid State Devices&Ccts II	3	0	3
EE	166	Fields and Waves II[11]	3	0	3
MA	223	Introduction to Probability[11]	3	0	3
CS	296	Computer Laboratory I	1	3	2
					18

Senior Year
Fall

HU/SS Concentration (Non-Skill)[5]			3	0	3
		Technical Elective[12]	3	0	3
EE	104	Feedback Systems[11]	3	0	3
EE	113	Solid State Devices&Ccts III[11]	3	0	3
EE	140	Communication Systems[11]	3	0	3
EE	196[11]	Senior EE Lab I (or CS 297)******	1	3	2
EE	395	Introduction to Project	½	1½	1
					18

Spring

Human/SocSci Elective (Free or Concen)[5]			3	0	3
		Technical Electives[12]	9	0	9
****** Senior EE Lab/Project (or EE 196)					3
					15

Total credits required for graduation: 136

Curricula are subject to modification; please consult EE Advising Bulletin Board prior to registration each term.

****** Sr EE Lab/Project is any of the following laboratories with projects: EE202 Electronics; EE204 Machinery (Brooklyn); EE206 Semiconductor Fabrication (L.I.C.); EE208 Special Topics; EE210 Summer Honors; CS297 Computer Lab II (in this case, CS297 is taken in Senior Fall and EE196 in Senior Spring); EE399 EE Lab Project III (3cr); EE398 (3cr) provided it is a lab or computer project; or EE397 Thesis. Emphasis on professional reports and oral presentation.

The Mathematics Placement Test in high-school algebra, geometry, and trigonometry, administered by the Office of the Dean of Student Life, is required of all entering students before registration, unless they have officially received entrance credit in MA 101. Well-prepared students are placed in MA 101 (4 hrs/wk). Less well-prepared students substitute MA 100 (7 hrs/wk) which includes Pre-Calculus Mathematics; MA110 is taken the following semester. Students with superior mathematical ability may replace MA101/2/3/4 by MA111/2/3/4; consult the Department of Mathematics about your eligibility and course availability.

[2] The English Composition Placement Test, administered by the Department of Humanities through the Office of the Dean of Students, is required of all entering students before registration, unless they have received transfer credit in HU 101 and HU 200. Many students are placed in HU101. A few students are placed in HU200; they replace HU101 by any HU/SS elective

Students placed in HU009 modify the program as follows:
Freshman I: Replace HU101 by HU009; SS104 by HU119.
Freshman II: Replace HU200 by HU101; HU119 by SS104 or a required HU/SS elective.
Summer before Sophomore year: Preferably take HU200.
Students placed in HU008 modify the program as follows:
Freshman I: Replace HU101 by HU008; SS104 by HU120.
Freshman II: Replace HU200 by HU103; HU119 by SS104 or a required HU/SS Elective.
Summer before Sophomore year: Preferably take HU200.

Students are strongly urged to learn to use a Word Processor for compositions, term papers, lab/project reports, resumes, and job applications.

[3]*Students may drop SS104 and HU200*, and replace them by IS140 and IS141 respectively. Before taking any of these four courses, however, students first complete HU008 or (009), if required, and HU 101 (or 103).

[4]*Composition Courses* must be completed at the earliest opportunity, in unbroken sequence: HU008 (or 009) if required; HU101 (or HU103); HU200 (or IS140); and HU110 — all with a grade of at least C- (or Pass) before proceeding to any course for which they are prerequisite. For EE majors, the HU110 prerequisite is HU200 (or IS140). HU119 (or 120) *Public Speaking* should usually be completed prior to the Junior year, and LA139 *Engineering Ethics* prior to the Senior year. Other HU/SS courses, including SS104, may be reordered for scheduling convenience.

[5]*Humanities/Social Science Courses* courses are prefixed HU, IS, LA, ML, or SS. Credits total 28 (and never less than 24) as follows:
(a) 16 credits of required courses: HU 101 (or 103)(3 cr); HU 200 and SS104 (or IS140 and IS141) (6); HU110 (3); HU119 (or 120) (2), LA139 (2).
(b) 12 credits of HU/SS Elective and Concentration courses. No more than three of these credits may be skills-oriented courses such as Journalism, Composition, and Public Speaking. It is essential that students follow the requirements for CONCENTRATIONS given elsewhere under Requirements in Humanities and Social Sciences for Majors in Engineering and Computer Science. Printed guidance from the Departments of Humanities and Social Sciences is available from the EE Undergraduate Advising Office.
(c) Without exception, a total of at least 16 HU/SS credits must be courses which are not skills-oriented. This ABET requirement is normally met with HU101 (or103) (1½ non-skills credits acceptable to ABET); HU200 (or IS140) (1½); SS104 (or IS141) (3cr); LA139 (2cr); and the 9 credits of non-skills electives.

When selecting a foreign language, a sequence terminating in the last course of the basic four-semester sequence is preferable. Foreign-speaking students may not elect a sequence in their own language without obtaining written permission from the Department of Humanities prior to registration.

The HU/SS Concentration Courses, HU/SS Electives, SS104, HU119 (or 120), and LA139 may be reordered for convenience in scheduling. For students of *proven competence*, on approval of the Departments of Humanities and Electrical Engineering, HU119 (but not HU120, if required), LA139, or HU110 (written exam required) may be replaced by a Free Elective (a course given by any department, provided it does not duplicate other material, advances the student's education, and has advisor approval). But the total number of HU/SS credits must not be less than 24, nor the number of HU/SS non-skills courses be less than 16, nor the number of courses in the Concentration less than three.

[6]*Reduced Load*: Students wishing to reduce their Freshman Fall load may defer CM101 and 111 until Spring, and in the following Summer take CM103 and 113, (or 102 and 112). If they were officially admitted under the Reduced-Load Program the Summer courses are tuition-free.

[7]*Cooperative Education Program*: CP101-102 are required of full-time students who elect the 5-year Cooperative Program, usually in Freshman Fall and Spring. While these courses are not required for the BSEE, the EE Department urges students to consider taking them in the Freshman year. Registration commits neither the students to accept the Program, nor vice versa. Students gain both engineering experience and salary during their three one-term job assignments. For further information, consult the Catalog index and the Cooperative Program Director.

[8]*Physical Education*: Four semesters of physical education are required of full-time students. Courses with the same numbers may be repeated. One semester of physical education will be excused for each 15 credits received for transfer courses, or for courses taken and passed while a part-time student — provided such credits are among the first 60 earned toward the degree. A part-time student is one who registers for less than 12 credits per semester (except summer). Polytechnic team members may get term-by-term credit for PE, on approval from the Department of Physical Education. MS 101, 102, 201, or 202 are substitutes for any PE course on a zero-credit basis.

[9]*Grade Requirements in Technical Courses*: The following must be completed with C- or better, before proceeding to any course for which they are prerequisite: PH104 (or 101); PH105 (or 102); MA101 (or 100); MA102 (or 110); CS112; CS236; EE101; EE102.

[10]*ME119* may be replaced by AM 201 *Thermodynamics I* (3cr) with prerequisites PH104 (or101), grade B or better; PH105 (or102), grade C or better; MA103; MA104. ME119 (3cr) may also be replaced by ME115 (4cr), or by ME116-117 (4cr); the extra credit may be counted toward Technical or Free Electives.)

[11]*Certain Courses May Be Shifted to Other Semesters*, to enable the students to sequence courses suited to their needs, provided prerequisites are fulfilled: both EE104 and EE196; both EE113 and EE196; both MA223 and EE140; or both EE166 and EE196.

[12]*Technical electives* are chosen from courses marked EE, EL, CS, AM, CM, LS, MA, MT, PH, or from other engineering departments with approval of the EE adviser. Each elective must have advanced content, not overlap other courses, usually have a strong analytic or design component, and contribute to the student's professional education. Students are urged to consider a second Senior EE Laboratory/Project as a Technical Elective. Graduate courses may be chosen if the student's GPA in related courses is a B, and overall GPA 2.7. An updated list of some allowed out-of-department courses is published by the EE Undergraduate Advising Office each semester. ROTC cadets may receive 3 technical elective credits if they complete MS301 and 303 *for credit*. They may receive 2 credits in lieu of LA139 if they complete MS401 *for credit*, provided they have completed at least 24 HU/SS credits, of which at least 16 are non-skills.

[13]*Freshman Seminar* SL 101 is required of all students entering with fewer than 6 transfer credits, and is recommended for others.

ELECTIVES, CONCENTRATIONS, AND PROJECTS

Students majoring in electrical engineering take 16 credits of advanced technical electives, including senior project, to prepare for the career of their choice. Courses are selected from electrical engineering; computer science; physical and life sciences; mathematics; management and operations research; and the other engineering disciplines. Many students take electives to sample fields not covered in required courses, or to take an advanced course in a subject already studied. Other students with firm professional goals prefer to concentrate their elective courses in a chosen area. Students who plan to take a sequence of related electives can defer one or two of the required junior year courses to a later semester.

Possible concentrations include, but are not limited to:

Advanced Electronic Design and VLSI
Bioengineering with Life Sciences; Pre-Medicine
Communication and Information Systems
Computer Architecture and Operating Systems
Computer Hardware Design and Organization
Computer Software Design and Artificial Intelligence
Control and Robotics
Data Structures, Machine Languages, and Compilers
Electric Power Engineering
Electromagnetic Fields and Waves
Lasers, Fiber Optics, and Microwave Devices
Linear Systems and Networks
Materials Engineering and Semiconductor Fabrication
Physics and Chemistry

All students undertake a 4-credit professional senior design laboratory or project guided by a staff member. See description of EE 395, Introduction to Project. Recent senior project topics include:

Modes of a Laser with Intracavity Frequency Doubler
In-Building Propagation of UHF Signals
Neural-Type Optimization
Continuous Phase-Modulation Digital Signaling
Compact, Low-Field, High-Harmonic Gyrotron
Pulsed Hollow-Cathode Lasers
Flashover in Crossed Electric and Magnetic Fields
Small-Scale Model of Coilgun
Power Electronics
Picosecond Optoelectronics for Ultrashort Pulses
Numerical Methods for Optical Microscopy
Morphological Analysis and Coding of Images
Radar and Sonar Signal Processing
Telecommunication Management Workstation
Expert System for Computer Music
Hardware Design of a DSP Processor
Digital Simulation of an Analog System
Computer-Aided Instruction for Digital Signal Processing
Local Area Networks (LAN)
The Processing of Images from Incomplete Data

Graduate courses (non-daggered) may be taken as electives by senior students whose junior-year grade-point average in technical courses exceeds 2.7, provided students have a B average in related and prerequisite courses. Daggered graduate courses in electrical engineering may usually be taken as senior electives by any undergraduate.

Five-year programs leading to two bachelor's degrees are possible—for example, electrical engineering and physics. Five-year programs leading to a bachelor's and a master's degree are also possible for qualified students—for example, BS in electrical engineering and MS in computer science.

All selections are discussed with and approved by an EE adviser.

COMPUTER-AIDED DESIGN

In the classroom, design principles are discussed. Sometimes the device is built in the laboratory to test it, but more often the engineer makes a mathematical simulation of very high accuracy using a computer. Circuits for the touch-tone telephone were designed this way, for example.

The computer-aided design (CAD) facilities and programs available to students included SPICE for transistor circuit design; communication filter and network design; power-system load flow; logic-circuit testing and simulation; integrated-circuit chip layout; control-system design; image processing; optimal expansion of power systems; micro-wave element design; printed-circuit-board layout; and others as needed for courses or designed by students working on a project.

EVENING UNDERGRADUATE PROGRAM

The electrical engineering program can be completed in Brooklyn entirely by attending classes Monday through Thursday from 5:55 p.m. to 10 p.m. (10:40 p.m. summer), on a part-time basis. On the Long Island campus evening course sections are offered, but evening students on that campus may have to take some day courses or come to Brooklyn to complete the degree.

Polytechnic University is unique in offering identical programs and diplomas to full-time and part-time students. Day and evening sections of courses have identical content. Full-time and part-time students attend the same evening classes, and are subject to the same academic standards. Transfer between full-time and part-time status is possible at any time.

Since the needs of evening students vary, a prescribed sequence of courses is not possible. Consequently students should consult the evening adviser in person or by telephone.

TRANSFER STUDENTS

Qualified graduates of two-year pre-engineering programs, such as those at liberal arts and community colleges, may fulfill the requirements for the B.S. degree in electrical engineering in two additional years. Since pre-engineering programs vary, a prescribed program is not possible; consequently, students should consult with an undergraduate adviser.

Graduates of technology programs may be able to fulfill the requirements for the B.S. degree in electrical engineering in two to three and a half years, depending on the scope and level of their previous education. Consult with an undergraduate adviser for details.

Transfer credits for courses taken at other schools are subject to frequent changes based on evaluation of content and level. Thus students completing the same program, but in different years, may receive different amounts of transfer credits. Consult the electrical engineering undergraduate adviser for current information.

Transfer students must arrive and present their records for evaluation at least one week before the regular registration period of their first semester at Polytechnic.

ACCELERATED HONORS PROGRAM

Full-time students in electrical engineering can be admitted into a BS/MS honors program which leads to simultaneous award of the bachelor's degree (electrical engineering) and master's degree (electrical engineering, electrophysics, computer science, or system engineering). Depending on the student's preparation and objectives, completion of the two degrees may come as early as the end of the fourth year of study. Admission into the program is normally made at the start of the freshman year; however, special programs may be worked out for other students individually with the departmental honors advisor. Acceleration can be achieved through advanced placement, through credit by examination, and through summer coursework or research participation. The program is intended for students with outstanding academic records.

SENIOR HONOR STUDENTS

A full-time day student whose performance during the first three years is outstanding will be named as a senior Honor Student and is permitted to replace some of the required senior technical courses with other courses, usually more advanced, which are directed toward the student's professional goals.

GUIDANCE FOR BSEE STUDENTS

Your instructors will help you during hours posted on their doors, or by appointment. Extensive help is available for students taking Project or Thesis.

Electrical Engineering advisers will be glad to advise on courses and program adjustments resulting from academic needs or personal problems. The Dean of Students is particularly helpful with personal problems and supervises fraternities and dormitories.

The Office of Special Services sponsors a peer tutoring program. The Learning Center provides drop-in tutoring in mathematics and physics. Operation Action is a six-week program to help students identify and remove roadblocks to their academic success. They also have a Stop-Procrastinating Workshop. "Lunch and Learn" helps with job interviews. Personalized career counseling is available. No charge is made.

The freshman seminar SL 101, Student Survival, introduces you to Polytechnic and its curricula.

The Placement Service helps with permanent, summer, and Cooperative - Program jobs. Financial Aid provides and reviews scholarship and loan information on a continuing basis.

Many courses provide extra hours or special programs on a regular basis. These include English for foreign and other students needing additional help: HU 008, HU 009, HU 103, HU 120); Mathematics (MA100, MA110); and EE101/102 and CS 112 tutorials. Labs have open periods for making up required experiments or for informal experimentation.

Students from upper classes can be particularly helpful. You are urged to join the student branch of the Institute for Electrical and Electronics Engineering, and to drop in to their lab. Many ethnic clubs help students adjust to our electrical engineering program.

DEPARTMENTAL STANDARDS AND PROBATION

The professional engineer is expected to achieve work of acceptable quality and quantity within a specified time. Similarly Polytechnic students need to assure satisfactory academic progress. It is this ability, the ability to work and to achieve, which is most desired by prospective employers.

To remain in good standing, electrical engineering majors must earn term-by-term (year-by-year, for part-time students), and cumulatively, minimum C technical averages (2.00 grade-point averages) in: (1) freshman and sophomore courses prefixed CS, EE, MA, and PH; and (2) required junior and senior courses, plus all electives prefixed CS, EE, and EL. (In the calculation of these two averages, the exclusion of the first grade earned in a course applies only for the first four such courses, and only when the new grade is earned within one calendar year of the date of the official final examination when the course was first taken). These requirements are in addition to the University requirement for a minimum 2.00 grade point average in all courses.

All students, majoring in any department, must earn at least C- in each of the following courses when first taken, and before proceeding to any EE or CS course for which it is prerequisite: HU101 (or 103), HU200 (or IS140), HU110, CS112, CS236, MA101 (or 100), MA102 (or 110), PH105 (or 102), PH106 (or 103), EE101, and EE102. Students with less than a C semester average, or less than a C average in a closely related course sequence, may be asked to repeat courses in which grades are less than C. Transfer credits may be removed if students earn less than C- in a subsequent course. With advisor permission, students may repeat a course, but must earn at least C (C- is not acceptable), or be disqualified from the Department. Permission to attempt a course a third time is almost never granted. Students who take a course without having fulfilled all course prerequisite, or who are in violation of any probation requirements, face deregistration and possible disqualification. An electrical engineering major is not permitted to accumulate more than five course withdrawals (W). Incomplete grades (I) must be removed before the beginning of the next semester. Exceptions may be made only by an official EE undergraduate advisor, in writing.

Students failing to meet any of the above requirements will be placed on probation as a warning that they are not progressing acceptably toward the degree. Continued inability to meet the probation conditions may lead to disqualification from the B.S.E.E. program. Students on probation may be required to decrease their course load,

repeat courses passed with a grade less than C, or undertake other remedial programs. Students on probation are usually not permitted to preregister for the following semester, but are obliged to consult their adviser between the time grades are posted and the official registration day prior to the start of classes, so that any necessary changes may be made.

Additional regulations may be posted outside the undergraduate advising office on each campus prior to each registration period, and are a part of these standards.

INFORMATION

The Undergraduate Advising Publications, available to all students, contains further details on honors, probation, approved electives, projects, elective concentrations, course offerings and other matters of interest. Curriculum and prerequisite changes, new courses, special sections, and other last minute announcements are posted on the bulletin boards outside the electrical engineering undergraduate office in Brooklyn and on the Long Island campus. All students are responsible for keeping informed.

GRADUATE STUDIES

The Department of Electrical Engineering and Computer Science offers graduate programs leading to the degrees of master of science, engineer and doctor of philosophy in the areas listed in the table at the beginning of this section. The programs leading to degrees in electrical engineering are described in the following paragraphs. Other sections of this catalog describe the programs in electrophysics, system engineering, computer science, and information systems engineering.

The requirements for graduate degrees in electrical engineering are quite general. Each student may follow a program in any one of a variety of fields, including those described in the following paragraphs. For up-to-date information, please refer to the departmental Graduate Student Manual, which is revised annually and is available from the EE Research and Graduate Office.

Outstanding students should apply for financial aid in the form of research fellowships, teaching fellowships or partial tuition remission.

Computer Engineering — Computer engineering deals with the design, construction and utilization of digital computers. This includes the special circuits and devices that are used in computers and the mathematical theories for their description, including switching and automata theory. Appropriate courses include those listed below under electronics and information science, as well as those listed under computer science.

Information Science — Information science deals with various communications systems, such as television, voice and data transmission, radar, telemetry and space communication, facsimile and display systems, plus the modern problems associated with data analysis and communication between man and machine and between machine and machine.

Systems and Control — System engineers are concerned with modeling and predicting the behavior of large systems from a knowledge of the component parts. Examples include air-traffic control systems, health-care delivery systems, and systems to monitor and control pollution of the environment. Control engineers are concerned with all aspects of automatic regulation of system performance. Together with the system engineer, they are trained in the fields of automation and system theory. Typical examples of control systems are automatic guidance systems for aircraft and space vehicles, electric motor control and chemical process control.

Electronics and Networks — The discipline of electronics and networks involves the design, construction and theoretical treatment of circuits used in modern electronic equipment, particularly those involving semiconductor devices and integrated cirucits.

Fields and Waves — Studies in fields and waves include electromagnetic and acoustic wave radiation and propagation under a variety of conditions, including nonlinear, anisotropic and periodic media. Such studies include microwave waveguides and antennas, optical fibers and integrated optics, diffraction and scattering effects, surface and bulk acoustic wave propagation and transduction. Applications include radar, microwave and optical communications, and surface acoustic wave technology.

Plasma and Atmospheric Physics — This area is involved with breakdown and ionization of gases and the interaction of the resultant plasma with electromagnetic waves. Such studies have application to thermonuclear power generation, understanding solar and planetary atmospheres, and propagation of radio waves in the ionosphere.

Power Systems and Energy Conversion — Studies in power and energy include not only the traditionally important generation, conversion and distribution of electrical power but also such modern topics as ion plasmas and fuel cells for the generation of electrical energy and the realization of electromagnetic propulsion for space rockets.

Quantum Electronics and Materials Science — Quantum electronics and materials science deal with the interaction of electromagnetic fields and waves with matter, which can be understood only through a quantum theoretic treatment. Topics of interest include lasers, nonlinear optics, quantum optics, holography, and electric, magnetic and thermal properties of materials.

THE MASTER'S DEGREE

Admission to the master of science program requires a bachelor's degree in electrical engineering, from an accredited institution, with a superior undergraduate academic record.

Students not meeting all these requirements will be considered for admission on an indivdual basis, and may be admitted subject to the completion of appropriate undergraduate courses to remove deficiencies in preparation. A student who also desires to obtain a Polytechnic B.S. degree in electrical engineering must do so first, *before* beginning studies for a master's degree in the Department of Electrical Engineering and Computer Science.

ELECTRICAL ENGINEERING

Applicants lacking an electrical engineering bachelor's degree who are otherwise sufficiently prepared for admission without undergraduate deficiencies may nevertheless be required to take specified introductory level *graduate* electrical engineering courses. Such graduate courses count toward the master's degree. A student with a B.S. degree in a field other than electrical engineering may also want to consider the departmental master's degree programs in electrophysics and in system engineering.

DEGREE REQUIREMENTS

To satisfy the requirement for the M.S. in electrical engineering degree, the student must complete a total of 36 units of courses, as described below. An overall grade average of B in all graduate courses is required by the University. In addition, a B average is required in specific groups of courses, as indicated below.

	Units
1. Core Courses	
Three courses from the following:	
EL 531 Probability	
EL 610 Linear Systems	
EL 611 Signals, Systems and Transforms	9
EL 641 Advanced Electronic Circuitry I	
EL 671 Fields and Waves	
CS 613 Computer Architecture I	
2. Two one-year sequences which may include courses in group (1). Both sequences must be in EL or CS courses and at least one must be an EL sequence.	6-12
3. Approved electives, which may include a thesis (9 units) and one reading course (3 units maximum).	21-15
Total:	36

At least 18 of the 36 units offered for the M.S. degree in electrical engineering must be in EL prefixed courses, and at least 24 units must be in EL or CS prefixed courses.

An overall B average is required in the combination of five to seven courses offered to satisfy categories (1) and (2) in the above table.

The core courses cover fundamental material and should be taken as early as possible.

A complete program of study, including the choice of one-year sequences, is arranged with a departmental adviser. The departmental *Graduate Student Manual* should first be consulted for detailed rules and procedures, such as student status, recommended one-year sequences, recommended electives, current areas of research, repetition of courses and disqualification for low grades. The manual also contains announcements of changes in degree requirements, if any, adopted by the faculty after the publication of this catalog.

Out-of-department courses (i.e., courses not carrying the departmental prefixes EL or CS): A maximum of 12 units of approved courses may be taken as electives.

Thesis: An exceptional student may elect to write a master's thesis for which 9 units toward the degree may be earned. Such a student should find an appropriate adviser who has agreed to monitor the thesis research. The research should adequately demonstrate the student's proficiency in the subject material. Oral defense of the master's thesis with at least three professors in attendance is required.

Transfer credits: The 9 units of transfer credits which may be allowed in accord with Polytechnic regulations can be applied toward the one-year sequence requirements and toward the electives. Transfer credits may not be used to satisfy the core course requirements.

Validation credit: Validation credits may be allowed in accord with Polytechnic regulations. In order to obtain credit, permission to take the validation examination must first be obtained by application to the EE Graduate Committee.

Repetition of courses: A student may register no more than three times for the same course *including* registration for which a W was earned. A course will not be allowed for degree credit if it was taken in violation of this rule.

Energy Program: Students in the Energy Program are required to offer a more specific list of courses within the foregoing tabulation:

1. Core courses: EL 531, EL 610 or EL 611, EL 671.
2. One-Year sequences: EL 661, EL 662, EL 665, EL 666.
3. Electives:
    (a) ES 927-928 is required.
    (b) 9 units from a list of specified courses.

For full details, consult the catalog section for the Energy Program.

THE ENGINEER DEGREE

The degree of engineer in electrical engineering is offered in recognition of the need of systems and component designers for advanced training beyond the master's degree. This degree program involves additional graduate courses and a substantial design project.

A guidance committee, usually drawn from the full-time faculty of the department, advises the student and grants final approval when the departmental requirements have been satisfied. The guidance committee usually consists of three members; the chairman and at least one other member should be from the Department of Electrical Engineering and Computer Science. Participation is encouraged by a committee member or members from the adjunct faculty or from other departments. The committee is appointed after the student is admitted to the program.

The complete program for each student is detailed following consultation between the student and the guidance committee. The minimum requirements of the program are 72 units past the bachelor's degree apportioned as follows:

1 A master's degree in electrical engineering, for which the student receives   36 units

2. An engineer project which demonstrates mature design, engineering economics, trade-offs, etc., for which the student receives   6-12 units

3. Approved electives   30-24 units

                  72 units

The engineer project may be suggested by either the student or the guidance committee and is officially approved on the student's submission of an acceptable written proposal which details the problem, background and approach, gives the budget for estimated project expenses and states the desired number of units (6, 9 or 12) to be earned. Upon completion of the engineer project, the student will submit bound copies of the project report and will defend the work at an oral examination. More detailed information regarding the project and defense may be found in the *Graduate Student Manual.*

In certain exceptional cases involving students with well-documented records of original significant analysis and design achievements, the guidance committee may waive the requirements that the analysis and design work be performed in residence. However, bound reports and an oral defense will still be required. In such cases, six units of project will be credited toward the degree.

The student shall choose elective courses with the advice and consent of the guidance committee to achieve a concentrated and well-integrated background in the chosen area. Courses outside the electrical engineering area are generally acceptable provided they build toward the student's goal. Typical areas of concentration are power, safety and reliability, electronics, systems and controls, communications, computers and electro-optics.

THE DOCTOR'S DEGREE

General — Graduate students who have exhibited a high degree of scholastic proficiency and have given evidence of ability for conducting independent research may consider extending their goals towards the doctorate. The degree of Ph.D. is awarded to a student who completes the program of studies and research described below, and prepares and defends a dissertation representing an original and significant contribution worthy of publication in a recognized scientific or engineering journal. For a more complete description of the topics summarized here, please refer to the latest EE/CS Graduate Student Manual.

Admission to Programs — Entrance into the doctoral program of study and research is contingent on the candidate's passing the departmental qualifying examination and forming a guidance committee (both described below). A student entering with a bachelor's degree will normally take the qualifying examinations after one year of study. Entering students holding master's degrees may take these examinations as soon as they are prepared, but are expected to submit to examinations within the calendar year.

Students entering the doctoral program at the baccalaureate level must meet the entrance requirement listed above for the master's program. Students entering at the master's level for the Ph.D. program in electrical engineering are normally expected to have a master's degree in electrical engineering.

Qualifying Examinations — The Ph.D. qualifying examinations are offered once each year. These examinations are divided into three sections: (a) a basic section—a written examination requiring broad knowledge and problem-solving ability at the undergraduate level; (b) an advanced section—a written examination requiring preparation at the first-year graduate level in several subject areas related to the student's principal area of interest; (c) a concentration section—an oral examination concentrating mainly on the student's declared area of interest. Principal areas of concentration are: communications; signal processing; automatic control; electronics; electromagnetics; electro-optics; and power. The basic section must be completed first and is generally offered in June. Students interested in the related areas of electrophysics and system engineering should refer to the corresponding Ph.D. programs described under those titles.

Details regarding allowed subject areas, recommended background courses, sample examination questions and the precise format for the coming year are available in the latest *Graduate Student Manual.*

Guidance Committee — Upon passing the qualifying examination, the graduate student must find a faculty member in the student's area of major interest who will become the thesis adviser. In consultation with the thesis adviser, the student suggests an adviser for a minor outside of electrical engineering, electrophysics, or system engineering, and a guidance committee of three or four faculty members, with the thesis adviser usually acting as chairmen. At least one other guidance committee member must be in the students' area of major research interest; this member may be from outside of the Polytechnic. The Minor adviser may, but need not, be a member of the guidance committee. The student must submit the names of these guidance committee members to the EE Graduate Committee for approval.

The thesis adviser approves the program of study in the student's major, and the minor adivser approves the program of courses in the minor. When the requirements for minor or major are completed, the student should have the appropriate adviser certify this in writing to the Office of Research and Graduate Affairs, with copies to the EE Graduate Office.

The guidance committee conducts the area examination and thesis defense, and approves the final thesis.

Course Requirements — Polytechnic requires that each candidate for the doctorate complete a minimum of 90 units of academic work beyond the bachelor's degree, including a minimum of 24 units of dissertation research. Candidates in EE must take a minimum of 51 units in formal courses (as distinct from "independent study" units such as reading, project, or thesis) as part of the general requirement of 90 units. Ph.D. students are required to take a minium of 12 units of courses in a minor area outside of electrical engineering. The minor must be taken in an area that is both distinct from and yet consonant with the student's major area of study. Approval of the minor program is described in the preceding paragraph. The major program of study is developed by the student in consultation with the thesis adviser. The major program should constitute a coherent study in depth of the most advanced knowledge in the student's area of concentration. Attendance at graduate seminars is expected when they are offered in the

student's principal area of interest (see course description EL 891).

Area Examination—The area examination consists of a presentation or review of the general background in the problem area of the student's dissertation. The purpose of the examination is to demonstrate that the student understands the fundamental prior research in the field of the thesis work. The examination should be taken early in the Ph.D. program, after no more than 12 units of dissertation have been taken, and should not be a review of partial thesis results. The examination may be in the form of an open seminar attended by other interested faculty and students. The guidance committee evaluates the student's performance and determines whether the depth of knowledge and understanding necessary to carry out research in the chosen area has been demonstrated.

Postponement of the area examination beyond registration for 12 units of thesis requires the approval of the EE Graduate Committee.

Submission of the Thesis and Final Examination—On completion of the doctoral dissertation the candidate will submit to an oral defense of the thesis. The examination is conducted by the guidance committee but is open to all members of the faculty and to such other persons as may be invited. Copies of the dissertation will be made available to prospective examiners a reasonable time in advance. The guidance committee chairman will notify the Office of Research and Graduate Studies of the candidate's readiness so that the examination date may be scheduled. The student is advised to consult the Office of Research and Graduate Studies regarding submission of the final manuscript, reproduction and binding.

UNDERGRADUATE COURSES

Students are advised to consult the departmental *Undergraduate Advising Publications* and the Schedule of Classes for changes of courses, course content and prerequisites in effect after the publication of this catalog. See page 51 ("A Brief Guide to Course Descriptions").

General prerequisites: students may not register for any junior- or senior-level courses until all freshman requirements are completed. Knowledge of computer programming at the level of CS 112 is assumed in all EE courses.

BASIC COURSES

EE 101   Electric Circuits I   **3:0:3**
Passive and active circuit elements. Node and loop analysis, source transformations, linearity and superposition, voltage and current division. Thevenin's and Norton's theorems. Source-free and forced responses of RL, RC and RLC circuits. Prerequisites: MA 101 (or 100), MA102 (or 110), PH104 (or 101), and CS 112 (all with grade C- or better); Co/Prerequisites: MA 104 and PH 105 (or 102); preferably EE 193.

EE 102   Electric Circuits II   **3:0:3**
Continuation of EE 101. Sinusoidal steady-state response. Phasors. Theorems, including maximum power, root-mean-square values and average power. Complex frequency. Resonance. Fourier series. Mutual inductance. Three-phase systems. Prerequisites: EE 101 (grade C- or better), PH 105 (or 102) (grade C- or better), MA 104; Co/prerequisite; preferably PH106 (or 103), EE 194.

EE 103   Signals & Transforms   **4:0:4**
Analog and digital systems. Integro-differential equations and recursion equations. Solutions by LaPlace and z-Transforms. Transfer functions and synthesis. Discrete and continuous convolution. Frequency response, Fourier series. Prerequisites: EE 102 (grade C- or better), and MA 104, and preferably MA 103.

CONTROL AND INSTRUMENTATION

EE 104   Feedback System Principles   **3:0:3**
Introduction to feedback systems: reduced sensitivity, disturbance input attenuation and stabilization. Analog and digital control systems. Position servo analysis and design. Performance specifications, signal flow graphs, root loci. Routh and Nyquist stability tests. Prerequisite: EE 103; either ME 119 (or AM 115, AM 117, or AM 119) or grade of B or better in PH 104 (or 101).

EE 107   Control System Design   **3:0:3**
Topics on the design of linear feedback control systems, selected from the following: lag-lead compensators; pole-placement controllers; state-variable feedback and observers; linear quadratic optimal control; stochastic systems; sampled-data and computer-controlled systems; and phase-plane and describing-function techniques for non-linear systems. (See departmental bulletin board for detailed descriptions of each offering and of any additional prerequisites). Prerequisite: EE 104.

ELECTRONIC CIRCUIT ANALYSIS AND DESIGN

EE 109   Solid State Devices and Circuits I   **4:0:4**
Semiconductor fundamentals. Physics of junction diodes. Diode circuits and applications: rectifiers, voltage regulators, clipper circuits. Physics and device models for Bipolar Junction Transistors (BJT) and Field Effect Transistor (JFET and MOSFET), including Ebers-Moll equations, large-signal analysis, operating modes, and switching times. Single-stage midband amplifier analysis: Q-point selection, stabilization, small-signal models and circuit analysis. Fabrication of integrated circuits. Prerequisites: EE 102 and PH 105 (or PH 102), both with grade C- or better; PH 234 (or 230). Corequisites: EE 165 (or 162); preferably EE 195. (Alternate prerequisite: EE 101, grade A- or better; PH 104 (or 101), grade B or better; PH 105 (or 102), grade B or better; and PH 234 (or 230), grade B or better. Corequisite: EE 102.) *First offered Fall 1988.*

EE 110   Solid State Devices and Circuits II   **3:0:3**
Small-signal analysis and design of transistor amplifiers at low, midband, and high frequencies. Computer-aided analysis and design. Operational amplifier building blocks: differential amplifiers, current sources, level shifters, output stages. Op-Amp examples. Applications of feedback to electronic curicuits. Prerequisites: EE 109; EE 165 (or 161). Co/Prerequisites: preferrably EE 195, EE 103 (Bode Plots). EE 111 is not an acceptable prerequisite. *First offered Spring 1989.*

EE 111   Solid-State Devices and Circuits I   **3:0:3**
Introduction to semiconductor physics, diode and bipolar transistor devices and models. Large- and small-signal operation of transistors. Inverters, emitter followers, differential amplifiers. Transient response of transistors and transistor capacitor circuits. Prerequisites: PH 230 and EE 102 (grade C- or better). *Last offered Spring 1988.*

EE 112   Solid-State Devices and Circuits II   **3:0:3**
Junction and MOSFET transistor physics and models. Single-device circuits and MOSFET inverter pairs. Low- and high-frequency response of single-stage amplifiers. Transient response, integrated circuit operational amplifier design, analysis and applications. Bipolar and MOSFET logic families. Prerequisite: EE 111. Co/Prerequisite: EE 103. *Last offered Fall 1988.*

EE 113 Solid-State Devices and Circuits III   3:0:3
Transient response of piecewise linear single energy storage element networks, diode wave-shaping networks, analysis and design of digital logic integrated circuits, voltage sweep circuits, and multivibrators. Prerequisite: EE 110 (or 112). Corequisite: recommended EE 196 (or 197), or CS 296 (or 298).

EE 115 Advanced Electronics   3:0:3
Special topics in electronic circuits and instrumentation, second-order modeling. Advanced transistor and integrated circuit design, active and passive memories. Application of bistate devices. Non-linear devices including topics such as digital circuits, blocking oscillators, ferro-electric and ferro-magnetic circuits. Prerequisite: EE 113.

EE 116 Communication Electronics   3:0:3
Design and analysis of small-signal and large-signal tuned amplifiers, sine-wave oscillators, mixers, AM modulators and demodulators, FM modulators and demodulators. Prerequisite: EE 110 (or 112). Co/Prerequisite: recommended EE 113.

EE 119 Semiconductor Technology*   3:0:3
Principal techniques involved in processing and fabrication of semiconductor devices and integrated circuits including material preparation, junction forming, circuit integration and packaging. Prerequisite: EE 109 (or 111), or MT 410.
Also listed under MT 375.

**EL 545-546 Microwave Integrated and
                    Semiconductor Circuits I,II***
See graduate course listings.

COMMUNICATIONS AND INFORMATION TRANSMISSION

EE 140 Principles of Communication Systems   3:0:3
Principles and techniques for modern communications systems. Analog and digital signals, sampling, quantization, signal representation. Analog and digital modulation, pulse code modulation, time and frequency multiplexing. Noise in communication systems. Prerequisites: EE 103 and MA 223.

EE 141 Signal Processing   3:0:3
Least squares and minimum variance estimates. Spectra for discrete-time random processes. Filtering, detection. Practical algorithms for signal processing, Fast Fourier Transforms. Projects involving applications of signal processing. Prerequisites: CS 112, MA 223 and EE 140.

ELECTROMAGNETIC FIELDS

EE 161 Transmission Lines and Waves   4:0:4
Transmission lines, acoustic and electromagnetic plane waves. Reflection and transmission at discontinuities, power and energy relations. Standing waves, impedance, reflection, transmission coefficients. Lossy transmission lines. Dispersion, group velocity. Vectors, Maxwell's equations in free space in integral form. Prerequisites: EE 102 (grade C- or better), PH 103, MA 103 and MA 104. *Last offered Fall 1988.*

EE 162 Electromagnetic Fields   4:0:4
Vector calculus. Gauss and Stokes' theorems. Maxwell's equations in differential form in free space. Fields in presence of conductors, dielectrics and magnetic materials. Plane waves in dielectrics and conductors. Electostatics, magnetostatics. Poynting's theorem. Waveguides. Radiation and antennas, far fields, arrays. Prerequisite: EE 161. *Last offered Fall 1988.*

EE 165 Electromagnetic Fields and Waves I   3:0:3
Electrostatic fields in vacuum. Gauss's law, potential, and capacitance. Magnetostatic fields in vacuum, Ampere's law, and inductance. Faraday's law and Maxwell's equations. Plane waves, transmission lines, and the propagation and reflection of waves. Prerequisites: EE 102 and PH 105 (or 102), each with grade C- or better; PH 106 (or 103), MA 103; MA 104 *First offered Fall 1988.*

EE 166 Electromagnetic Fields and Waves II   3:0:3
Conductors, dielectrics, magnetic materials and boundary conditions. Plane waves in dielectrics. Transmission-line impedance transformation, standing waves, and the Smith chart. Rectangular conducting wave guides. Radiation from dipoles and arrays. Prerequisite: EE 165. EE 161 is not an acceptable prerequisite. *First offered Spring 1989.*

EL 571-572† Engineering Electromagnetics I, II
See graduate course listings.

EL 573† Introduction to Microwave Engineering*
See graduate course listings.

ELECTRONIC MATERIALS SCIENCE

EE 167 Quantum and Solid State Electronics   3:0:3
Review of experimental necessity for introduction of quantum states and wave-particle dualism. Elements of wave mechanics and quantum statistics. Application to electronic structure of atoms, periodic table, properties of electrons in metals, semiconductors, insulators. Laser systems. Prerequisites: PH 234 (or 230) and EE 166 (or 162)

EE 199 Semiconductor Laboratory   1:3:2
Special section of course listed under Senior Electrical Engineering Laboratory II. Fabrication of PMOS transistors starting with a blank silicon wafer: mask generation, lithography, oxidation, diffusion, metallization, and encapsulation. Test and analysis of completed packages. Available on Long Island Campus. Lab fee required. Prerequisite: EE 119. *Last offered Spring 1989.* See EE 206.

EL 551-552† Electro-Optics I, II
See graduate course listings.

**EL 557† Introduction to Electric and Magnetic
                    Properties of Solids**
See graduate course listings.

ELECTRIC POWER

EE 180 Electrical Machinery I   3:0:3
Description, theory and analysis of steady-state performance for the four types of electrical machine: transformer, induction motor, synchronous machine and DC machine. Equivalent circuits and vector diagrams derived and used as the primary tools for analysis. Prerequisite: EE 165 (or 161), preferably EE 162; after Spring 1989, 166 (or 162).

EE 181 Electrical Machinery II   3:0:3
Two alternative unifying viewpoints of electrical machines are presented. One is based on physical considerations and leads to design guidelines. The second is based on Kron's theory and provides means for system analysis. Prerequisite: EE 180.

EE 183 Electric Power Systems   3:0:3
Principles of operating electric power systems. Transmission lines: inductance and capacitance parameters and current-voltage relations. Power system representation. Introduction to network calculations, symmetrical phase components, dynamic stability and economic dispatch. Prerequisite: EE 166 (or 161).

EE 199 Electrical Machinery Laboratory
Special section of course listed under Senior Electrical Engineering Laboratory II. Experiments on transformers, DC and AC motors, and AC generators. Available on Brooklyn Campus. Lab fee required. Prerequisite: EE 180, EE 195. *Last offered Spring 1989.* See EE 204.

EL 564† Electromechanical Power Conversion*
See graduate course listings.

EL 568-569† Electric Drives I, II*
See graduate course listings.

EL 581† Introduction to Plasma Engineering*
See graduate course listings.

ELECTRICAL ENGINEERING LABORATORY

Students enrolled in electrical engineering laboratory courses are charged a laboratory fee which includes the cost of a laboratory kit consisting of electronic parts and components. Transfer students who enroll in junior and senior level laboratory courses may be required to purchase components of preceding courses for which they have transfer credits.

EE 193 Sophomore Electrical Engineering Laboratory I   ½:1½:1
Introduction to electrical measurements. Lab fee required. Co/Prerequisite: EE 101, PH 105/115 (or 102).

EE 194 Sophomore Electrical Engineering Laboratory II   ½:1½:1
Electrical circuits laboratory. Lab fee required. Prerequisites: EE 101 and EE 193, PH 105/115 (or 102). Co/Prerequisite: EE 102, preferably PH 106/116 (or 103).

EE 195 Junior Electrical Engineering Laboratory I   1:3:2
Circuits and electronics laboratory. Lab fee requried. Prerequisites: EE 194, EE 102; Co/Prerequisite: EE 109 (or 111).

EE 196 Junior Electrical Engineering Laboratory II   1:3:2
Experiments selected from various areas of electrical engineering. Lab fee required. Prerequisite: EE 195 and Co/Prerequisites: EE 165 (or 162) EE 104 and EE 110 (or 112). Last offered Summer 1989.

EE 196 Senior Electrical Engineering Laboratory I   1:3:2
Experiments in electronics, control, and electromagnetic waves. Lab fee required. Prerequisite: EE 195, EE 110 (or 112), EE 166 (or 162); Co/Prerequisite EE 104. First offered Fall 1989.

EE 197 Senior Electrical Engineering Laboratory I   1:3:2
Experiments selected from various areas of electrical engineering. Lab fee required. Prerequisites: EE 196, EE 112 (or 110), and EE 161 (or 165); Co/Prerequisite: EE 113. Last offered Spring 1990.

EE 199 Senior Electrical Engineering Laboratory II   1:3:2
Experiments selected from various areas of electrical engineering. Special sections in electrical machinery, semiconductor technology, etc., may be offered. Lab fee required. Prerequisite: EE 113 and Co/Prerequisite: CS 237 (or 337). (Alternative prerequisites are specified for special sections.) Last offered Summer 1989. See below.

EE 202 Senior Electronics Laboratory/Project   1:6:3
Experiments and projects in electronics. Emphasis on professional written and oral project reports. May satisfy EE Lab/Project or Elective requirement. Lab fee required. Not open to students who have taken EE 199 (Electronics). Prerequisites: HU 110 (Minimum grade C-), EE 113; EE 395 (beginning Fall 1991); all junior courses; one laboratory and at least 9 technical credits of the senior year. First offered Spring 1990.

EE 204 Senior Machinery Laboratory/Project   1:6:3
Experiments and projects in electric machinery. Emphasis on written and oral project reports. May satisfy EE Lab/Project or Elective requirement. Brooklyn only. Lab fee required. Not open to students who have taken EE 199 (Machinery). Prerequisites: HU 110 (minimum grade C-); EE 180; EE 395 (beginning Fall 1991); all junior courses; one laboratory and at least 9 technical credits of the senior year. First offered Spring 1990.

EE 206 Senior Semiconductor Laboratory/Project   1:6:3
Experiments and projects on the fabrication of PMOS transistors, starting with a blank silicon wafer: mask generation, lithography, oxidation, diffusion, metalization, and encapsulation. Test and analysis of completed packages. Emphasis on written and oral project reports. May satisfy EE Lab/Project or Elective requirement. Long Island Campus only. Lab fee required. Not open to students who have taken EE 199 (Semiconductors). Prerequisites. HU 110 (minimum grade C-); EE 119; EE 395 (beginning Fall 1991); all junior courses; one laboratory and at least 9 technical credits of the senior year. First offered Spring 1990.

EE 208 Senior Special Topics Laboratory/Project   1:6:3
Experiments and projects related to current research laboratories. Emphasis on written and oral project reports. Lab fee required. Prerequisites: HU 110 (minimum grade C-); EE 395 (beginning Fall 1991); all junior courses; one laboratory and at least 9 technical credits of the senior year. Depending on the project topic, other pre/corequisites may be required by instructor. Offered as needed.

EE 210 Summer Honors Laboratory/Project   1:6:3
An individual or small-group intensive 9-week research-oriented project offered in the summer following the junior year, under the supervision of a staff member. Emphasis on written and oral project reports. No lab fee. May be used as a senior technical elective or in place of Senior Laboratory/Project. Prerequisites: HU 110 (minimum grade C-); completion of junior year; technical GPA 3.3 or greater; competitive selection by Steering Committee and Staff Sponsor. First offered Summer 1989.

INTERDEPARTMENTAL COURSES

EE 370 Principles of Electrical Engineering   3:0:3
Electrical signals and circuit elements. Network analysis. Transient and sinusoidal steady-state analysis of first and second order circuits. Diode and transistor circuits. Digital and logic circuits. (Cannot be used to satisfy any electrical engineering degree requirements.) Prerequisite: MA 102 (or 110), PH 105 (or 102); Co/Prerequisite: MA 104.

EE 374 Instrumentation Laboratory   0:3:1
Experiments designed to supplement EE 370. (Cannot be used to satisfy any electrical engineering degree requirements.) Lab fee required. Prerequisite: PH 115; Co/Prerequisite: EE 370.

EE 377 Introduction To Electronics   2½:1½:3
Circuit principles; Kirchhoff's laws; single-energy circuits. The PN junction; diodes, junction transistors, field-effect transistors. Survey of integrated circuit technology. TTL concepts. Logic gates, flip-flops, memories, and applications. Linear amplifiers, operational amplifiers and applications. Introduction to electronic laboratory instruments and measurements. (Cannot be used to satisfy any electrical engineering degree requirements.) Lab fee required. Prerequisites: MA 102 (or 110) and PH 105/115; Co/Prerequisite: preferably MA 104.

PROJECTS AND SPECIAL LISTINGS

EE 391-394 Special Studies in Electrical Engineering*   credit to be arranged
Advanced course in electrical engineering given to selected students. Course is vehicle for presenting novel material, trying new educational methods, taking advantage of special competences of visiting staff. Prerequisite: permission of electrical engineering adviser.

EE 395 Introduction to Project   ½:1½:1
Group lectures and individual discussions to prepare students for professional achievement in their senior projects. This is the first phase of a project (or projects) which requires the design, construction, testing, and documentation of a piece of equipment or software package. Choosing a topic, selecting an advisor, consulting the library and references, probing for information and advice, estimating time and cost, ordering parts, selecting a worksite. Evaluation of progress with advisor Departmental guidelines for the professional written report and final oral presentation before an audience, using audio-visual aids. Working in a group: leadership and sharing; responsibility and irresponsibility. No lab fee. Required of all Seniors beginning Fall 1991. Required of all students planning to take EE 399. Prerequisite: HU 110 (minimum grade C-); completion of all technical and lab courses of the junior year. Corequisites: First-term senior laboratory (Senior EE 196; EE 197, CS 297, or CS 299); preferably one or more electives in the area of expected specialization.

EE 396 EE Laboratory Project II   1:3:2
Second phase of project design: construction, testing, and documentation of a piece of hardware or of a software package. Written final report must be filed in the department office for a passing grade. Lab fee required. Prerequisite: EE 395. *Last offered Summer 1990.*

**EE 397 Bachelor's Thesis in
         Electrical Engineering**   **3 credits**
Individual solution of electrical engineering problem involving adequate statements of problem, choice of methods of attack, proper solution of problem. Presentation of results in formal bound report. Lab fee required. Prerequisite: senior status and approval of head of EE undergraduate program.

**EE 398 Project in Electrical
         Engineering**   **credit to be arranged**
Solution of electrical engineering problem or detailed study of advanced area of electrical engineering under supervision of adviser Written report must be filed in the departmental office for a passing grade. Lab fee required. Prerequisite: senior status and approval of head of EE undergraduate program.

EE 399 Senior EE Laboratory Project III   1:6:3
Second phase of project design: construction, testing, and documentation of hardware or a computer software package, supervised by the faculty or staff adviser selected in EE 395 (required prerequisite). Emphasis on depth of analysis, quality of system performance; comparison with possible alternative methods; and consideration of such other engineering features as cost, safety, utility, and need for further development. Written final report, conforming to professional standards specified by the Department, must be filed in the department office for passing grade. Oral presentation and discussion before group of students and staff required Lab fee required. Prerequisites: EE 395 (after Fall 1991); HU 110 (minimum grade C-), two junior and one senior laboratories; all technical courses of the junior year; and at least 9 technical credits of the senior year; usually a 2.5 GPA on related technical courses of the junior and senior year. Depending on the project topic, the Project Advisor or the EE Advisor may require additional prerequisites or corequisites, and acceptable technical grade-point average or grades in courses related to the project.

GRADUATE COURSES

Graduate courses in electrical engineering are offered on each campus on a regular basis, annually or in two-year or three-year cycles. Consult the *Graduate Student Manual* for these scheduling cycles as well as for information about day offerings and about the summer program. The electrical engineering graduate mailing, sent out to continuing students prior to each registration, contains the latest information on selected topics course offerings, curriculum and course revisions. See page 51 ("A Brief Guide to Course Descriptions").

Course number system: the courses below are grouped in terms of the *middle* digit which defines the academic area. The first digit represents the level:

5 — senior/graduate level
6 — first-year graduate level
7,8 — advanced courses
9 — miscellaneous courses

Courses in selected topics bearing the same numbers may be repeated for credit provided the topics are different, subject to adviser's approval.

LINEAR SYSTEMS AND NETWORKS

EL 610 Linear Systems   2½:0:3
Basic system concepts. Equations describing continuous and discrete-time linear systems. Response representation and calculation by digital and analog computer. Time domain analysis, state variables, transition matrix, impulse response. Transform methods. Time-variable systems. Prerequisite: Graduate status and EE 103.

EL 611 Signals, Systems and Transforms   2½:0:3
Continuous and discrete linear systems, system function. Fourier transforms, periodic functions, Z-transforms, discrete Fourier series, fast Fourier transforms. Analog and digital filters, finite order system functions. Digital processing of analog signals. Sampling theorems. Prerequisite: Graduate status and EE 103.

EL 613 Applied Matrix Theory   2½:0:3
In-depth introduction to theory and application of linear operators and matrices in finite-dimensional vector space. Invariant subspaces, elementary divisors, canonic forms and minimax theorems for eigenvalues of hermitian pencils. Prerequisites: Graduate status and MA 103, MA 104.
Also listed under MA 837

**EL 615 Network Theory of Lumped and
         Distributed Structures***   2½:0:3
Network principles derived from physical constraints are emphasized. Immittance and scattering formalisms, general energy and reciprocity theorems, properties of distributed parameter and nonreciprocal networks, broadband theory and the synthesis of transmission line broadband quarter-wave transformers. Prerequisite: Graduate status, and EE 101 and EE 102.

EL 617 System Reliability*   2½:0:3
Structural reliability, redundancy, bounds on reliability of complex systems. Repairable systems: Markov models, maintainability and availability. Optimization of spare parts inventories, inspection intervals and replacement times. Failure models: accumulated shocks and stress-strength-time. Marginal failures, dependent failures. Prerequisite: EL 531 or MA 561 or equivalent.
Also listed under IE 685

EL 618 Component Reliability*   2½:0:3
Failure models for industrial components: exponential, Weibull, lognormal, gamma, Gumbel and other distributions. Failures and hazard rates, graphical probability plots and maximum-likelihood parameter estimation and testing. Sampling plans based on life tests and accelerated life tests. Serial and parallel analysis on component reliability. Prerequisite: EL 531 or MA 561 or equivalent.
Also listed under IE 686

EL 711 Advanced Signals and Systems*   2½:0:3
Approximation methods in digital simulation of analog signals. Sampling theorems. Maximum system response under constraints. Analytic properties of LaPlace transforms, complex inversion factorization, windows, extrapolation, maximum entropy. Two-dimensional and Hankel transforms. Diffraction. Fourier optics. Ambiguity functions and pulse compression. Spectral estimation. Prerequisite: EL 611.

EL 713   Digital Signal Processing I   2½:0:3
Time and transform domain description of discrete-time signals and filters. Z-transforms, difference equations, discrete Fourier analysis and the FFT. Properties and design of recursive and non-recursive filters. Effects of finite precision arithmetic and round-off errors. Hardware realizations of digital filters. Introduction to spectral analysis. Prerequisites: EL 611.

EL 714   Digital Signal Processing II   2½:0:3
Two-dimensional signals and systems: Fourier representations and multi-dimensional sampling. 2-d discrete Fourier transform and convolution. Difference equations, Z-transforms and multi-dimensional stability. Design and implementation of non-recursive and recursive digital filters. Multiparameter statistical estimation theory: the principle of maximum likelihood. Signal parameter estimation in additive noise and performance degradation due to parameter uncertainty. The Kalman filter: Steady state theory and frequency domain analysis. Kalman filters for smoothing, correlated signal in noise and colored noise. Prerequisites: EL 631 and EL 713.

**EL 911-919   Selected Topics in Systems
                     and Networks**   each 2½:0:3
Selected topics of current interest in systems and networks. (See departmental mailing for detailed description of each particular offering.) Prerequisite: specified when offered.

CONTROL SYSTEMS

EL 621   Feedback Control I   2½:0:3
Analysis and synthesis of single-input-output, continuous-time control systems. Stability. Specifications for closed-loop system performance. Classical and modern compensation methods. Introduction to optimization: integral-square-error compensation. Prerequisites: Graduate status and EE 104.

EL 622   Feedback Control II   2½:0:3
Analysis of sampled-data and discrete-time systems by Z-transform and state variable methods. Specifications for closed-loop system performance. Introduction to nonlinear systems and stability. Non-linearities, linearization, limit cycles and describing function. Stability theory and Lyapunov functions. Prerequisites: EL 610 and EL 621.

EL 720   System Theory and Feedback*   2½:0:3
Design of multivariable feedback systems in the complex s-plane. Stability of interconnected systems from component transfer matrices. The class of stabilizing controllers. Optimal and suboptimal design considerations for two-degree-of-freedom systems. Prerequisites: EL 610 and EL 613.

EL 723   System Optimization Methods   2½:0:3
Formulation of system optimization problems. Elements of functional analysis applied to system optimization. Local and global system optimization with and without constraints. Variational methods, calculus of variations, and linear, nonlinear and dynamic programming. Iterative methods. Examples and applications. Prerequisite: EL 610 or EL 613.

EL 821   Analysis of Stochastic Systems*   2½:0:3
Stochastic difference and differential equations. Wiener process and Markov systems. Kolmogorov's equations for Markov systems. Stability of stochastic systems: stochastic Laypunov functions, moment equations. Prerequisite: EL 631.

EL 823   Optimal Control Theory*   2½:0:3
Optimal control problem for deterministic systems with various constraints. Solution for both continuous and discrete-time systems using the maximum principle and dynamic programming. Hamilton-Jacobi theory as applied to the synthesis problem. Prerequisite: EL 723.
Also listed under MA 844

**EL 921-929   Selected Topics in Control
                     Engineering**   each 2½:0:3
Topics of current interest to feedback and control system engineers. (See department mailing for detailed description of each particular offering.) Prerequisite: specified when offered.

INFORMATION SCIENCE

EL 531   Probability   2½:0:3
Events, probability, repeated trials. Random variables, distributions, moments, characteristic functions. Functions of random variables. Sequences of random variables. Limit theorems. Engineering applications of statistics. Prerequisite: Graduate status and MA 223.

EL 535   Elements of Communications Networks   2½:0:3
An introductory course in telecommunications networks. Review of calculus, and probability theory in the context of telecommunications. Modulation of sinusoida waves. Amplification and regeneration. Characterization of telecommunications traffic in terms of spectrum, capacity, response, and duty cycle. Voice communications systems, Switches, PBXs, and transmission options. Circuit switching, Facsimile, image, and video communications. ISDN and other integrated services approaches. Prerequisite: Graduate status. This course cannot be applied towards degrees offered by EE/CS.

**EL 631   Engineering Applications of
                     Stochastic Processes**   2½:0:3
Correlation, power spectrum, coherence, with applications in linear systems. Nonstationary signals, normal processes, mean square estimation, spectral analysis. Topics in Markov processes. Prerequisite: EL 531.

EL 632   Principles of Analog Communications   2½:0:3
Performance analysis of AM and FM systems, FM bandwidth, Hilbert transform and it's applications, noise models. Threshold effect in FM receivers and the application of phase locked loops to threshold extension. Sampling theorem, pulse modulation, A/D conversion, pulse code modulation (PCM) and delta modulation, pulse design. Prerequisite: EE 140 or equivalent and MA 223 or equivalent.

EL 633   Detection and Estimation Theory   2½:0:3
Detection of signals in noise, matched filters, M-ary digital communications. Signal detection and feature extraction in noisy environment based on likelihood ratio tests. Game-theoretic formulation of classification problems. Bayesian and point estimators: Near-optimum detectors. Combined estimation and detection. Wiener theory and Kalman-Bucy filters. Co/Prerequisite: EL 631.

**EL 635   Principles of Communication
                     Networks**   2½:0:3
An introductory course in data communications and computer communication networks. Many examples of networks, modeling. Basic principles of the design and performance analysis of networks. Data communication hardware: terminals, modems, multiplexers, concentrators, communications media. Nodal processor and host processor architecture. Software considerations and design. Protocols. Line control, polling and random access methods. Satellite and local area networks. Prerequisite: graduate status.

EL 733   Digital and Data Communications   2½:0:3
Detection of signals in noise. Signaling through bandlimited channels: intersymbol interference, equalizers. Principles of M-ary communication: signal space methods, optimum detection. Bandwidth efficiency of modulation schemes, combined coding and modulation. Spread spectrum systems: bandwidth expansion schemes, performance in jamming and multi-user environments. Prerequisites: EE 140 and EL 531.

EL 735   Communication Networks I   2½:0:3
Analysis and modelling of centralized and distributed data communication networks. Modeling of user traffic, communications links and processors. Queueing analysis. Packet-switched networks. Time delay analysis of networks. Capacity assignment. Concentration, multiplexing, polling, and buffer analysis. Multiple access for broadcast networks-satellites, ALOHA, ground radio, local area networks. New switching techniques. Integrated voice and data. Prerequisites: EL 531 and EL 635.

EL 736   Communication Networks II   2½:0:3
Principles of network design, network design algorithms, centralized network design, static and dynamic routing algorithms, concentrator and switching node location, network reliability analysis, application of minimum spanning tree and shortest path algorithms to problems in network design, linear and integer programming techniques, distributed network design, case studies. Prerequisites: EL 635 and CS 603.

EL 738   Algebraic Codes*   2½:0:3
General theory of linear codes. Groups, rings, fields, matrices and vector spaces. Coding and error correction methods. Encoding and decoding cyclic codes. Convolutional codes and other encoding schemes. Capabilities and limitations of error-correcting codes. Emphasizes codes used in computers. Prerequisite: graduate status and a basic knowledge of probability and linear algebra.

EL 739   Information Theory*   2½:0:3
Concepts of entropy and mutual information as mathematical measures for discrete information sources and discrete communication channels. Source encoding theorems and source coding techniques. Extension to sources with memory, channel capacity and noisy channel coding theory. Extensions to continuous waveforms. Prerequisite: EL 531.

EL 833   Advanced Signal Processing*   2½:0:3
Radon-Nikodym derivatives, Hajek-Feldman theorem for Gaussian stochastic processes. Detection and parameter estimation of stochastic and deterministic signals imbedded in colored and nonstationary Gaussian noise. Nonparametric methods in detection and estimation. Diversity reception systems. Prerequisite: EL 633.

**EL 931-939   Selected Topics in Information
             Science**   each 2½:0:3
Selected topics of current interest in information science. (See departmental mailing for detailed description of each particular offering.) Prerequisite: specified when offered.

ELECTRONIC DEVICES, CIRCUITS AND SYSTEMS

EL 540   Solid-State Devices and Circuits*   2½:0:3
Electric Circuit Fundamentals. Semiconductor fundamentals. Physics of p-n junctions, bipolar transistors, and field effect devices. Models and circuit applications of solid state devices. Frequency response of transistor circuits. Analog and digital electronic circuits. (Not accepted for the degree requirement in the Department of Electrical Engineering and Computer Science). Prerequisite: MA 104.

**EL 545†   Microwave Integrated and Semiconductor
           Circuits I**   2½:0:3
Electric and magnetic properties of materials which are used in integrated and semiconductor circuits. Common guiding structures such as microstrip with application to coupled transmission lines. Passive microwave PN, PIN and Schottky diodes. Active Gunn and IMPATT diodes. System sensitivity characterization (tangential sensitivity and noise figure). Prerequisites: EE 166 (or 162) and EE 110 (or 112).

**EL 546†   Microwave Integrated and Semiconductor
           Circuits II***   2½:0:3
Non-reciprocal devices. Microwave bipolar and GaAs FET devices. Transistor amplifier design and transformers. Various types of microwave oscillators. Monolithic GaAs circuits. Enrollment limited. Prerequisite: EL 545 and approval of adviser.

EL 641   Advanced Electronic Circuitry I   2½:0:3
Basic semiconductor physics. Small-signal, low-frequency models for junction transistors, biasing of junction transistors. Physics, models and biasing for field-effect transistors and vacuum tubes. General treatment of nonlinear controlled sources. High-frequency models. Single- and two-stage broadband small-signal amplifiers, discrete and integrated circuits. Prerequisite: Graduate status and EE 109 (or 111) and EE 110 (or 112).

EL 642   Advanced Electronic Circuitry II   2½:0:3
Tuned circuits and impedance transformers, narrow-band linear amplifiers. Tuned-circuit sine-wave oscillators, mixers, AM modulators and demodulators, and FM modulators and demodulators. Prerequisite: EL 641.

EL 643   Advanced Electronic Circuitry III   2½:0:3
Junction and field-effect transistors as switches. Basic digital and switching circuits. Integrated circuit logic schemes and "building blocks". Sweep circuits and synchronization. Prerequisite: EL 641.

EL 645   Integrated Circuit (VLSI) System Design 2½:0:3
Overview of digital electronic circuit functions on a single silicon chip. Systematic approach to design from circuit function to basic layout, subsystem layout, and mask layout using techniques based on computer-aided design. Computer testing of logic functions and simulation of circuit functions. Prerequisites: Graduate status, CS 237 and EE 113.

**EL 646   Integrated Circuit (VLSI) Fabrication
           Techniques**   2½:0:3
Study of process technology used to produce integrated circuits with emphasis on silicon technology: bipolar, MOS, and VLSI processes. Definition of process requirements in terms of the circuit structure, i.e., concentration profiles and topographical layout as defined by previously determined mask set. Analysis of the steps from crystal growth through diffusion, ion implantation, oxidation, photolithography, metallization, inter-connection, and packaging to final tests. Study of impact and process on design rules. Prerequisites: Graduate status and EE 112 (or 110).
Also listed under MT 709.

EL 647   Power Electronics   2½:0:3
Principles of thyristor devices, dynamic characteristics of DC choppers, dependence of turnoff circuits on load characteristics. Phase control, full wave circuits with inductive load, commutation. Power inverters. Prerequisite: Graduate status and EE 103, and EE 110 (or 112).

**EL 941-942   Selected Topics in
             Electronics**   each 2½:0:3
Special topics of current interest to staff in the field of electronic devices, circuits and systems. (See departmental mailing for detailed description of each particular offering.) Prerequisite: specified when offered.

ELECTRO-OPTICS, QUANTUM ELECTRONICS AND MATERIALS SCIENCE

EL 551-552†   Electro-Optics, I, II   **each 2½:0:3**
Propagation of plane waves: polarization, reflection, refraction and diffraction of light. Interference: spatial and temporal coherence, the Michelson and Fabry-Perot interferometers and applications. Visible and infrared light sources, black-body radiation, radiation by atom, stimulated emission of radiation, coherent light sources, Dielectric materials, anisotropy and birefringence, electro-optic effects and applications. Image formation: holography, spatial signals, spatial Fourier transform, spatial filtering, optical information processing, optical communication, computer applications. EL 551 prerequisite: EE 162 or 166 or equivalent. EL 552 prerequisite: EL 551.

EL 557†   Introduction to Electric and Magnetic Properties of Solids   **2½:0:3**
Crystal structures and dynamics, lattice vibrations, the phonon, thermal conductivity of solids. Energy-band theories, Brillouin zones, conductors, semiconductors, insulators, semiconductor junctions, junction devices, light-emitting diodes, detectors for visible and infrared. Prerequisite: EE 167.

EL 651   Statistical Mechanics I   **2½:0:3**
Equilibrium distributions. Relationships to laws of thermodynamics. Quantum effects. Maxwell-Boltzmann, Fermi-Dirac, Bose-Einstein distributions. Applications to bulk properties of matter and to thermal radiation. Kinetic theory. Nonequilibrium phenomena using Boltzmann transport equation. Prerequisite: graduate status.
Also listed under PH 663

EL 652   Statistical Mechanics II   **2½:0:3**
Micro-, Macro-, and grand-canonical ensembles and principles of classical statistical mechanics. Condensation phenomena. Treatment of fluctuation and transport phenomena. Density matrix formalism of quantum statistical mechanics. Many-body problems. Prerequisite: EL 651 or PH 663.
Also listed under PH 664

EL 653-654   Quantum Electronics I, II   **each 2½:0:3**
Interaction of electromagnetic radiation with matter. Spontaneous and induced emission and absorption of radiation. Gaseous and solid-state maser devices. Theory of linear dielectrics. Phenomenological theory of nonlinear dielectrics. Quantum theory of nonlinear susceptibility with application to nonlinear conductivity. Raman nonlinearities, nonlinear absorption and scattering processes, two quantum photoelectric effect and quantum theory of damping. Wave propagation in nonlinear media with application to parametric generation, down conversion and oscillation, harmonic generation and mixing. EL 653 prerequisites: Graduate status and EE 167. EL 654 prerequisite: EL 653.

EL 655-656   Quantum Mechanics I, II   **each 2½:0:3**
Quantum mechanics with applications to atomic systems. The use of Schroedinger's equations. Angular momentum and spin. Problems and approximation methods. Semiclassical theory of field-matter interaction. EL 655 prerequisite: graduate status. EL 656 prerequisite: EL 655.
Also listed under PH 667-668

EL 658   Fiber Optic Communications*   **2½:0:3**
Preview of fiber optic communications, optical fibers, light sources, detectors, modulation techniques. Transmitter, receiver and repeater technology. System applications. Integrated optics. Prerequisite: graduate status.

EL 950   Laboratory in Electronic Materials and Electro-Optics*   **0:5:3**
Selected experiments in electrical properties of materials. Physical properties of semiconductors, Hall effect measurements, photoelectricity, superconductivity, magnetoresistance, masers and lasers, harmonic generation, frequency mixing and modulation in optics and quasi-optic region. Experiments of project type designed to prepare students for independent research in above areas. Lab fee required. Prerequisite: graduate status.

EL 951-959   Selected Topics in Quantum Electronics, Material Science and Electro-Optics   **each 2½:0:3**
Topics of current interest dealing with interaction of matter with electromagnetic fields. (See department mailing for detailed description of each particular offering.) Prerequisite: specified when offered.

POWER ENGINEERING

EL 564†   Electromechanical Power Conversion*   **2½:0:3**
Motion of elementary charged particles in electromagnetic fields. Transformation laws for the electromagnetic field intensities. Magnetoplasma-dynamical equations. Power density relations and the design of the armature conductors in terms of power densities. Representation of fields in terms of traveling waves; synchronous and asynchronous interaction. Steady-state performance of synchronous converters. MHD power generation. Prerequisite: EE 166 (or 162).

EL 568†   Electric Drives I: Characteristics and Controls   **2½:0:3**
Transient conditions in electric drives. Load torques, moments of inertia, masses and forces translated to a rotating shaft. Acceleration and deceleration time. Consideration in selecting motor power rating. Motor heating (cooling) under different kinds of duty. Load diagram consruction. Speed control of electric drives. Four quadrant operation of dc and ac drives with static converter supply. Worked examples effectively illustrate the application of the mathematical derivations. Prerequisite: EE 180.

EL 569†   Electric Drives II: Design*   **2½:0:3**
Torque-speed envelopes, electrical and mechanical ports. Modeling of the motor and speed control. Outline of direct approach to the design. Mechanical and thermal stress limitations. Magnetic and electrical loading. Relations between flux and current densities. Determination of losses. Scaling laws. Flux plotting techniques. Procedures, computer programs and applications. Prerequisite: EL 568.

EL 661   Introduction to Power System Engineering*   **2½:0:3**
Power system engineering analysis: three-phase circuit calculations, static stability limits, network representations and loadflow calculations. Reliability analysis: generation and transmission reliability. Generation costing and economic dispatch. Prerequisite: EE 183.

EL 662   Introduction to Power System Planning*   **2½:0:3**
Power system economics: revenue requirements, load duration and reserve requirements. Load forecasting—econometric methods. Optimal expansion planning and methodologies: optimal generation mix and optimal network expansion. Decision analysis techniques. Prerequisite: EL 661.

EL 663   Electrical Transients in Power Systems*   **2½:0:3**
Analysis of lumped-circuit, normal and abnormal transients in power equipment and systems. Short-circuit fault analysis and transient recovery of three-phase circuits. Analysis of traveling-wave surges on transmission lines, windings and on integrated systems. Computer modeling. Prerequisite: EE 183

EL 664   Relay Fault Protection*   **2½:0:3**
Protective relay functions and classification. Electromechanical relay types, operating principles and basic characteristics. Communication channels for relaying. Current and voltage transformers, transducers. Protection of busses, transformers, generators, motors and other station equipment by the zone protection method. Distribution and transmission line relaying systems. Relay setting calculations. Primary and backup protection, application and philosophy with applied relay engineering examples. Prerequisite: EL 663.

EL 665   Power System Stability I*   2½:0:3
Introduction to the study of power system dynamics: mathematical modeling of prime movers, power plants, synchronous machines, field exciters, transmission lines, relay loads and stabilizers. Prerequisite: EE 104 and EE 183.

EL 666   Power System Stability II*   2½:0:3
Study of electrical machine and system dynamics, system governing and generation control prime-mover, energy supply, system dynamics and control. Prerequisite: EL 665.

EL 647   Power Electronics
See course listings under electronic devices, circuits and systems.

EL 961-969   Selected Topics in Power   2½:0:3
Topics of current interest in electric power engineering. (See departmental mailing for detailed description of each particular offering.) Prerequisite: to be specified when offered.

FIELDS AND WAVES

EL 571-572†   Engineering Electromagnetics I, II*
                                      each 2½:0:3
Engineering applications of electromagnetics. A device-hardware oriented course for graduate and advanced undergraduate students. Topics include: hollow conducting waveguides; dielectric guides; two-wire, coaxial and strip transmission lines; linear antennas, arrays, horn and dish antennas. Waveguide components: attenuators, phase shifters; waveguide-coaxial transitions, etc. Electromechanical transducers: loud speakers, microphones, relays. EL 571 prerequisite: EE 166 (or 162). EL 572 prerequisite: EL 571.

EL 573†   Introduction to Microwave Engineering   2½:0:3
Review of transmission line theory and its relation to waveguides: transverse resonance procedure for propagation characteristics. Waveguide discontinuities: alternative representations, equivalent circuits for various structures with examples in rectangular waveguide, microstrip and free space. Network methods for waveguides of composite or complex cross section, for waveguide attenuation and for resonant cavity Q. Introduction to leaky waves and to periodic structures. Prerequisite: EL 571.

EL 671   Fields and Waves   2½:0:3
Basic concepts of electric and magnetic fields, their sources and their propagation via waves are treated. Emphasis is on understanding electromagnetic wave phenomena (interference, reflection, refraction, etc) and their engineering applications over the entire electromagnetic spectrum. Prerequisites: graduate status and EE 166 (or 162).

**EL 672   Electrodynamics: Wave Propagation
              and Guidance**   2½:0:3
Course for students requiring understanding of electromagnetic fields from an engineering point of view. Physical concepts, systematic mathematical methods, and engineering interpretation of results equally emphasized. Excitation and propagation in metallic and dielectric guiding structures, discontinuities, resonators, radiation from antennas. Prerequisite: EL 671.

EL 673   Electrodynamics: Fields and Materials   2½:0:3
Interaction of electromagnetic fields with material media from classical viewpoint. Macroscopic description of dielectric, magnetic and conducting materials, energy relations, dispersion, and attenuation in dielectrics and ionized media. Wave propagation in anisotropic crystals and ferrites; waves in inhomogeneous media. Prerequisite: EL 671 or PH 623.
Also listed under PH 625.

EL 676   Fundamentals of Radar*   2½:0:3
Principles of range and direction finding by means of radio echoes. Requirements and limitations of radar, the radar equation and statistical nature of reception. Establishment of design criteria for radar receivers, indicators, modulators and microwave components. Presentation of systems and techniques including MTI, Doppler radars and pulse compression. Prerequisite: EL 611.

EL 771-772   Radiation and Diffraction I, II*   each 2½:0:3
First semester: An introductory level with asymptotic methods for radiation and diffraction Saddle point approximations of radiation and diffraction integrals for harmonic and transient fields; wave packets; ray description of reflection and refraction; diffracted rays (geometrical theory of diffraction). Second semester: rigorous methods. Eigen-function expansions; discrete and continuous spectra, Green's functions; alternative representations, asymptotic reduction of rigorous integral representations. EL 771 prerequisite: EL 672. EL 772 prerequisite: EL 771.

EL 773-774   Guided Waves and Beams I, II*   2½:0:3
Theory and application of guided waves and beams in areas of electromagnetics (radar), microwave acoustics and integrated optics. Propagation characteristics of surface and leaky waves; effects of loss; mode coupling; characterization of discontinuities. Propagation in periodic structures. Beam fields; properties of laser beams; divergence, Fresnel and Fraunhofer approximations; scattering and guiding of beams by planar structures; beam displacement and distortion; coupling to surface waves. EL 773 prerequisite: EL 672. EL 774 prerequisite: EL 773.

EL 775   Antenna Theory   2½:0:3
Concepts of antenna radiation patterns; radiation resistance; equivalent network; gain; effective area; reciprocity. Electromagnetic fields due to prescribed sources. Huygens' principle. Fresnel and Fraunhofer regions. Finite and infinite arrays. Mutual coupling. Aperture antennas. Traveling-wave antennas. Frequency independent antennas. Prerequisite: EL 672.

EL 776   Advanced Antenna Theory*   2½:0:3
Phased arrays. Floquet's theorem. Active impedance in infinte linear arrays of dipoles. Two-dimensional aperture element phased array analysis. Realized gain element pattern. Reciprocal lattice for rectangular and triangular grid planar arrays. Active admittance and element patterns in planar arrays. Blindspots. Cylindrical phased arrays. Effects of curvature and of dielectric windows. Concave collector arrays for lenses and dome antennas. Prerequisite: EL 775.

EL 777-778   Ultrasonics I, II*   each 2½:0:3
Wave propagation in solids and applications to microwave acoustic devices and ultrasonic nondestructive evaluation. Elasticity and piezoelectricity in crystals, stress-strain relation, piezoelectric coupling, crystal symmetry. Plane-wave propagation and reflection, Rayleigh, Love and other guided waves, leaky waves. Devices treated include interdigital transducers and filters, RACS, real-time and storage correlators and convolvers. EL 777 prerequisite: EL 672. EL 778 prerequisite: EL 777.

**EL 871   Advanced Ray Methods in
              Wave Propagation***   2½:0:3
Asymptotic theory of radiation and diffraction, with emphasis on inhomogeneous and dispersive media. WKB approximations and comparison methods, advanced saddle-point techniques and relation to ray optics. Space-time rays is inhomogeneous dispersive media, diffraction and transition phenomena for transients. Prerequisite: EL 772.

EL 873   Nonlinear Waves*   2½:0:3
Generic nonlinear wave equations. Whitham's Lagrangian formulation and averaging method. Quasi-particle techniques in nonlinear problems. Inverse scattering methods. Application of KdV, nonlinear parabolic, tec., equations in electrophysics. Prerequisite: EL 671.

EL 970   Microwave Engineering Laboratory*   1:4:3
Experiments with microwave sources (electron tube and solid state), rectangular waveguide components, power measurements, resonance cavities, non-reciprocal devices, microwave integrated circuits; S-parameter measurements of semiconductor devices; noise measurements; computer simulation; and surface acoustic wave measurements. Enrollment limited. Laboratory fee required. Prerequisites: EL 571, EL 545, and the approval of the microwave program adviser.

**EL 971-979 Selected Topics in Electromagnetic
Theory   2½:0:3**
Aspects of electromagnetic and acoustic wave propagation, diffraction and radiation of current interest, including wave interactions with materials and special mathematical and numerical techniques. (See departmental mailing for detailed description of each particular offering.) Prerequisite: specified when offered.

PLASMA SCIENCE AND ENGINEERING

EL 581†   Introduction to Plasma Engineering*   2½:0:3
Basic plasma concepts; collisional phenomena; elastic collisions, excitation, ionization, attachment, recombination; DC and AC breakdown and discharges; diffusion and mobilities; propagation of electromagnetic waves in plasma. Prerequisite: EE 166 (or 162).

EL 781-782   Wave Turbulence I, II*   each 2½:0:3
Analysis of inhomogeneous and nonstationary turbulent fields. Kinetic and fluid dynamic descriptions of many-particle systems at both quasilinear and nonlinear levels. Wave-particle and wave-wave instabilities treated as collision processes both classically and quantum theoretically. Determination of self-consistent kinetic equations for both particles and waves. Applications to space-time evolution of coupled background and turbulent wave fields. EL 781 prerequisite: graduate status. EL 782 prerequisite: EL 781.
Also listed under AE 753-754

**EL 783-784   Linear Wave Process in
Plasmas I, II*   each 2½:0:3**
Oscillatory and guided wave representation of fields in general linear systems. Self-consistent nonequilibrium field description of particle and wave dynamics in classical plasma-like systems. Kinetic versus fluid dynamic description of gaseous and solid-state plasmas. Dispersion relations, wave structure and instabilities in isotropic and anisotropic plasmas. EL 783 prerequisite: EL 581. EL 784 prerequisite: EL 783

EL 981-989   Selected Topics in Plasmas   each 2½:0:3
Aspects of plasmas of current interest. Subjects drawn from plasma composition dynamics and interactions with electromagnetic fields. (See departmental mailing for detailed description of each particular offering.) Prerequisite: specified when offered.

DEPARTMENT PROJECTS, READINGS, THESIS AND SEMINAR

**EL 591-599   Selected Topics in Electrical
Engineering   each 2½:0:3**
Topics of current interest in electrical engineering offered for credit to both selected undergraduate and graduate students. (See departmental mailing for detailed description of each particular offering.) Prerequisite: specified when offered.

EL 891   Graduate Seminar*   2½:0:3
Seminars in various areas of electrical enginering, electrophysics, system engineering and science, and computer science. Reports and discussions by staff members and students concerning recent developments in relevant areas. May be repeated for credit. Prerequisite: graduate status.

EL 990-991   Laboratory Internship I, II*   each 0:5:3
Work in graduate laboratories under immediate guidance of faculty member. May be used as adjunct to or continuation of departmental graduate laboratory courses. Lab fee required. Prerequisite: degree status.

**EL 993-994   Readings in Electrical
Engineering I, II   2½:0:3**
Designed primarily for students who desire to push toward frontiers of their specialization in electrical engineering, electrophysics or system engineering and who have completed essentially all related course offerings. Readings conducted under guidance of a faculty member who is expert in the field, consisting in general of readings in advanced literature. Examination required. Not more than 3 units may be offered toward the master's degree. Prerequisite: degree status.

EL 995-996   Advanced Projects I, II   each 0:5:3
Theoretical and experimental projects in various research areas in electrical engineering and electrophysics for the advanced graduate student. Projects assigned on basis of specialized interest and preparation of the student. A written report or oral examination is required at the discretion of the adviser. Prerequisite: degree status.

**EL 997   Thesis for Degree of Master of Science
in Electrical Engineering   each 3 units**
Independent engineering project demonstrating professional maturity, performed under guidance of adviser. Oral thesis defense and formal, bound thesis volume required. Registration of 9 units required (continuous thesis registration required). Prerequisite: degree status.

**EL 998   Projects for Engineer Degree in
Electrical Engineering   each 3 units**
Comprehensive planning and design of electrical engineering project under guidance of faculty adviser. Emphasis on current techniques. Oral examination and formal, bound report required. Scope of project is 6-12 units by prior agreement with adviser (continuous project registration required). Prerequisite: degree status.

**EL 999   Dissertation for Degree of Doctor of
Philosophy in Electrical Engineering   each 3 units**
Original investigation of electrical engineering problem. Must demonstrate creativity and include features of originality and utility worthy of publication in recognized journal. Candidate must successfully defend dissertation orally. Registration of 24 units required (continuous dissertation registration required). Prerequisite: passing qualifying examination. Registration beyond twelfth unit requires passing of area examination.

FACULTY

Leonard G. Shaw, Professor of Electrical Engineering and Head of Electrical Engineering and Computer Science
B.S., University of Pennsylvania; M.S. Ph.D., Stanford University
Signal processing, reliability

Joseph J. Bongiorno, Jr., Professor of Electrical Engineering and Assistant Department Head, Long Island Center
B.E.E., M.E.E., D.E.E., Polytechnic Institute of Brooklyn
Control systems

Leonard Bergstein, Professor of Electro-Optical Sciences
Ph.D., Polytechnic Institute of Brooklyn
Electro-optics

Henry L. Bertoni, Professor of Electrophysics
B.S., Northwestern University; M.S., Ph.D., Polytechnic Institute of Brooklyn
Electromagnetics; acoustics

Robert R. Boorstyn, Professor of Electrical Engineering and Computer Science
B.E.E., CCNY; M.S., Ph.D., Polytechnic Institute of Brooklyn
Computer communication networks, telecommunications

Frank A. Cassara, Professor of Electrical Engineering
B.S., Rutgers—The State University; M.S., Ph.D., Polytechnic Institute of Brooklyn
Electronic circuits, communication systems

Edward S. Cassedy, Professor of Electrical Engineering
B.S., Union College; S.M., Harvard University; Dr.Eng., The Johns Hopkins University
Power, plasmas, energy economics

Bernard R.-S. Cheo, Professor of Electrical Engineering
B.S., Taiwan College of Engineering (Taiwan); M.S., University of Notre Dame; Ph.D., University of California (Berkeley)
Electromagnetics, plasmas, power

Leopold B. Felsen, Institute Professor
B.E.E., M.E.E., D.E.E., Polytechnic Institute of Brooklyn
Propagation and diffraction, optics

Ivan Frisch, Director of the Center for Advanced Technology in Telecommunications and Professor of Electrical Engineering and Computer Science
B.S., Queens College; B.S., M.S., Ph.D., Columbia University
Information systems, computer networks and network control

Stanley H. Gross, Professor of Electrophysics
B.S., CCNY; M.S., Ph.D., Polytechnic Institute of Brooklyn
Ionospheric plasmas and atmospheric physics

Donald F. Hunt, Professor of Electrical Engineering
B.S., University of Pennsylvania
Networks and systems

Aaron Kershenbaum, Professor of Computer Science
B.S., M.S., Polytechnic Institute of Brooklyn; Ph.D., Polytechnic Institute of New York
Computer communications,; algorithms

Erich E. Kunhardt, Professor of Electrophysics and Physics; Director, Weber Institute
B.S., M.S., New York University; Ph.D., Polytechnic Institute of New York
Gaseous electronics, plasma dynamics, pulse power physics

Frank Kozin, Professor of System Engineering
B.S., M.S., Ph.D., Illinois Institute of Technology
Stochastic systems

Szu-Ping Kuo, Professor of Electrical Engineering and Electrophysics
B.S., M.S., National Chiao-Tung University (Taiwan); Ph.D., Polytechnic Institute of New York
Magnetohydrodynamics

Ludwik Kurz, Professor of Electrical Engineering
B.E.E., M.E.E., CCNY; Eng. Sc.D., New York University
Communications, pattern recognition, and image processing

Arthur E. Laemmel, Professor of Electrical Engineering and Computer Science
B.E.E., Polytechnic Institute of Brooklyn
Coding and computer circuits

James T. LaTourrette, Professor of Electrical Engineering and Computer Science
B.S., California Institute of Technology; A.M., Ph.D., Harvard University
Quantum electronics; computer software

Maurice C. Newstein, Professor of Electrophysics
A.B., Temple University; Ph.D., Massachusetts Institute of Technology
Quantum electronics

Istvan Palocz, Professor of Electrical Engineering and Electrophysics
Dip. E.E., Docent, University of Technical Sciences (Budapest);, Ph.D., Polytechnic Institute of Brooklyn
Wave propagation

Athanasios Papoulis, Professor of Electrical Engineering
M.E., E.E., Athens Polytechnic Institute (Greece); M.S., M.A., Ph.D., University of Pennsylvania
Signal theory

Henry Ruston, Professor of Electrical Engineering and Computer Science
B.S.E. (Math) B.S.E. (E.E.), Ph.D., University of Michigan; M.S., Columbia University
Software engineering, programming, circuit theory

Philip E. Sarachik, Professor of Electrical Engineering
A.B., B.S., M.S., Ph.D. Columbia University
Optimal and adaptive systems

Harry Schachter, Professor of Electrical Engineering
B.E.E., CCNY; M.S. Columbia University; Ph.D., Polytechnic Institute of Brooklyn
Microwave acoustics and communication systems

Gehrard Schaefer, Professor of Electrophysics
Ph.D., University of Berlin
Lasers, high power electronics

Benjamin Senitzky, Professor of Electrophysics and Physics
B.E., Ph.D., Columbia University
Optical and semiconductor devices

Jerry Shmoys, Professor of Electrical Engineering
B.E.E., Cooper Union; Ph.D., New York University
Antennas, propagation

Martin L. Shooman, Professor of Electrical Engineering and Computer Science
S.B., S.M., Massachusetts Institute of Technology; D.E.E., Polytechnic Institute of Brooklyn
Software engineering, system reliability and safety

Leonard Strauss, Professor of Electrical Engineering
B.E.E., CCNY; M.S., Columbia University
Integrated circuits

Theodor Tamir, Professor of Electrical Engineering and Electrophysics
B.S., Dipl. Ing., M.S., Technion (Israel)
Ph.D., Polytechnic Institute of Brooklyn
Electromagnetics, electro-optics

ELECTRICAL ENGINEERING

Richard Van Slyke, Professor of Electrical Engineering and Computer Science
B.S., Stanford University; Ph.D., University of California (Berkeley)
Computer communications, telecommunications

Wen-Chung Wang, Professor of Electrical Engineering and Electrophysics
B.S., Taiwan Engineering College (Taiwan); M.S., Ph.D., Northwestern University
Microwave acoustics

Dante C. Youla, Institute Professor
B.E.E., CCNY; M.S., New York University
Networks, control systems

Zivan Zabar, Professor of Electrical Engineering
B.Sc., M.Sc., Sc.D., Technion (Israel)
Power electronics, electric drives, power systems

Douglas A. Davids, Associate Professor of Electrophysics
B.S., M.S., Newark College of Engineering; Ph.D., Johns Hopkins University
Microwave acoustics, quantum electronics

Richard A. Haddad, Associate Professor of Electrical Engineering and Assistant Department Head of Westchester Center
B.E.E., M.E.E., Ph.D., Polytechnic Institute of Brooklyn
Digital filters, power systems

Basil S. Maglaris, Associate Professor of Electrical Engineering and Computer Science
Dipl. EE, National Technical University of Athens (Greece); M.S., Polytechnic Institute of New York; Ph.D., Columbia University
Computer communication networks, performance evaluation of computer systems

Saul W. Rosenthal, Associate Professor of Electrophysics
B.E.E., M.E.E., Polytechnic Institute of Brooklyn
Microwave techniques, bioengineering

Leo M. Silber, Associate Professor of Electrophysics
B.S., University of Massachusetts; M.S., Ph.D., Purdue University
Magnetic materials, plasmas

Samy M. Hanna, Assistant Professor of Electrical Engineering
B.Sc., M.Sc., Alexandria University (Egypt), M.S.E.E., California Institute of Technology, Ph.D., Purdue University
Microwave magnetics, microwave acoustics

Hyuk Lee, Assistant Professor of Electrophysics
B.S., Seoul National University (Korea); M.S., Ph.D., California Institute of Technology
Electro-acousto-optical devices

I-Tai Lu, Assistant Professor of Electrical Engineering
B.S., National Chiao-Tung University (Taiwan); M.S., National Taiwan University; Ph.D., Polytechnic Institute of New York
Electromagnetics, microwave circuits

Shivendra S. Panwar, Assistant Professor of Electrical Engineering
B. Tech., Indian Institute of Technology; M.S., Ph.D., University of Massachusetts
Communication networks

S. Unnikrishna Pillai, Assistant Professor of Electrical Engineering
B. Tech., M. Tech., Indian Institute of Technology (Bombay); Ph.D., University of Pennsylvania
Signal processing

Prodip Sen, Assistant Professor of Electrical Engineering
B. Tech., Indian Institute of Technology; Ph.D., Indian Institute of Science (Bangalore)
Signal processing, distributed and parallel processing, communications

Peter Voltz, Assistant Professor of Electrical Engineering
B.S., M.S., Ph.D., Polytechnic Institute of New York
Systems and Control

X. K. Chen, Visiting Assistant Professor
B.S., Hua Zhang University of Science and Technology (China); M.S., Ph.D., Polytechnic University

ASSOCIATED FACULTY

Shalom S. Bergstein, Industry Professor of Electrical Engineering
B.S., M.S., Ph.D., Polytechnic Institute of New York
Communications, fiber optics

Barry Jones, Industry Professor of Electrical Engineering and Computer Science
B.S., Cooper Union; M.S., Marist College
Electromechanical systems, Real-time computer systems

Myron M. Rosenthal, Industry Professor of Electrical Engineering
B.S., City College of New York; M.S., Adelphi University; P.E. (New Jersey)
Radar, microwave techniques, EMI techniques

Joel B. Snyder, Industry Professor of Electrical Engineering and Computer Science
B.E.E., M.E.E., Polytechnic Institute of Brooklyn, P.E. (New York, Massachusetts)
Microprocessor systems, data acquisition and transmission, signal processing

Leo Birenbaum, Research Associate Professor of Electrical Engineering and Electrophysics
B.E.E., Cooper Union; M.E.E., M.S., Polytechnic Institute of Brooklyn
Bioeffects of microwaves, microwave measurements, electrical machinery

Vrinda P. Dewal, Academic Associate in Electrical Engineering
B.E., M.E., University of Rorkee (India)
Communications, instrumentation

Stanley Novak, Industry Professor
Ph.D. (theoretical electrotechnique), Slovak Technical University
High frequency microwaves, electronics

Walter Grote, Academic Associate in Electrical
Engineering
E.E., Universidad Techica Federico Santa Maria (Chile);
M.S., Polytechnic Institute of New York

Chi-Ren Liu, Academic Associate in Electrical Engineering
B.S., National Taiwan University; M.S., Polytechnic Institute
of New York
Electronic circuits, communication systems

ADJUNCT FACULTY

Bernard Friedland, Adjunct Professor
A.B., B.S., M.S., Ph.D., Columbia University

Hamid Gharavi, Adjunct Professor
B.Sc., Tehran Polytechnic; M.Sc., Ph.D., Loughborough
University of Technology

Richard Gran, Adjunct Professor
B.S., M.S., Polytechnic Institute of New York

Dimitris Protopappas, Adjunct Professor
B.Sc., University of Athens; M.S., University of Toronto;
Ph.D., Polytechnic Institute of New York

Jonathan Chao, Adjunct Assistant Professor
B.S., M.S., National Chiao-Tung University (Taiwan); Ph.D.,
Ohio State University

Faut Agi, Lecturer
B.S., M.S., I.T.O. (Istanbul); P.E. (New York)

John H. Chang, Lecturer
B.S., National Taiwan University; M.S., Ph.D., Yale
University

Jerome Fishel, Lecturer
B.S.E.E., CCNY; M.S., Polytechnic University

Frederick W. Freyre, Lecturer
B.S., City College of New York; M.S., Rensselaer Polytechnic Institute; Ph.D., Polytechnic Institute of New York

Ralph Gittleman, Lecturer
B.S., Massachusetts Institute of Technology; M.E.E., Polytechnic Institute of Brooklyn

Jalal Gohari, Lecturer
B.S., City College of New York

Phillip Grieve, Lecturer
B.S., Cornell University; M.S., Ph.D., UCLA

Frank Gruppuso, Lecturer
B.S., M.S., Polytechnic Institute of New York

Howard Hausman, Lecturer
B.S., M.S., Polytechnic Institute of Brooklyn

Wilfred Ju, Lecturer
B.S., University of New Mexico; M.Sc., Ph.D., Brown
University

Charles W. Kulisan, Lecturer
B.S., M.S., Polytechnic Institute of New York

Chi-Leung Lau, Lecturer
B.S., M.S., Ph.D., University of Pennsylvania

Robert Leahy, Lecturer
B.E.E., M.E.E., Polytechnic Institute of Brooklyn

Sang H. Lee,
B.S., Seoul National University (Korea); M.S., Ph.D.,
University of Pennsylvania

Gary Lomp, Lecturer
B.S., M.S., Polytechnic Institute of New York; Ph.D.,
Polytechnic University

Muni Mitchell, Lecturer
B.S., M.S., University of Illinois; Ph.D.E.E., Polytechnic
Institute of New York

James Moulic, Lecturer
B.S., M.S., University of Illinois; Ph.D.E.E., Polytechnic
Institute of New York

Wilbur Pritchard, Lecturer
B.S., City College of New York

Jack Richman, Lecturer
B.C.E., City College of New York; M.S., New York University

Doru T. Roll-Mecak, Lecturer
B.S., M.S., Polytechnic Institute of New York

K. Saadatmand, Lecturer
B.S., James Madison University; M.S., Ph.D., RPI

Heinz Schreiber, Lecturer
B.E.E., City College of New York; M.S., Adelphi; Ph.D.,
Polytechnic Institute of New York

James Wetterau, Lecturer
B.E.E., CCNY; M.S., Polytechnic Institute of New York; P.E.
(New York)

RETIRED FACULTY

Rudolf F. Drenick, Professor Emeritus of Electrical
Engineering
Ph.D., University of Vienna (Austria)

Herman Farber, Associate Professor Emeritus of
Electrophysics
B.A., Brooklyn College; M.E.E., Polytechnic Institute of
Brooklyn

Anthony B. Giordano, Professor Emeritus of Electrical
Engineering and Dean Emeritus
B.E.E., M.E.E., D.E.E., Polytechnic Institute of Brooklyn

Alexander Hessel, Professor Emeritus of Electrophysics
M.Sc., Hebrew University; D.E.E., Polytechnic Institute of
Brooklyn
Antenna theory

Rudolf G.E. Hutter, Professor of Electrophysics
State Exam, University of Berlin (Germany); Ph.D., Stanford
University

ELECTRICAL ENGINEERING

Enrico Levi, Professor of Electrophysics
B.S. (M.E.), B.S. (E.E.), Dipl.Ing., Technion (Israel); M.E.E.,
D.E.E., Polytechnic Institute of Brooklyn
Energy conversion

Frank J. Lupo, Professor of Electrical Engineering and
Computer Science
B.E.E., M.E.E., New York University; Ph.D., Columbia
University; P.E. (New Jersey)
Bioengineering, networks and systems

William A. Lynch, Professor Emeritus of Electrical
Engineering
M.E., M.E.E., Polytechnic Institute of Brooklyn

Nathan Marcuvitz, Institute Professor Emeritus
B.E.E., M.E.E., D.E.E., Polytechnic Institute of Brooklyn

Eli Absalom Mishkin, Professor Emeritus of Applied
Physics
Ingenlevr, Sc.D., Technion (Israel)

Arthur A. Oliner, Professor Emeritus of Electrophysics
B.A., Brooklyn College; Ph.D., Cornell University

Marvin Panzer, Associate Professor of Electrical
Engineering
B.E.E., Cooper Union; M.E.E., D.E.E., Polytechnic Institute
of Brooklyn

Beulah Rudner, Assistant Professor of Electrical
Engineering
B.A., Hunter College; M.E.E., Polytechnic Institute of
Brooklyn

Sidney S. Shamis, Professor Emeritus of Electrical
Engineering and Associate Provost
B.E.E., Cooper Union; M.S., Stevens Institute of Technology

Edward J. Smith, Professor Emeritus of Electrical Engineering and Computer Science
B.E.E., Cooper Union; M.E.E., D.E.E., Polytechnic Institute
of Brooklyn

Ernst Weber, Professor Emeritus and President Emeritus
Dr. Phil., University of Vienna (Austria); Dr. Techn.,
Technical University of Vienna (Austria)

Gerald Weiss, Professor Emeritus of Electrical Engineering
B.E.E., Cooper Union; S.M., Harvard University; D.E.E.,
Polytechnic Institute of Brooklyn; P.E. (New York)

ELECTROPHYSICS PROGRAM

Polytechnic offers a program of study leading to the degrees of master of science and doctor of philosophy in electrophysics. The program is intended to prepare students to work at the interface between electrical engineering and physics, where new engineering applications of various physical phenomena are developed. Emphasis is placed on wave propagation and wave interactions with matter, as applied to a wide range of topics. Students entering the program typically have an undergraduate background in electrical engineering or in physics, a strong interest in physical phenomena and/or applied mathematics, and a desire to participate in research.

The program is administered by the Department of Electrical Engineering and Computer Science.

The program of study consists of basic courses in wave propagation, electromagnetic theory and mathematical techniques offered through the Department of Electrical Engineering and Computer Science. In addition a variety of more specialized courses at both the master's and doctor's levels are offered, covering technical areas where there is research and development activity on a world-wide basis. Traditional areas of active research that are covered include propagation and diffraction of waves, antennas, microwave networks, plasmas and solid-state devices. Areas of modern optics that are covered include quantum electronics, lasers and optical communications. Additional areas are nonlinear wave propagation, ultrasonic waves in solids, planetary atmospheres and waves in the earth's atmosphere. The basic courses are offered yearly on both the Brooklyn and Long Island campuses. Specialized courses may be offered on one or the other campus, or in alternate years on the two campuses.

The electrophysics faculty at Polytechnic has made significant contributions to each of the areas cited above and maintains active theoretical and experimental programs in them. Because the electrophysics program is an outgrowth of these research activities, students in the program are exposed to the most current technical developments in each area and can be guided in research at the forefront of the areas. The theoretical effort is supported by extensive computational facilities existing at Polytechnic. The experimental research is carried out in laboratories in Long Island and Brooklyn. At Long Island, experimental facilities include laboratories devoted to surface acoustic waves, magnetostatic wave devices, lasers, semiconductors, ion implantation, microwaves and millimeter waves, gas discharges and plasmas. The Brooklyn campus has laboratories devoted to electro-optics, ultrasonics, and magnetic materials.

REQUIREMENTS FOR THE MASTER'S DEGREE

The entrance requirements for the master of science in electrophysics are a bachelor's degree in engineering or science from an accredited institution, with a superior undergraduate record, including undergraduate courses in differential equations, electromagnetic theory, quantum and solid-state physics, and linear systems. Students with deficiencies in these areas may be admitted if they take appropriate introductory courses to remove these deficiencies. Outstanding students are advised to apply for financial aid in the form of research fellowships, teaching fellowships or partial tuition remission.

To satisfy the requirements for the M.S. in electrophysics degree, the student must complete a total of 36 units of courses, as described below. An overall grade average of B in all undergraduate courses is required by the University. In addition, a B average is required in specific groups of courses, as indicated below.

1. Three courses from among the following:

EL 551	Electro-Optics I	
EL 581	Introduction to Plasma Engineering	
EL 611	Signals, Systems and Transforms	
EL 651	Statistical Mechanics I	
EL 653	Quantum Electronics I	
EL 671	Fields and Waves	9 units

2. Two one-year sequences, which may include the above courses. Both of these one-year sequences must be in electrical engineering or physics courses, and at least one must be an EL sequence.   6-12 units.

3. Approved electives.   <u>21-15 units</u>

          Total: 36 units

A complete course of study, including the choice of the one-year sequences, should be arranged in consultation with an adviser. A master's thesis of 9 units may be included as part of the elective courses. At least 24 of the 36 units must be in courses with EL, EP or CS prefixes, and 18 units of these must be in EL prefixed courses.

An overall B average is required in the combination of five to seven courses offered to satisfy categories (1) and (2) in the above table.

The departmental *Graduate Student Manual* should be consulted for more detailed rules and procedures, including student status, recommended electives and one-year sequences, current areas of research and disqualification for low grades.

REQUIREMENTS FOR THE DOCTOR'S DEGREE

Graduate students who have demonstrated a high degree of scholastic proficiency and have given evidence of ability to conduct independent research may consider extending their studies toward the doctorate.

Admission to Program—Admission to the program is based on qualifying examinations which a student usually takes after having completed one year of graduate studies. Successful completion of the master's requirements in electrophysics should provide adequate course preparation for the examinations.

ELECTROPHYSICS

Specific requirements for this degree parallel those for the Ph.D. in E.E. as described elsewhere in this catalog and in the EE/CS *Graduate Student Manual*. These include course requirements, guidance committee formation, area examination, submission of the bound thesis, etc.

Outstanding students are advised to apply for financial aid in the form of research fellowships, teaching fellowships or partial tuition remission.

Qualifying Examinations—The format for the qualifying examinations is described in connection with the Ph.D. in electrical engineering. Principal areas of concentration for electrophysics candidates are: quantum and statistical mechanics, quantum electronics, solid state electronics, electromagnetics and electro-optics. Current information about examination topics should be obtained from the Electrical Engineering graduate office.

GRADUATE COURSES

**EP 997   Thesis for Degree of Master of
                    Science in Electrophysics   each 3 units**
Independent research project demonstrating professional maturity, performed under guidance of adviser. Oral thesis defense and formal, bound thesis volume required. Registration of 9 units required (continuous thesis registration required). Prerequisite: degree status.

**EP 999   Dissertation for Degree of Doctor of
                    Philosophy in Electrophysics   each 3 units**
Original investigation of electrophysics problem. Must demonstrate creativity and include features of originality and utility worthy of publication in a recognized journal. Candidate must successfully defend dissertation orally. Registration of 24 units required (continuous dissertation registration required). Prerequisite: passing of qualifying examination. Registration beyond the 12th unit requires passing of area examination.

PARTICIPATING FACULTY

Leonard Bergstein, Professor of Electro-Optical Sciences

Henry L. Bertoni, Professor of Electrophysics

Edward S. Cassedy, Professor of Electrical Engineering

Bernard R-S Cheo, Professor of Electrical Engineering

Leopold B. Felsen, Institute Professor

Alexander Hessel, Professor of Electrophysics

Erich E. Kunhardt, Professor of Electrophysics

Szu-Ping Kuo, Professor of Electrical Engineering and Electrophysics

James T. LaTourrette, Professor of Electrophysics

Enrico Levi, Professor of Electrophysics

Maurice C. Newstein, Professor of Electrophysics

Istvan Palocz, Professor of Electrical Engineering and Electrophysics

Harry Schachter, Professor of Electrical Engineering

Gerhard Schaefer, Professor of Electrophysics

Benjamin Senitzky, Professor of Electrophysics

Jerry Shmoys, Professor of Electrical Engineering

Theodor Tamir, Professor of Electrical Engineering and Electrophysics

Wen-Chung Wang, Professor of Electrical Engineering and Electrophysics

Douglas A. Davids, Associate Professor of Electrophysics

Saul W. Rosenthal, Associate Professor of Electrophysics

Leo M. Silber, Associate Professor of Electrophysics

Samy M. Hanna, Assistant Professor of Electrical Engineering

Hyuk, Lee, Assistant Professor of Electrophysics

I-Tai Lu, Assistant Professor of Electrical Engineering

Leo Birenbaum, Research Associate Professor of Electrical Engineering and Electrophysics

Bernardino M. Penetrante, Research Assistant Professor of Electrophysics

HUMANITIES AND COMMUNICATIONS

The Department of Humanities and Communications offers undergraduate degree programs in journalism and technical writing and in the humanities. The department also offers a unique program in specialized journalism leading to an M.S. degree. The graduate and undergraduate programs exploit the advantages and strengths of a technological university and thus are particularly beneficial to students who combine strong interests in the humanities or journalism and technical writing with interests in science and technology.

In a world of narrowly-focused specialists, human progress depends upon those who can synthesize knowledge and communicate it with real understanding. Such persons are not locked into rigid academic disciplines and patterns of thinking; they are as intellectually comfortable in the sciences as in the arts and humanities. While such persons are rare, they are in demand in virtually every profession and can expect to fill vital roles in fields which are only now being explored. These programs give men and women in the humanities and in communications integrated educations.

The department also plays an essential role in the education of students who are majors in other departments. Today's engineers and scientists must know the humanities in order to make well-reasoned decisions involving human values implicit in technological options, to understand the ways human beings see themselves and the natural and social worlds, and to communicate effectively.

As freshmen, all students admitted to Polytechnic University are placed at appropriate levels in the freshman English sequence. On the basis of an English composition placement test evaluated by the department, most students are placed in one of the standard freshman courses (HU 101 or HU 103); some may be exempted and placed in HU 200, the second required course of the sequence; others may first be required to take one or more semesters of an introductory course in English (HU 008 or HU 009) with a reduced course load (a maximum of 14 credits).

After completing HU 101 (or HU 103) and HU 200,* non-majors are encouraged to complete a sequence of courses in one of the disciplines within the department—literature, art and music, philosophy and religion, or modern languages. Courses in public speaking and technical writing are especially practical for students preparing for careers in engineering or science. Engineering and computer science majors should read carefully the requirements governing their selection of humanities and social sciences courses. These requirements will be found in the Degree Requirements section of this catalog and under the individual department's course listings. Up-to-date information about such requirements is also available from departmental advisers.

UNDERGRADUATE PROGRAMS

The Department of Humanities and Communications offers Bachelor of Science degrees in Journalism and Technical Writing and Bachelor of Science degrees in Humanities.

JOURNALISM AND TECHNICAL WRITING

Our graduates have successful careers in journalism, science writing and technical writing. Science and technical writers in particular—those with the skills of journalists combined with strong interests in science and technology—continue to be in great demand. In these fields, professional status and salaries are virtually on a par with those of engineers. Majors in journalism and technical writing arrange programs of studies in consultation with departmental advisers. Generally they also fulfill the requirements of the contemporary liberal arts core curriculum outlined in that section of the catalog, pp. 115-117. A maximum of nine credits in graduate courses in Specialized Journalism may be taken to satisfy undergraduate degree requirements. Generally these should be taken no earlier than the second half of the junior year.

Requirements for Bachelor of Science Degrees in Journalism and Technical Writing

	Credits
Core Curriculum	
Humanities (HU 101 and HU 200)*	6
Social Sciences (SS 104)*	3
Mathematics & Computers (LA 120, 121, 125)	11
Science (LA 130, 131, 132)	12
Interdisciplinary courses (LA 110, 140, 141, 142, 143, 144, 150, 160)	25
Journalism and Technical Writing Courses	33
Electives	
Humanities electives	6
Social Sciences electives	6
Free electives	24
Total credits required for graduation	126

THE HUMANITIES

For students wishing to pursue a degree in the humanities, the department offers specializations in English, American and comparative literature; philosophy; German language and literature; and general humanistic studies (a multidisciplinary major in the humanities). Here, too, students will work out a program of studies in consultation with a departmental adviser. Generally they also fulfill the requirements of the contemporary liberal arts core curriculum outlined in that section of the catalog, pp. 115-117. Students who wish to obtain certification for teaching in public schools in the New York City area should plan to take the necessary education courses at another institution.

*IS 140-141 may be taken in place of HU 200 and SS 104. See the Humanities and Social Sciences requirements on page 31.

Credit will be given for these education courses as free electives in meeting degree requirements.

Requirements for Bachelor of Science Degrees in Humanities

	Credits
Core Curriculum	
Humanities (HU 101 and HU 200)*	6
Social Sciences (SS 104)*	3
Mathmatics & Computers (LA 120, 121, 125)	11
Science (LA 130, 131, 132)	12
Interdisciplinary courses (LA 110, 140, 141, 142, 143, 144, 150, 160)	25
Humanities Courses	39
Electives	
Social Sciences electives	6
Free electives	24
Total credits required for graduation	126

Dual majors and degrees—A number of students elect to pursue dual majors—one in journalism and technical writing and another in engineering or science. Besides completing all requirements for degrees in engineering or science, students must complete 33 credits of communications courses in the Department of Humanities and Communications. These courses must be approved by a departmental adviser. Other,combinations are possible, such as a dual major in the humanities and social sciences or management.

Students may also pursue two separate degrees. In such instances, the 33 credits of communications or humanities courses must be over and above any humanities and communications courses required for the first degree.

Interdisciplinary Studies—The purpose of the interdisciplinary studies program, sponsored by the Department of Humanities and Communications and the Department of Social Sciences, is to enhance the humanistic elements of education. The program promotes courses, seminars and special lectures demonstrating the fruitfulness of interdisciplinary approaches to human knowledge. IS 140-141 is a year-long, unified humanities/social sciences sequence intended for freshman students. This sequence may be taken in place of the HU 200/SS 104 requirement for undergraduates. IS 145 and IS 146 may be taken as advanced humanities/social sciences electives.

Core Curriculum—A contemporary liberal arts core curriculum, representing a new vision of liberal education, is available for students in Bachelor of Science degree programs in Social Sciences or the Humanities. For a full description, see section entitled Contemporary Liberal Arts Core Curriculum, pages 115-117.

GRADUATE PROGRAM IN SPECIALIZED JOURNALISM

The Department of Humanities and Communications offers a master of science degree in specialized journalism. To be eligible for admission to this program, applicants must hold a baccalaureate degree or its equivalent from an acceptable institution of higher learning. The department admits students holding undergraduate degrees in the humanities, journalism, engineering, the sciences and the social sciences.

Applicants are expected to have a good command of English and should have taken as undergraduates at least one semester of college-level mathematics and one year of college-level science (to be met by any combination of courses in biology, chemistry, physics, geology, geography, engineering and history of science). Applicants lacking any of these courses may be matriculated on a provisional basis—as long as they meet all other requirements for admission—but are required to take undergraduate courses to fulfill the basic requirements for admission. No graduate credits are given for such undergraduate courses taken to meet deficiencies.

In general, applicants should have a minimum undergraduate grade point average of 3.0 from an accredited college or university. However, candidates with lower grade-point averages may be considered if they have demonstrated success in some area of professional writing. Others with lower grade-point averages may be admitted provisionally or as non-degree students. Applicants are not required to take the Graduate Record Examination.

FIELDS OF SPECIALIZATION

Financial Reporting

Financial and business reporting calls for professional journalists who can write about business and finance for knowledgeable business professionals and market analysts as well as the general public. Writers should have a solid background in economics and a clear understanding of business and financial concepts and terminology (including the workings of the various exchanges) in order to report and interpret developments accurately and comprehensibly. Clear, crisp, concise writing is a necessity.

Business-Magazine Journalism

Trade-magazine journalism entails writing and editing news and feature articles for technical and marketing-oriented publications serving particular industries. Such publications may be owned by independent publishing companies, professional societies or large corporations.

Medical and Science Reporting

Medical and science writers or editors work on magazines serving physicians, nurses and other technical and scientific personnel; on the news staffs of print and broadcast media; on public relations staffs of pharmaceutical houses and hospitals, medical schools and research centers; in the writing departments of corporations; and in editing departments of textbook publishers. In addition to writing clearly and succinctly, writers and editors must have sound backgrounds in the sciences.

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*IS 140-141 may be taken in place of HU 200 and SS 104. See the Humanities and Social Sciences requirements on page 31.

Industrial Advertising and Public Relations

Industrial advertising and public relations work is concerned with the promotion of corporate products to industrial clients rather than to the general public. Industrial advertising involves copywriting, choosing graphics, selecting media, organizing ad campaigns and performing market research. Those in this profession work as copywriters, account executives, advertising managers and media directors.

Industrial public relations work has the same overall goals as industrial advertising—to promote a positive corporate image to industrial clients. Public relations workers issue news releases on new products and technological advances to the trade and business press serving their clients' industries, hold press conferences to announce new products and technology developed by client companies, prepare feature articles on company products for publication in business magazines and technical journals, write speeches for engineering and management personnel and prepare literature (product brochures, annual reports, house organs and other technical and semi-technical material) for distribution to corporate customers.

Technical Writing

Technical writers — also called publications engineers and engineering writers — gather, organize, write and edit technical and scientific materials for management and technical personnel within their own companies as well as for customers and prospective customers. Such information takes a variety of forms: proposals to the federal government and to other corporations for primary and subcontract work, progress reports on government-sponsored programs, manuals for use by customer-service and maintenance personnel, corporate-capability brochures and technical and scientific news releases. Technical writers may also be called upon to write speeches and business-magazine articles for scientists and engineers.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE

The M.S. degree requires 36 units of graduate work. All students must take JW 605 (Libel Law and Press Ethics), JW 701 (Special Project in Professional Writing) and four courses (12 units) selected from the following list in consultation with an adviser:

		Units
JW 600	Introduction to Specialized Journalism	3
JW 601	Style for the Professional Writer	3
JW 602	Proposal Writing	3
JW 603	Reporting on Science, Technology and Medicine	3
JW 604	Graphics and Production Techniques	3
JW 607	Writing News for Radio and Television	3

The remaining 18 units are taken in elective courses. Generally, students select electives from among the remaining graduate courses offered in the department. Students who wish to enhance their scientific and technical knowledge or who are interested in management or social sciences courses may take a maximum of nine credits of graduate courses in other departments of Polytechnic University. Approval for this option must be given by the head of the department.

Elective courses are usually conducted as workshops, providing students with the kinds of writing and editing assignments they receive when actually working in the field.

While students select their individual programs in consultation with an adviser, the department strongly recommends that they select most of their electives in one of the five specializations below.

		Units
Financial Reporting		
JW 608	Introduction to Documentation	3
JW 609	Computer Documentation	3
JW 620	Financial and Business Reporting	3
JW 621	Reporting and Editing for the Business Press	3
JW 622	Writing Copy for Industrial Public Relations	3
JW 623	Publications Management and Budgeting	3
JW 641	Graphics Workshop	3
JW 701	Special Project in Professional Writing	3
Trade-Magazine Journalism		
JW 511	Technical Writing about Digital Electronics	4
JW 608	Introduction to Documentation	3
JW 609	Computer Documentation	3
JW 620	Financial and Business Reporting	3
JW 621	Reporting and Editing for the Business Press	3
JW 622	Writing Copy for Industrial Public Relations	3
JW 624	Writing Product-Information Copy	3
JW 641	Graphics Workshop	3
JW 701	Special Project in Professional Writing	3
Medical and Science Reporting		
JW 603	Reporting on Science, Technology and Medicine	3
JW 608	Introduction to Documentation	3
JW 609	Computer Documentation	3
JW 621	Reporting and Editing for the Business Press	3
JW 625	Advanced Medical Reporting	3
JW 626	Medical Public Relations	3
JW 627	Writing Copy on Pharmaceuticals and Drugs	3
JW 641	Graphics Workshop	3
JW 701	Special Project in Professional Writing	3
Industrial Advertising and Public Relations		
JW 608	Introduction to Documentation	3
JW 609	Computer Documentation	3
JW 621	Reporting and Editing for the Business Press	3
JW 622	Writing Copy for Industrial Public Relations	3
JW 624	Writing Product-Information Copy	3

JW 628	Writing Industrial Advertising Copy	3
JW 629	Writing the Marketing Report	3
JW 641	Graphics Workshop	3
JW 701	Special Project in Professional Writing	3

Technical Writing

JW 511	Technical Writing about Digital Electronics	4
JW 603	Reporting on Science, Technology and Medicine	3
JW 608	Introduction to Documentation	3
JW 609	Computer Documentation	3
JW 622	Writing Copy for Industrial Public Relations	3
JW 624	Writing Product-Information Copy	3
JW 630	Basic Technical Report Writing I	3
JW 631	Basic Technical Report Writing II	3
JW 632	Writing Technical Manuals	3
JW 641	Graphics Workshop	3
JW 701	Special Project in Professional Writing	3

CERTIFICATE PROGRAM IN A FIELD OF SPECIALIZATION

Certificates in specialized journalism are available to students completing five courses with grades of B or higher. Courses must be taken in a prescribed sequence arranged with an adviser. Students enrolled in the certificate program must meet the same rigorous standards of performance required of those working for M.S. degrees. At any time during enrollment, or following the awarding of the certificate, students in this program may transfer into the master's degree program if their performance has been satisfactory and they meet the standards for admission set by the department. Transfer into the master's program, however, may not mean automatic acceptance of all courses which students have taken while working toward certificates. Acceptance of credits depends upon the area of specialization in which students plan to work for degrees.

ENGLISH AND HUMANISTIC STUDIES AND MODERN LANGUAGES

Advanced courses and seminars in the humanities may be offered from time to time for graduate students in the sciences, engineering, specialized journalism, management, and the social sciences. HU 605 (Report Writing) is regularly offered by the department. Some departments permit graduate students to construct minors in the humanities to fulfill a part of their requirements for advanced degrees. Advisers in the Department of Humanities and Communications are available to recommend appropriate courses for such minors.

UNDERGRADUATE COURSES

FRESHMAN ENGLISH SEQUENCE

HU 008   Reading and Writing in English as a Second Language   6:0:0
English as a second language at the high-intermediate level. Development of grammatical control in writing and improved comprehension of college-level texts. Practice in listening and speaking; intensive preparation in language skills for academic and professional purposes. Graduate students may register with permission of department. Admission by placement examination.

HU 009   Introductory Composition   6:0:0
Intensive course in reading comprehension and composition skills for native speakers of English who have not been adequately prepared for college composition. Emphasis on development of control over standard written English and fluency in writing. Admission by placement examination.

HU 101   Writing and the Humanities I   3:0:3
Introduction to the humanities and to effective techniques of college-level writing. Examination of basic concepts, forms and techniques of philosophy, art and literature, with emphases on fluency, precision and imaginative use of source materials in writing. Admission by placement examination.

HU 103   Writing and the Humanities I (English as a Second Language)   6:0:3
Introduction to the humanities and to effective techniques of college-level writing, designed for students taking English as a second language. Examination of basic concepts, forms and techniques of philosophy, art and literature, with emphases on fluency, grammar, syntax, precision and imaginative use of source materials in writing. Admission by placement examination.

HU 200   Writing and the Humanities II   3:0:3
Introduction to the humanities and to advanced techniques in writing. Thematic emphasis on change and continuity in the humanities and an exploration of the interrelationship of the humanistic disciplines through study of great works of art, philosophy, literature and, in some sections, music. Advanced work in stylistic options and more complex forms of writing: the longer critical study, the formal report, the research paper. Prerequisite: HU 101 or HU 103 or advanced placement.

JOURNALISM AND TECHNICAL WRITING COMMUNICATIONS

Please note: HU 101 or HU 103 is a prerequisite for all courses in this section except for HU 119, 120 and 121.

HU 105   Advanced Composition   3:0:3
Lucid expository writing. Gathering and organization of factual material into larger units of composition. Methods of research and uses of library. Topics based on models of expository prose. Long paper.

HU 106   Writing for Publication: The Magazine Article   3:0:3
Development of students' interviewing and writing skills to produce medium-to-long-length magazine articles. With instructor's help, students develop story ideas on technical or non-technical subjects, complete the necessary library research and personal interviews and write pieces for specific publications. Students are encouraged to publish their work, although this is not a specific course requirement. Students also examine editorial practices of various popular, business and technical magazines and learn how successful magazine articles are put together.

HU 108   News Writing   3:0:3
Workshop to guide students in all basic news writing techniques. Writing of leads. Style and structure of news stories. Methods of news gathering. Writing of different types of news stories—meeting, speech, interview, human interest, interpretation.

HU 109   Feature Writing   3:0:3
Theory and practice of writing short or moderate-length magazine articles on general subjects. Principles and practices of writing in readable style. Guidance in selecting interesting topics, in market study, in slanting, in dramatizing, in outlining and writing minimum of three articles.

HU 110   Basic Report Writing I   3:0:3
Fundamentals of report writing applied to short, informal papers written by scientists and engineers in actual business situations; technical correspondence, memoranda, trip reports, periodic reports and new-product information sheets. Summaries, process and technical descriptions, instructions, analyses. Effective style, organization of material and mechanics. Students learn to coordinate tables, graphs and other illustrative matter with textual matter.

HU 111   Basic Report Writing II   3:0:3
Writing the longer technical forms commonly used in industry. Technical proposals, sections of manuals, letter reports, formal reports, technical sales literature, and semi-technical and technical articles for trade journals.

HU 112   Advanced Copyediting Techniquea   3:0:3
Improvement of students' editorial skills through intensive practice in writing headlines, decks and subheads for both general and industrial publications and through assignments in editing, revising and rewriting copy intended for a variety of publications. Writing leads and reorganizing garbled copy. Newspaper and magazine page layout and makeup.

HU 113   Writing for Advertising and
Public Relations   3:0:3
Writing effective advertising copy and publicity releases with emphasis on the industrial side. Students write product ads, brochure copy, product data sheets, news releases, short articles for trade journals, copy for house organs and speeches. Preparation and implementation of a typical advertising campaign and arrangements for press conferences. Layout of ad copy and accompanying color, design, typographic and illustrative features.

HU 114   Libel Law and Ethical Issues
in Journalism   3:0:3
What libel is and how writers can avoid its many pitfalls. Complete and partial defenses raised during libel suits and the possible damages awarded, the principles of "fair comment and criticism," criminal and civil libel, and one's right to privacy vs. the public's "need to know." The ethical issues facing journalists and other writers today, concerning writing about new products and technology believed to be defective or hazardous, pornography and the courts, shield laws, gag orders and copyrights.

HU 115   Reporting and Writing about
Science and Technology   3:0:3
How to interview scientists and engineers and how to present the information obtained in formats understandable to the layperson. Students write both news and feature stories, and are encouraged to publish their best pieces.

HU 116   Introduction to Computer Documentation   3:0:3
Computer systems and software documentation. The history of computer documentation; the role of documentation specialists, basic concepts and techniques, types of manuals, planning and management documentation. Prerequisite: one technical writing course and basic familiarity with computers. This course cannot be used to satisfy the HU/SS elective requirements.

HU 119   Public Speaking   1½:1½:2
Training and practice in speaking before groups, preparation of materials for oral presentations, discussion and interviewing techniques, extemporaneous speaking. Not open to students who were required to take HU 008. Students who take HU 120 or HU 121 may not take HU 119. Prerequisite: Placement in HU 009, HU 101, HU 103, or HU 200 as a result of the English Composition Placement Examination.

HU 120   Public Speaking and Pronunciation   1½:1½:2
Training and practice in speaking before groups, preparation of materials for oral presentations, discussion and interviewing techniques, extemporaneous speaking, pronunciation and speaking of English. This course is only for intermediate English as a Second Language students who are required to take HU 008 as a result of the English Composition Placement Examination. Students who take HU 119 or HU 121 may not take HU 120. Prerequisite or corequisite: HU 008.

HU 121   Public Speaking   3:0:3
Training and practice in speaking before groups, preparation of materials for oral presentations, discussion and interviewing techniques, extemporaneous speaking. Not open to students who were required to take HU 008. Students who take HU 119 or HU 120 may not take HU 121. Prerequisite: Placement in HU 009, HU 101, HU 103, or HU 200 as a result of the English Composition Placement Examination.

HU 125   Reporting and Writing
for the Wire Services   3:0:3
Reporting, writing, and editing the news under the pressure of tight deadlines (often the same day). Many assignments require field research as this course attempts to simulate a wire-service reporter's daily experiences. Trips to AP and UPI headquarters are arranged. Reporting accuracy, thoroughness and good journalistic style stressed. Wire-service history and editorial practices covered.

HU 130   Creative Writing I   3:0:3
The art and craft of writing poetry, fiction and drama. Students experiment with all genres. Students' own work stressed. Weekly written assignments discussed and criticized.

HU 131   Creative Writing II   3:0:3
Advanced art and craft of writing poetry, fiction and drama. Application of individual talents to specific forms. Development of intelligent critical responses to all forms of literature. Weekly written assignments, plus one longer writing project: a story, play or small collection of poems. Prerequisite: HU 130 or permission of instructor.

HU 135   Introduction to Corporate Communications   3:0:3
Intensive study, through a review of case histories and writing assignments requiring field research, of all aspects of editorial work in the communications department of a medium-sized or large corporation. Students research, write and edit copy for press releases, newsletters, proposals, house organs, community-relations campaigns, brochures, and annual reports. Business correspondence, short nontechnical memos and reports, and formats for minutes of meetings and job descriptions.

HU 136   Writing Annual Reports   3:0:3
The single most important document produced by a corporation is its annual report. Students learn and practice procedures by which such a publication is written and produced: planning, scheduling, researching, writing, editing, graphics and production.

HU 140   Proposal Writing   3:0:3
Solicited and unsolicited proposals in government and private sectors covered. Elements of typical proposals, such as statements of the problem, technical discussions, how teams organize to perform work, fiscal information, technical competence of companies to perform the task and key personnel discussed. Students prepare an outline and write a proposal on a specific topic as the major course assignment.

HUMANITIES AND COMMUNICATIONS

HU 141   Graphics and Production Techniques   3:0:3
Graphic design and production techniques and procedures for technical writers and editors. Magazine layout and production of technical reports, manuals and proposals. Composition methods, copy preparation and processing, page makeup, mechanics, printing processes, magazine imposition. Workshop atmosphere.

**HU 142   Writing Operations and
                Maintenance Manuals   3:0:3**
Preparation of industrial and military technical instruction manuals covering all phases of operation and maintenance of various kinds of equipment discussed. How to write these documents according to government specifications. Compilation of technical information for manuals and use with graphics and tabular material (such as troubleshooting charts) in practical writing situations. Assembling of parts lists.

**HU 150-151   Special Projects
                      in Communications   each 3:0:3**
Independent work in an area of communications selected by student in consultation with instructor. For majors only.

HU 155   Special Topics in Journalism   3:0:3
Courses on special topics in journalism are offered from time to time by department staff or by visiting scholars. Specific titles and prerequisites are announced prior to registration. May be repeated for credit.

HU 160   Writing the News for TV and Radio   3:0:3
The special formats required for writing news for TV and radio. Rewriting of newspaper articles and wire copy in styles necessary for these formats. Practice in broadcasting news and writing newscasts under pressure. Prerequisites: HU 108 or permission of instructor.

**HU 161   Writing and Producing
                Documentaries for Broadcast   3:0:3**
Working in teams, students research, write and narrate documentary radio and television broadcasts on pressing social, economic, political, scientific and technological issues, with emphasis on local topics. Production as well as journalistic side of broadcasting. Study of classic models at the Museum of Broadcasting.

LITERATURE

Please note: HU 200 or IS 140-141 is a prerequisite for all courses in this section.

Engineering department sequencing requirements impose additional prerequisites for many of these courses. See the Degree Requirements section in this catalog.

(See also Literature in Translation and Interdisciplinary Studies, below)

HU 201   Literature of Western Civilization I   3:0:3
Sources of modern ideals and values in ancient world: Greek drama, Plato, Lucretius, the Bible and others.

HU 202   Literature of Western Civilization II   3:0:3
Source of modern ideals and values from Middle Ages to 18th century: miracle plays, Shakespeare, Milton, Voltaire and others.

HU 203   Literature of Western Civilization III   3:0:3
Intellectual and cultural, moral and spiritual values of modern world in novels, drama, philosophy, poetry. Literature of Romantic revolt, Goethe, Dostoevski, Brecht, Sartre, Solzhenitsyn, American and European poetry.

HU 211   English Literature from Beowulf to 1800   3:0:3
English literature from Beowulf through Chaucer, Elizabethans and Jacobeans to 1800.

HU 212   English Literature from 1800 to Present   3:0:3
English literature from Romantics to present (Wordsworth, Byron, Dickens, Tennyson, Shaw, Conrad, Beckett and others).

HU 213   Science and Literature   3:0:3
With emphasis on modern period, examination of the literary merits of scientific and imaginative literature devoted to and affected by science. Readings in such authors as Charles Darwin, T.H. Huxley, Bertolt Brecht, Sinclair Lewis, Arthur Koestler, Heinar Kipphart, James Watson, Kurt Vonnegut and Isaac Asimov.

HU 222   Shakespeare   3:0:3
Representative tragedies, comedies, histories. Cultural, social and literary influences. Textual problems, recent criticism, Elizabethan theatre

HU 251   American Literature to 1880   3:0:3
Puritan and neoclassic periods through romantic movement and rise of realism. Jonathan Edwards, Paine, Irving, Poe, Hawthorne, Emerson, Thoreau, Whitman, Twain, James and others.

HU 252   American Literature from 1880 to Present   3:0:3
Major American writers from 1880. Background and thought of Crane, Dreiser, Robinson, Frost, Millay, Sandburg, O'Neill, Cather, Wharton, Lewis, Hemingway, Fitzgerald, Wolfe, Faulkner.

HU 258   American Thought*   3:0:3
Background, development and dynamics of American thought. Protest and conformity, individualism and collectivism, sentimentality and pragmatism. Americans as moral agents, as revealed in mass media and in readings in literature and philosophy.

HU 262   Contemporary American Novel   3:0:3
Contemporary American novel as affirmative expression of the human situation. Technical and philosophical analyses of such writers as Golding, Salinger, Updike, Roth, Vonnegut, Clarke, Bellow and others.

HU 264   The Short Story
Themes, structure, techniques of short stories by writers as diverse in style and philosophy as Chekhov, Twain, O. Henry, Mansfield, Lardner, Faulkner, Thurber and Hemingway.

HU 272   Contemporary American Poetry*   3:0:3
Contemporary American poetry as affirmative expression of the human situation. Technical and philosophical analyses of recent writers.

HU 281   Comedy   3:0:3
Nature and uses of humor as viewed by playwrights, psychologists, philosophers. Theories of comedy from Aristotle to Freud. Plays from Aristophanes and Moliere to Giraudoux and Shaw. Humor from Tarleton to Chaplin and Benchley.

HU 283   Modern American Drama   3:0:3
Technical and philosophical analyses of O'Neill, Miller, Anderson, Hellman, Williams, Inge, Albee and others. Some contemporary American films may be included.

HU 291   Short Fiction   3:0:3
Major writers of the novella (long short story). Study of the relationship between literature and ideas in such writers as Saul Bellow, Albert Camus, Joseph Conrad, Ernest Hemingway, Franz Kafka, Thomas Mann, Alexander Solzhenitsyn, Nathaniel West. Class discussions, cinematic presentations of some works and theatre visits are integral to course.

HU 295   Literary Interpretation and Criticism*   3:0:3
Literary criticism from Plato and Aristotle through Dryden and Pope to T.S. Eliot. Principles of classicsm, romanticism, realism, existentialism. Aesthetic problems of literary genres. Explications and interpretations of texts

HU 297   English Language*   3:0:3
History and development of English language. Readings in old, middle and early modern English. Middle English exemplified by selections from Chaucer's *Canterbury Tales.*

PHILOSOPHY AND COMPARATIVE RELIGION

Please note: HU 200 or IS 140-141 is a prerequisite for all courses in this section.

Engineering department sequencing requirements impose additional prerequisites for many of these courses. See the Degree Requirements section in this catalog.

HU 341   Introduction to Philosophy   3:0:3
An initial inquiry into problems, methods and terminology of Western philosophy through study and discussions of selected philosophical texts.

HU 344   Introduction to Logic   3:0:3
Principles and problems in syllogistic and propositional logic. Introduction to first order predicate logic. Some discussion of the history of logic, informal fallacies and relations between logic and language.

HU 345   Advanced Logic   3:0:3
Review of propositional logic, followed by an extended study of first order predicate logic. Examination of metamathematical and philosophical issues associated with formal systems. Introduction to higher order logic, semantics and modal logic. Prerequisite: HU 344 or equivalent.

HU 346   Ethical Theories   3:0:3
A study of one or more major ethical theories. The nature of human action, distinctions between good and bad, virtue, sources of obligation, freedom of action, human valuation and conscience.

HU 347   Ethics and Technology   3:0:3
An examination of some basic ethical theories of human action and how these relate to technological making and using. Use will be made of case studies of various ethical problems as well as some classic ethical texts.
Also listed under LA 140.

HU 348   Great Philosophers I   3:0:3
Selected works of such philosophers as Plato, Aristotle, the Stoics, neo-Platonists, St. Augustine, Maimonides, St. Thomas Aquinas.

HU 349   Great Philosophers II   3:0:3
Philosophy from the Renaissance to the 19th century, emphasizing the rationalist tradition (Descartes, Spinoza, Leibniz), the empiricist tradition (Bacon, Locke, Hume) and Kant.

HU 352   Philosophy of Science   3:0:3
Central problems in theories of science and scientific methodology. Relation between science and philosophy; scope and objectives of natural sciences, role of mathematics in science; observation and experimentation; laws, theories, explanations; causality and induction.

HU 353   Philosophy of Technology   3:0:3
The nature and meaning of human making and using activities, examined by means of a critical reading of various conceptual, anthropological, ethical-political and metaphysical-epistemological studies.

HU 354   Social and Political Philosophy*   3:0:3
Examination of philosophical and ethical foundations of divergent sociopolitical theories and systems. Analysis of such concepts as justice, the good, freedom, authority, rights in the thoughts of selected political philosophers.

HU 363   World Religions*   3:0:3
Fundamental beliefs and practices of the major world religions: Hinduism, Buddhism, Confucianism, Taoism, Judaism, Christianity, and Islam. Readings in religious texts complemented by audiovisual presentations.

HU 364   Philosophy of Religion*   3:0:3
An examination of some of the key issues in understanding religion: the nature of religion and religious experience; relationships between faith and reason; arguments for and against the existence of God; problems of human destiny, death, immortality, religious language and pluralism in religion.

HU 365   Science, Technology and Religion*   3:0:3
The implications of science and technology for religion, and of religion for science and technology. Does scientific cosmology support or undermine religious beliefs? Does the scientific method influence the interpretation of religious texts? What is the religious response to moral issues raised by technology? Is religion responsible for the development of Western technology?

MUSIC AND FINE ARTS

Please Note: HU 200 or IS 140-141 is a prerequisite for all courses in this section.

Engineering department sequencing requirements impose additional prerequisites for some of these courses. See the Degree Requirements section in this catalog.

HU 371   Understanding of Music   3:0:3
Active, intelligent listening to masterpieces of Western music from its origins through Bach, Beethoven, and Brahms. Major musical forms: concerto grosso, fugue, sonata, symphony, concerto, music drama, tone poem. Analysis of orchestra scores. Parallel trends in other arts. The changes in the social roles of music.

HU 375   Modern Music   3:0:3
Music from 1850 to present: Wagner, Strauss, Mahler, Debussy, Stravinsky, Ives, Schoenberg, Berg, Weber, Varese. Revolt against romanticism; breakdown of traditional tonal-harmonic system. Polyharmony, polytonality, pantonality, melodic fragmentation, aleatory and electronic music as expressions of the 20th century. Jazz, modern popular music and music of other cultures.

HU 382   Fine Arts I   3:0:3
Historical and analytical study of Western architecture, sculpture, painting. Egyptian, Greek, Roman architecture and sculpture. Gothic and Renaissance art. Parallel trends in other arts.

HU 383   Fine Arts II   3:0:3
Historical and analytical study of Western architecture, sculpture, painting from 1600 to present. Baroque, neoclassic, romantic styles. Revolt against romanticism and quest for new artistic, decorative and tectonic forms to express contemporary civilization.

HU 389   Art of Asia*   3:0:3
Architecture, sculpture, painting as cultural, social and religious expressions of India, China, Japan, Southeast Asia and Islamic world. Comparisions between Oriental and Occidental arts as modes of thinking and feeling.

SPECIAL TOPICS

Please Note: HU 200 or IS 140-141 is a prerequisite for all courses in this section.

Engineering department sequencing requirements impose additional prerequisites for these courses. See the Degree Requirements section in this catalog.

HUMANITIES AND COMMUNICATIONS

The following special topics courses are offered from time to time by the staff of the department or by visiting scholars. Specific titles and prerequisites are announced before registration. May be repeated for credit.

HU 300 Special Topics in Humanities   3:0:3
HU 301 Special Topics in Literature   3:0:3
HU 302 Special Topics in Philosophy   3:0:3

MODERN LANGUAGES

Note: Students must begin a language sequence at the level of their proficiency. Normally students who have had two years of a language in high school would begin with the third semester of a language in college. If in doubt of the level of proficiency, a student should consult the appropriate instructor in the department.

GERMAN

ML 111   German I: Foundation Course   3:0:3
For students with no previous training in German. Audiolingual techniques used to develop proficiency in reading, comprehension, speaking. Early practice in reading original German prose and representative poems.

ML 112   German II   3:0:3
Continuation of foundation provided by ML 111. Reading of original German prose; selections from Hesse, Kastner, Zweig and others. Prerequisite: ML 111 or equivalent.

**ML 113   German III: Readings in
                  German Literature Since 1800   3:0:3**
Reading and discussion of prose, lyric poetry and drama to acquaint students with outstanding writers, ideas, movements in German literature. May be taken by students who have had secondary school training in German. Prerequisite: ML 112 or equivalent.

ML 114   German IV   3:0:3
Continued reading of significant German writing with critical and aesthetic evaluation. Also selected reading in philosophical and scientific subjects. Practice in conversation. Prerequisite: ML 113 or equivalent.

ML 115   Conversation and Composition*   3:0:3
Spoken German with particular attention to idiomatic expressions; compositions with training in syntax and style. Prerequisite: ML 114 or equivalent.

ML 121   Scientific German I*   3:0:3
Introductory course for students who wish to acquire facility in translation of scientific material from German into English. Fundamentals of grammar, problems of syntax and idioms, with emphasis on scientific terminology. May not be offered in fulfillment of any language sequence or as a humanities elective.

ML 122   Scientific German II*   3:0:3
Continuation of ML 121. Reading material selected from periodical and technical journals covering several fields in science and engineering. May not be offered in fulfillment of any language sequence or as a humanities elective. Prerequisite: ML 121 or equivalent.

ML 213   German Drama from 1800 to Present*   3:0:3
Major 19th-century dramatists, including Hebbel, Kleist, Grillparzer, Hauptmann. Background, analysis, interpretation of German drama of 20th century. Lectures, readings and reports. Prerequisite: ML 114 or equivalent.

ML 214   Contemporary German Literature*   3:0:3
20th-century German writers and literary movements. Lectures, readings, reports. Prerequisite: ML 114 or equivalent.

ML 215   Goethe's Faust, Part I*   3:0:3
Background and genesis of Goethe's drama. Reading and discussion of Part I, examining its aesthetic, moral, ethical values. Prerequisite: ML 114 or equivalent.

ML 216   Goethe's Faust, Part II*   3:0:3
Reading and discussion of Part II, examining its modern cultural implication. Consideration of Goethe's contribution to science. Prerequisite: ML 215.

**ML 217-218   German Thought from
                       Kant to Present I, II*   each 3:0:3**
Significant intellectual currents in writings of philosophers, scientists, poets, social critics. First semester from Kant to Nietzsche, second semester from Nietzsche to present. Readings in German and English. Prerequisite: ML 114 or equivalent

ML 220   German Civilization*   3:0:3
Cultural and political history of Germany, with discussions of physical and political geography, art, music, religion, philosophy, education, social and economic structures. Prerequisite: ML 114 or equivalent.

FRENCH

ML 131   French I: Foundation Course   3:0:3
For students with no previous training in French. Audiolingual techniques used to develop proficiency in reading, comprehension, speaking. Early practice in reading original French prose and representative poems.

ML 132   French II   3:0:3
Continuation of foundation provided by ML 131. Reading of modern French prose and poetry. Prerequisite: ML 131 or equivalent.

**ML 133   French III: Readings in
                  French Literature Since 1800   3:0:3**
Reading and discussion of prose, lyric poetry, drama to acquaint students with outstanding writers, ideas, movements in French literature. May be taken by students who have had secondary school training in French. Prerequisite: ML 132 or equivalent.

ML 134   French IV   3:0:3
Continuation of ML 133. Reading of cultural, philosophical, scientific subjects. Practice in conversational French. Prerequisite: ML 133 or equivalent.

ML 135   Conversation and Composition*   3:0:3
Spoken French with particular attention to idiomatic expressions; compositions with training in syntax and style. Prerequisite: ML 134 or equivalent.

**ML 235-236   French Thought From
                       Rabelais to Sartre I, II*   each 3:0:3**
Traces course of two major currents in French thought: liberalism and traditionalism. First semester on Rabelais, Montaigne, Descartes, Pascal, Rousseau, Voltaire, the Encyclopedists. Second semester on Joseph de Maistre, Balzac, Michelet, Comte, Taine, Renan, Bergson, Sartre, Maritain, Levi-Strauss. Readings in French and English. Prerequisite: ML 134 or equivalent.

ML 237   Contemporary French Literature   3:0:3
Varied currents of 20th-century literature from Proust to Camus, Sartre, the exponents of the nouveau roman. Lectures, readings, reports. Prerequisite: ML 134 or equivalent.

ML 238   French Civilization   3:0:3
Cultural and political history of France and French community, with discussion of physical and political geography, art, music, religion, philosophy, education, the social and economic structures. Prerequisite: ML 134 or equivalent.

RUSSIAN

ML 151 Russian I: Foundation Course* **3:0:3**
For students with no previous training in Russian. Audiolingual techniques used to develop proficiency in reading, comprehension, speaking. Early practice in reading original Russian prose and representative poems

ML 152 Russian II* **3:0:3**
Continuation of foundation provided by ML 151. Reading of Russian prose and poetry. Prerequisite: ML 151 or equivalent.

ML 153 Russian III: Readings in 19th-Century Russian Literature* **3:0:3**
Reading and discussion of prose, lyric poetry, drama to acquaint students with outstanding writers, ideas, movements in Russian literature. Prerequisite: ML 152 or equivalent.

ML 154 Russian IV* **3:0:3**
Continuation of ML 153. Reading of cultural, philosophical, scientific subjects. Practice in conversational Russian. Prerequisite: ML 153 or equivalent.

ML 155-156 Contemporary Russian Literature and Civilization* **each 3:0:3**
Reading of Soviet prose and poetry. Simultaneous study of USSR's geographic, political, cultural status. All readings in Russian. Prerequisite: ML 154 or equivalent.

SPANISH

ML 161 Spanish I: Foundation Course **3:0:3**
For students with no previous training in Spanish. Audiolingual techniques used to develop proficiency in reading, comprehension, speaking. Early practice in reading original Spanish prose and representative poems.

ML 162 Spanish II **3:0:3**
Continuation of foundation provided by ML 161. Reading of modern Spanish prose and poetry. Prerequisite: ML 161 or equivalent.

ML 163 Spanish III: Readings in Spanish Literature Since 1800 **3:0:3**
Reading and discussion of prose, lyric poetry, drama to acquaint students with outstanding writers, ideas, movements in Spanish literature. May be taken by students who have had secondary school training in Spanish. Prerequisite: ML 162 or equivalent.

ML 164 Spanish IV **3:0:3**
Continuation of ML 163. Reading of cultural and philosophical subjects. Practice in conversational Spanish. Prerequisite: ML 163 or equivalent

ML 265-266 Culture of Latin America I, II **each 3:0:3**
Intellectual and literary aspects of Hispano-American civilization touching on historical, sociological, political, economic backgrounds. Readings in Spanish. Discussion of contemporary life and practice in speaking Spanish. Prerequisite: ML 164 or equivalent.

LITERATURE IN TRANSLATION

Please note: HU 200 or IS 140-141 is a prerequisite for all courses in this section.

Engineering department sequencing requirements impose additional prerequisites for these courses. See the Degree Requirements section in this catalog.

ML 311 Currents of Unrest in 20th Century: German Literature (in English translation)* **3:0:3**
Study of some major writers of German-speaking countries against turbulent political background of Europe in 20th century: Hesse, Kafka, Mann, Boll, Grass.

ML 312 Currents of Unrest in 20th Century: French Literature (in English translation)* **3:0:3**
Study of modern French authors: Sartre, Camus, Beckett, Ionesco, Genet.

ML 313 Currents of Unrest in 20th Century: Russian Literature (in English translation)* **3:0:3**
Modern Russian literature in post-revolutionary political and social setting. Sholokhov, Pasternak, Solzhenitsyn.

ML 318 The Hebrew Bible* **3:0:3**
A study of three parts of Hebrew Bible with emphasis on language of Bible and traditional modes of interpretation. Discussion of recent paleographic and archaeological materials.

ML 319 The Jewish Heritage* **3:0:3**
Rapid survey of Jewish history. Language of the Jews: Rabbinical Hebrew, Aramaic, Yiddish (West and East), Judeo-Arabic, Judeo-Persian, Ladino, modern Hebrew. The Jewish Year: laws and customs. Survey of sources and guide to literature.

LINGUISTICS

Please note: HU 200 or IS 140-141 is a prerequisite for all courses in this section.

ML 381 Language and Society* **3:0:3**
Nature and social functions of language. Its key properties as contrasted with animal communication. Theories on origin of speech. Vocal organs. Introduction to phonetics and phonemics. History of writing. Phonetic changes. Survey of world's languages. Etymology, semantics, semantic shifts. May be taken as humanities elective.

ML 382 Introduction to the Study of Language* **3:0:3**
Principles and methods of descriptive study of language; survey of major linguistic theories; development of writing; typological diversity in world's languages and mechanisms of language change that give rise to linguistic variety. May be taken as humanities elective.

ML 383 Advanced Topics in Study of Language* **3:0:3**
Descriptive and historical linguistics. Detailed analysis of topics in syntax, phonemic problems in study of English and foreign languages, graphemics, linguistic phylogeny and phylogenetic changes. Generative-transformational, mathematical and computational linguistics. Machine translation. May be taken as humanities elective. Prerequisite: ML 381 or ML 382 or equivalent.

INTERDISCIPLINARY STUDIES

IS 140 Language and Communication **3:0:3**
Types of language and modes of communication, including animal (bee, chimpanzee) and human communication, language development in children and the "languages" of music, art, literature and engineering (the Brooklyn Bridge). Readings, films, group projects and reports, museum visits, expository and creative writing.

IS 141 The Self and Society **3:0:3**
An exploration of the relationship between the individual and society, language as a vehicle of culture, cultural variety and the significance of cultural models (from Homer's *Odyssey* to Orwell's *1984* and O'Neill's proposed space colony). Readings, films, group projects and reports, museum visits, writing. Prerequisite: IS 140 or permission of instructor.

IS 145　The American, This New Man　3:0:3
The changing pattern of nationalism in the United States and the changing self-definition of the American in response to forces from within and from without—as found in literary, artistic and historical sources from the 17th century to the present. Prerequisites: IS 140-141 or HU 200 and SS 104.

IS 146　Brooklyn: History and Culture　3:0:3
An interdisciplinary exploration of the evolution of Brooklyn from a collection of aboriginal communities to a European colony and eventually an American city. Stressing social, political, economic and cultural factors, this course covers the physical growth, political evolution, economic development, transportation networks and cultural life of evolving Brooklyn. Prerequisites: IS 140-141 or HU 200 and SS 104.

GRADUATE COURSES

SCIENCE, TECHNICAL AND FINANCIAL WRITING AND JOURNALISM

JW 511†　Technical Writing about Digital Electronics　3½:0:4
Designed for students with no background in electronics, this course provides the fundamentals required for writing about digital electronics. Throughout the course emphasis is placed upon recognizing standard circuits, developing timing diagrams and writing functional descriptions. A three-tier approach is used in the written functional descriptions: high-level block diagram, intermediate block diagram, and detailed circuit analysis.

JW 600　Introduction to Specialized Journalism　2½:0:3
A course designed to familiarize the student with the career opportunities available and the writing requirements demanded in these major fields of specialization: financial and business journalism, industrial and trade magazine journalism, medical journalism, industrial public relations and advertising, scientific and engineering writing. Students will be required to research and write articles in each of these areas.

JW 601　Style for the Professional Writer　2½:0:3
Designed to strengthen the student's command of usage, style, grammar, punctuation, precision, logical structure and color through intensive copyediting practice.

JW 602　Proposal Writing　2½:0:3
Solicited and unsolicited proposals in both the government and private sectors are covered. The different types of proposals are covered. Topics include writing and editing, ability to work as a team member and to cope under heavy pressure, knowledge of graphics and production and procedures in proposal writing. Emphasis on the elements of a typical proposal, such as statement of the problem, technical discussion, how the team will organize to perform the task, fiscal information, technical competency of the company to perform the task and key personnel. The student will be required to prepare an outline and then to write a proposal on a specific topic worked out with the instructor as the major course assignment.

**JW 603　Reporting on Science, Technology
and Medicine　2½:0:3**
Emphasis on spot-news reporting and the Sunday-supplement feature aimed at a general newspaper audience. The longer interpretive pieces done for this course will required personal and/or telephone interviews with recognized medical, scientific and engineering authorities in a given discipline. The stories, however, will be written in a popularized vein for a general audience. Course will consider how science writers develop feature-article ideas and how they follow them through to publication. Students will be encouraged to submit the work they do in the course for publication.

JW 604　Graphics and Production Techniques　2½:0:3
An introduction to graphic design and production techniques and procedures for technical writers and editors, with emphasis on magazine layout and producing technical reports, manuals and proposals. Topics covered will include composition methods, copy preparation and processing, page makeup, mechanics, printing processes, magazine imposition. Course will be conducted in a workshop atmosphere.

JW 605　Libel Law and Press Ethics　2½:0:3
Based on a study of some classic cases, this course will familiarize the student with the essentials of libel law necessary when writing for publication. Journalistic ethics and writer's responsibilities to sources and readers are also considered.

JW 606　Oral Technical Presentations*　2½:0:3
The factors that make an engineering or scientific talk or panel discussion not only informative but interesting to the listener from an audio-visual standpoint as well. Major considerations are content of the talk, the speaker's demeanor, use of visual aids, delivery of the paper (diction, enunciation, voice, posture, gestures, methods of presentation). Students will participate in speechmaking situations and in panel discussions covering a wide variety of technical subjects.

JW 607　Writing News for Radio and Television　2½:0:3
This course is designed to train students to write news for the electronic media. The focus will be on science and business news stories. The course will entail intensive practice in writing for radio and television, and will teach students accepted format and style of media news writing. The course will also acquaint students with the requirements and limitations of the media and how these must be taken into account in news writing. Students will use video and audio technology in the course.

JW 608　Introduction to Documentation　2½:0:3
An introduction to the field of technical documentation in general and to computer documentation in particular. Includes a brief history of documentation and management needs in the documentation area, particularly techniques, production and core studies.

JW 609　Computer Documentation　2½:0:3
An overview and introduction to computer systems and software documentation. Topics include the history of computer documentation, market trends in the field, role of the documentation specialist, basic concepts and techniques, types of manuals, planning and management documentation. Prerequisite: one technical writing course and MG 602: Computers in Management.

JW 620　Financial and Business Reporting　2½:0:3
For students who intend to go into financial and business reporting or financial public relations, this course will be conducted as a workshop. Students will cover the business and financial scene as if they were reporting for a business periodical or the financial section of a newspaper. Hard business news reporting and interpretive pieces will be stressed in such areas as economic trends, marketing, corporate activities, the stock market, government regulations, industrial technology, labor-management relations, energy, industry and the environment and advertising. Course will familiarize the student with the corporate annual report, the investment company's research report, stock analysis reports, the financial press release. Financial and business publications will be studied.

JW 621 Reporting and Editing for the Business Press 2½:0:3

The need exists on business and trade magazines — both technical and non-technical — for reporters and editors with solid journalistic skills and a knack for digging out facts. This course surveys the diverse editorial opportunities in business-press journalism and helps the student develop the necessary skills in writing, editing and interviewing that such publications demand. Among the assignments: writing short news stories, copy-editing (including the writing of heads and decks), rewriting weak copy for a magazine's departments (new products, books and literature, case histories, news, company and personality profiles, etc.), short features describing plant layouts, machine operation, maintenance procedures and business conditions. Consideration will be given also to the longer feature article often referred to as the roundup story. Since most specialized business (trade) magazines serve a particular field of industry (automotive, electronics, petrochemicals, etc.), many of the articles appearing in them are contributed by industry authorities. The course will emphasize the responsibility of the editor to cultivate good working relationships with such people to induce them to write.

JW 622 Writing Copy for Industrial Public Relations 2½:0:3

A workshop approach to doing public relations work for a corporation requiring both product and corporate publicity. Course covers the PR functions from the standpoint of both the in-house staffer and the account executive at the agency. Among the subjects taken up: publicity methods used to introduce a new product, writing the standard press release, preparation of the technical article dealing with a phase of the company's expertise, writing and placement of case histories, arranging press conferences and plant tours, handling press inquiries, writing speeches. The course also considers the working relationship that develops between the PR agency and the in-house staff of the client in cases where companies utilize both services.

JW 623 Publications Management and Budgeting* 2½:0:3

Setting up and managing a budget for a publication. This course deals with all phases of expenses (fixed and variable) incurred in the establishment and operation of both a corporation's publications group and a business magazine's editorial department: sources of income, salaries and fringe benefits, art costs, production costs (including printing), travel and entertainment, telephone, space rental, office supplies, temporary help and other expenses normally incurred by editorial departments. Budgeting for the business magazine will concentrate on five key elements, showing how they relate to the editorial department's operation: editorial, mechanical, advertising, circulation, administration. Students will work on specific projects involving page budgets and dollar budgets.

JW 624 Writing Product-Information Copy 2½:0:3

Consideration of the mass of sales-promotional and technical catalogues, brochures, manuals, spec sheets, flyers and news releases that promote a company's products. Emphasis will be on the approaches to writing such material. In addition to preparing copy for the shorter product-promotion bulletins, students will be responsible for providing the text for a major catalogue or brochure promoting a given product or technology and based on raw data either provided by the instructor or gathered by students. Course will stress the need for product information of varying degrees of technical complexity to suit the technical competency of the prospective customer for whom the literature is intended.

JW 625 Advanced Medical Reporting 2½:0:3

Writing on medical and biological subjects, with emphasis on interviewing. Students will gather much of the information for their writing assignments from sources in the field and will prepare articles for the general press, semi-technical reports for pharmaceutical houses, articles for professional magazines and sales and promotional literature for medical products.

JW 626 Medical Public Relations 2½:0:3

The special considerations, responsibilities and problems faced by public relations officials at medical research facilities, hospitals, medical schools, foundations and fund-raising organizations and pharmaceutical companies. Emphasis on writing medical and pharmaceutical press releases, brochures, film scripts, other in-house publications, speeches, press kits for press briefings. Visits to medical facilities to talk with public relations officials and research scientists.

JW 627 Writing Copy on Pharmaceuticals and Drugs 2½:0:3

Course is geared to preparing students for expanding opportunities in writing copy for pharmaceutical and drug companies. Intensive practice in writing new-product data sheets, bulletins and other technical literature generally used by "detail" men; research reports, progress reports and other technical papers based on information supplied by the instructor and gathered on trips to local pharmaceutical companies; technical speeches; advertising and public relations copy. A major paper will be assigned as a term project.

JW 628 Writing Industrial Advertising Copy 2½:0:3

Covers the objectives of industrial and technical advertising and how to achieve them through the three basic ingredients of the magazine ad: copy, artwork and layout. Emphasis is on the principles of writing effective copy and heads, the process of media selection for a given ad (product promotion, institutional), the preparation of an ad campaign, how to set up booths for industrial displays and exhibits, conducting the direct-mail campaign, the value and preparation of sales literature and an analysis of business-publication advertising today. The roles of the company advertising manager and the agency's account executive and their interrelationship are delineated. Completion of a special project and several ad-writing assignments will be required.

JW 629 Writing the Marketing Report 2½:0:3

The purpose of the marketing report is to aid the client in finding the best means to increase sales of a given product. It is also employed to present the findings of test-marketing programs and to make recommendations based on these findings. This course deals with the writing of reports based on intensive analysis of customer reaction to a given product. Students will acquire the basic skills needed to research, analyze and interpret raw data gathered in putting together their own reports. The importance of making intensive use of tabular data and graphs will be stressed. Case histories will be studied.

JW 630 Basic Technical Report Writing I 2½:0:3

Fundamentals of technical writing. Emphasis on organization, clarity and accuracy in writing abstracts, descriptions of processes and mechanisms, definitions, short technical correspondence, trip reports, technical sales letters, technical information sheets and trouble-shooting reports. Study of related library information-retrieval techniques and use of data banks for background and verification of technical information.

JW 631 Basic Technical Report Writing II 2½:0:3

The longer report forms: progress, evaluation, feasibility, investigation. Analysis of parts of text, including statement of problem, methods, conclusions, and use of graphic and tabular material. Emphasis on logical organizations and clarity. Introduction to editing, layout and production techniques.

JW 632 Writing Technical Manuals 2½:0:3

Intensive practice in preparing industrial and military technical instruction manuals covering all phases of operation and maintenance of various kinds of equipment. Training in how to write these documents according to government specifications. The compilation of technical information for the manual and its use in conjunction with extensive graphics and tabular material (such as troubleshooting charts) are emphasized in practical writing situations. Assembling of a parts list is covered. The writing of military training manuals is also included.

JW 640 The Video Documentary*   2½:0:3
This course will provide students with an opportunity to write and produce video documentaries. The emphasis in the course will be on video materials used in industry, i.e., tapes used in training, sales and promotion. The course will be both a writing course and a production course. Since this course will involve large-scale projects, students should take it after JW 607, which will provide some background in video and media writing.

JW 641 Graphics Workshop   2½:0:3
A workshop devoted to the actual production of technical graphics — charts, graphs, newsletters, etc. Prerequisite: JW 604 or equivalent.

**JW 701 Special Project in
         Professional Writing**   2½:0:3
Students, working in conjunction with a faculty member, will pursue a course of independent study dealing with a special facet of professional writing. They will be expected to gather the bulk of their information firsthand, that is, from personal contact with their sources, in addition to conducting the usual literature search. The end result of this project will be an original, thought-provoking interpretive report to be submitted to the department for faculty review and approval.

JW 702 Special Topics in Journalism   2½:0:3
This special topics course will be offered from time to time by faculty members, visiting scholars and professionals. The special titles and prerequisites will be announced prior to registration.

ENGLISH AND HUMANISTIC STUDIES

HU 521 Seminar in Oral English   3:0:0
For speakers of English as a second language, practice in pronunciation, articulation, informal discussion and formal oral presentation. Emphasis on discourse skills characteristic of the American university environment. Admission by placement test as required by graduate departments or by student choice. Course may be taken more than once.

HU 522 Seminar in Written English   3:0:0
Writing workshop for foreign-born graduate students. Emphasis on integrating grammar and rhetoric into effective technical writing, using scientific data. Admission by placement test as required by graduate departments or by student choice. Course may be taken more than once.

HU 605 Report Writing   2½:0:3
Various standard forms of technical and scientific writing. Emphasis on clarification of purpose, logical organization, effective style. Analysis and discussion of reports appearing in current professional journals. Methodology of bibliography.

HU 622 Seminar in Shakespeare*   2½:0:3
Art and artifice in construction and motivation of several major plays by Shakespeare. Discussion and research papers. Prerequisites: HU 211, HU 212, HU 222 or equivalent.

HU 638 Seminar in American Thought*   2½:0:3
Basic American attitudes and concepts as revealed culturally—literature, films, periodicals, comics, art—with emphasis on development of American mythology. Prerequisites: HU 251, HU 252, HU 262 or equivalent.

HU 650 Symbolic Logic   2½:0:3
A study of the principles of logic as analyzed in the Aristotelian, Stoic, and modern mathematical traditions. Emphasis on the philosophical interpretations of and issues raised by these various approaches to the formalization of thought.

HU 651 Ethics and Technology   2½:0:3
Study of one or more of the ethical issues involved with technology: engineering ethics, environmental ethics, consumerism, the ethics of large scale systems, nuclear ethics, biomedical ethics, the ethics of technology transfer and development, media ethics, etc. Emphasis on the special ethical concepts developed in order to deal with these issues: responsibility, safety, liability, etc.

HU 652 Seminar in Philosophy of Science*   2½:0:3
Selected aspects of methodology, presuppositions, scope, goals of natural sciences. Relations between science and philosophy; relation of scientific knowledge to world of experience; status of logical and mathematical truth; nature of explanation; causality, determinism, induction; laws and theories; nature of meaning.

HU 653 Philosophy of Technology   2½:0:3
Selected investigation of issues in philosophy and technology studies: the nature of technology, its social and political context and implications, and its metaphysical, epistemological, and religious dimensions.

**HU 654 Seminar in Social and
         Political Philosophy***   2½:0:3
Central concepts of social and political thought, freedom, law, justice, rights, democracy, property in writings of historical and contemporary philosophers. Emphasis on various interpretations of these concepts found in currently influential and conflicting sociopolitical ideologies.

HU 655 Science, Technology, and Literature   2½:0:3
Selective examination of how science and technology have been reflected in imaginative literature, and on occasion been influenced by that literature. Emphasis on the period since the Renaissance.

HU 697 Seminar in English Language*   2½:0:3
History and development of English language. Sound shifts, morphology, phonology. Readings in old, middle, early modern English.

HU 700 Special Topics in Philosophy   2½:0:3
Specialized study devoted to a particular philosopher, philosophical tradition, or problem. With permission of the department, may be repeated for credit.

HU 701 Independent Study in Philosophy   2½:0:3
Directed independent study or project dealing with a particular philosopher, philosophical tradition, or problem. With permission of the department, may be repeated for credit

MODERN LANGUAGES

ML 611 German for Research*   2½:0:3
For students in all fields who need practice in translation of scientific writings from German into English. Enlargement of scientific vocabulary. Problems of syntax and idioms characteristic of scientific German. Intended to prepare students for M.S. and Ph.D. language examinations. Prerequisite: one year of German or instructor's permission.

ML 655 Russian for Research I*   2½:0:3
Introductory course for students who wish to acquire facility in translation of scientific material from Russian into English. Fundamentals of grammar, problems of syntax and idioms, with emphasis on scientific terminology. Not for thorough formal knowledge of the language. May not be offered in fulfillment of language requirement.

ML 656 Russian for Research II*   2½:0:3
Continuation of ML 655. Reading material from periodicals and technical journals covering fields of engineering and science. Prerequisite: ML 655 or equivalent.

FACULTY

Duane DeVries, Associate Professor of English and Head of Department
B.A., Kalamazoo College; M.A., Ph.D., Michigan State University
Dickens, the nineteenth-century English novel, expository writing

Victor Bobetsky, Professor of Modern Languages
B.S., M.A., Columbia University
German language and literature

Donald Hockney, Professor of Philosophy of Science
B.A., McMaster University; Ph.D., Cornell University
Philosophy of science, philosophy of language

Bernard Rechtschaffen, Professor of Modern Languages
B.S., M.A., Ph.D., New York University
Comparative literature, science and literature

Anne Eisenberg, Associate Professor of Humanities and Communications
B.A., Barnard College; M.A., University of Iowa; Ph.D., New York University
Linguistics, technical writing, reading

Sylvia Kasey Marks, Associate Professor of English
B.A., M.A., University of Michigan; Ph.D., Princeton University
Samuel Richardson, the eighteenth-century English novel, public speaking

Carl Mitcham, Associate Professor of Philosophy and Director of the Philosophy and Technology Studies Center
B.A., M.A., University of Colorado
Philosophy of technology

Lowell L. Scheiner, Associate Professor of Humanities and Communications
B.A., City College, City University of New York; M.A., Columbia University; M.S., Columbia University (Graduate School of Journalism)
Technical writing, journalism

Wolhee Choe, Assistant Professor of English
B.A., Adelphi University; M.A., Ph.D., City University of New York
Nineteenth-century English literature, literary theory, English as a second language

Jane Robinett, Assistant Professor of Humanities and Communications
B.A., Goshen College; M.A., Ph.D., University of Notre Dame
Software documentation, twentieth-century poetry

ASSOCIATED FACULTY

Paul Levinson, Visiting Professor of Humanities and Communications
B.A., New York University; M.A., The New School for Social Research; Ph.D., New York University

ADJUNCT FACULTY

Richard L. Amper, Jr., Adjunct Instructor of Communications
B.A., University of Missouri

Thomas Amper, Adjunct Instructor of Communications
B.A., Dartmouth College

Andrew Appel, Adjunct Instructor of Music
D.M.A., Julliard School of Music

Barbara Bartholomew, Adjunct Instructor of Communications
B.A., San Diego State University; M.S., Polytechnic Institute of New York

Edward Bell, Adjunct Instructor of Communications
B.A., City College, City University of New York

Trudy Bell, Adjunct Lecturer of Communications
B.A., University of California, Santa Cruz; M.A., New York University

Gerard Cardillo, Adjunct Lecturer of Communications

Allen M. Cobrin, Adjunct Instructor of Communications
B.A., City College, City University of New York; M.A., Columbia University

Frederick Courtney, Adjunct Assistant Professor of Modern Languages
B.A., Columbia College; M.A., University of Michigan; Ph.D., Columbia University

Manning Dandridge, III, Adjunct Instructor of English
B.A., M.A., State University of New York at Stony Brook.

Dennis Eskow, Adjunct Lecturer of Communications
B.A., Lehman College, City University of New York

Alice Ettenson, Adjunct Instructor of English
B.A., M.A., Hofstra University

Deborah Freedman, Adjunct Instructor of English
B.A., M.S., Brooklyn College, City University of New York; M.S., Polytechnic University

Peter Fusco, Adjunct Instructor of English
B.A., Hunter College, City University of New York

Peter Z. Grossman, Adjunct Associate Professor of Humanities and Communications
M.A., M.F.A., Columbia University

Erin Hayes, Adjunct Instructor of English
B.A., University of Wisconsin, Madison; M.A., City College, City University of New York

John Horgan, Adjunct Lecturer of Communications
B.A., Columbia University; M.S., Columbia University (Graduate School of Journalism)

Eric Katz, Adjunct Assistant Professor of Philosophy
B.A., Yale University; M.A., Ph.D., Boston University

HUMANITIES AND COMMUNICATIONS

Joan Kelly, Adjunct Instructor of English
B.A., Adelphi University; M.A., Long Island University

Edward Kerins, Adjunct Lecturer of Communications
Julliard School of Music

Leonore Kuhn, Adjunct Instructor of Communications
B.A., Hunter College; M.A., University of Arizona; M.S., Polytechnic University

Dirk Leach, Adjunct Instructor of Humanities
B.A., Bucknell University; M.A., State University of New York at Stony Brook

Linda Lerner, Adjunct Instructor of English
B.A., M.A., Brooklyn College, City University of New York

Dolores Massari, Adjunct Instructor of Communications
B.S., Fordham University; M.S., Polytechnic University

Isobel Mendelson, Adjunct Instructor of English
B.A., Syracuse University

Fred Messner, Adjunct Lecturer of Communications
B.A., B.S., Columbia University

Alan M. Nadler, Adjunct Instructor of English
B.A., Queens College, City University of New York; M.A.T., University of Iowa; M.F.A., Columbia University

Peter E. S. Nichols, Adjunct Instructor of English
B.A., Beloit College; M.A., City College, City University of New York

Mary Orovan, Adjunct Instructor of English
B.A., University of Southern California; M.A., New York University

Hans Ostermann, Adjunct Instructor of Modern Language
B.A., M.A., Hofstra University

Michelle Owens, Adjunct Instructor of English
B.A., Yale University; M.F.A., Columbia University

Colleen M. Sandford, Adjunct Assistant Professor of English
B.A., Washburn University; M.A., Ph.D., University of Illinois

John Sannuto, Adjunct Instructor of Speech
B.A., Brooklyn College, City University of New York; M.A., New York University

Wolfgang Schirmacher, Visiting Adjunct Associate Research Professor of Philosophy
Ph.D., University of Hamburg (Germany)

Nanci Milstein Shapiro, Adjunct Instructor of Art
B.A., M.A., State University of New York at Binghamton

EMERITUS FACULTY

John G. Cavanna, Professor Emeritus
Ph.D., University of Minnesota

Clifford Osborne, Professor Emeritus
M.A., University of Denver

IMAGING SCIENCES AND ENGINEERING

Imaging sciences and engineering (IS&E) is an interdisciplinary subject which concerns all aspects of the acquisition, communication, display, recording and understanding of pictorial information. It is the basis of world-wide industries, which include photography, graphic arts and television as well as newer areas of medical imaging, remote sensing, radar, computer graphics, pattern recognition and computer vision.

Until now, imaging has been taught as a component of other disciplines: optics as part of physics, image processing under electrical engineering, photoactive materials in chemistry. Now there has emerged the new discipline of Imaging Sciences and Engineering, to deal comprehensively and in an integrated fashion with the needs of this industry. The Institute of Imaging Sciences, founded at Polytechnic in 1981, offers a graduate program in these disciplines which provides the intellectual foundation for all imaging technologies.

Drawing on faculty from five departments and from industry, the Institute conducts a variety of projects in image processing, communications, optics and devices, and photoactive materials. Its educational program is centered on the master of science degree in imaging sciences and engineering.

THE GRADUATE PROGRAM

The preferred background for students entering the graduate program of IS&E is a bachelor's degree in electrical engineering from an ABET-accredited institution. Alternatively, a bachelor's degree in computer science, physics, mathematics or chemistry is suitable. Students with deficiencies in specific areas, particularly in mathematics, may be required to take one or more preparatory courses before entering the imaging sciences program. Professional experience in areas relating to imaging is given strong consideration during admission.

All courses in the curriculum are offered in the evening for the convenience of working professionals. The curriculum may be pursued either part-time or full-time, with normal completion in 3 years or 2 years respectively. All courses are open and may be taken under non-degree status. Candidates for the master of science degree in IS&E must plan their program with reference to the list of required courses.

Apart from the academic courses listed in the table, the Institute organizes a series of imaging colloquia where well-known experts offer seminars on a variety of imaging subjects. The colloquia are open to everyone and they do not carry academic credit, but they provide an opportunity for students and faculty to listen to and meet imaging experts from industry as well as from other universities.

Requirements for Master of Science Degree in Imaging Sciences and Engineering

No.	Required Courses	Units
IM 602	Optics	3
IM 603	Vision, Color	3
IM 604	Image Processing Principles I: Deterministic Signals	3
IM 605	Image Processing Principles II: Stochastic Signals, Information Theory	3
IM 606	Imaging Laboratory	3
IM 701	Image Analysis	3
IM 702	Image Processing Laboratory	3
IM 703	Chemical and Physical Image Recording: Graphic Arts	3
IM 704	Electronic Imaging	3

Having completed the required courses, the student registers for a master's project with his adviser. He also registers at that time for two elective courses to support that project.

Electives (Two from list)

No.	Course Title	Units
IM 730	Introduction to Medical Imaging	3
IM 731	Pattern Recognition	3
IM 740	Microlithography	3
IM 741	Topics in Imaging	3
IM 742	Topics in Imaging	3
PH 637	Radiation Physics, Medical Applications	3
PH 801	Medical Imaging Processing	3
CS 651	Computer Graphics	3
CS 653	Interactive Computer Graphics	3
CS 661-662	Artificial Intelligence	3
CS 908	Computer Vision and Scene Analysis	3
EL 551-552	Electro-Optics	3
EL 635	Data Communication Networks	3
EL 658	Fiber Optic Communication	3
EL 676	Fundamentals of Radar	3
EL 739	Information Theory	3
EL 935	Principles of Image Coding, Transmission and Reconstruction	3
MT 603-604	Electron Microscopy	3
MT 705	Semiconductor Technology	3

MS Project

No.	Course Title	Units
IM 990	Project in Imaging Science	3
	Total Credits (Required Courses, Two Electives, Project)	36

In order to qualify for the master of science degree, the student must obtain 36 credits. The MS project counts for 3 credits. All other courses are also 3 credit courses as

shown. It is possible to take courses separately on a non-degree basis. The academic credit accumulated by the special student will be counted towards the MS degree if later the student decides to complete the program for a degree. Some of our courses are accepted as electives in electrical engineering, physics and chemistry.

GRADUATE COURSES

IM 602   Optics   2½:0:3
Imaging: Introduction to Imaging; review of wave physics; radiation sources; ray optics and optical imaging; coherent optics and holography; graded refractive index materials. Fiber optics; optical signal processing. Electron and x-ray imaging systems; radiation detectors, electronic imaging.

IM 603   Vision, Color   2½:0:3
Radiometry and photometry; objective tone reproductions. Psychophysics of vision, color vision. Basic color science; principles of color reproduction.

**IM 604   Image Processing Principles I: Deterministic
                Signals   2½:0:3**
Representation and analysis of deterministic signals; periodic functions, non-periodic functions, and singularity functions; Hilbert transforms, the Laplace transform; systems of constant coefficient ordinary differential equations; samplings and measurements of signals. The discrete Fourier transform and the fast Fourier transform. Spectral computations with sampled signals.

**IM 605   Image Processing Principles II: Stochastic Signals,
                Information Theory   2½:0:3**
Input-output description, analysis and synthesis of linear systems; analog and digital linear systems as linear operators, non-recursive digital systems, recursive digital systems; digital and continuous systems, analog and digital filter designs. Review of random functions, random sequences and spectral estimates. Essentials of information theory. Prerequisite: IM 604

IM 606   Imaging Laboratory   0:5:3
This laboratory is designed to give students physical contact with imaging techniques. Image formation is explored from matrix ray tracing to Fourier transform optics and holography. Polarized light in anisotropic materials and electro-optic effects are investigated, and one experiment in a major imaging technology (silver halide photography, electrophotography) is included. Prerequisite: IM 602.

IM 701   Image Analyses   2½:0:3
Fundamental macroscopic and microscopic imput-output relationship for imaging processes. Signal and noise transfer functions: the modulation transfer function and the Weiner spectrum. Detective quantum efficiency and ultimate sensitivity. DQE analysis for practical imaging processes; image-theoretic metric. Prerequisite: IM 604.

IM 702   Image Processing Laboratory   0:5:3
This course is intended to familiarize graduate students with the basic tools of and recent developments in digital image processing. Topics include image registration, geometric correction, image restoration and enhancement, coding and retioing, image segmentation by edge detection and region analysis, texture and shape analysis and image reconstruction. Prerequisite: IM 605.

**IM 703   Chemical and Physical Image Recording;
                Graphic Arts   2½:0:3**
Chemistry of image recording; silver halide photography; electrophotography; other non-conventional imaging processes; photopolymers. Graphic arts.

IM 704   Electronic Imaging   2½:0:3
This is a survey of the field of electronic imaging and image recording, including a discussion of the principles of operation and the matrix of choices available to the systems designer. Figures of merit are established and state-of-the-art systems and building blocks of future systems of electronic imaging are presented. Prerequisite: IM 605.

IM 730   Medical Imaging   2½:0:3
An introduction to the physics and information theoretical aspects underlying recent developments in medical imaging are presented. Prerequisite: IM 605.

**IM 731   Pattern Recognitions, Principles and
                Methods   2½:0:3**
Basic principles and techniques for the design and analysis of automatic pattern processing and pattern recognition systems are reviewed. Emphasis is on the application of statistical decision theory, threshold logic and syntactic approaches to solving pattern recognition problems. Specific examples from physics, chemistry and medicine are discussed. Prerequisites: IM 603 and IM 605.

IM 740   Microlithography and Resists   2½:0:3
This course is addressed to chemists, material scientists and technologists working in microlithography, photofabrication and graphic arts. It deals with the chemistry, physics and applications of polymer-based imaging systems.

IM 741   Special Topics in Imaging   2½:0:'
Presentations, at intervals, of advanced or specialized topics in imaging science or technology. Projected subjects include integrated optics, graded index materials in imaging, holographic methods microimaging, radiation-sensitive materials and photogrammetry.

IM 742   Introduction to Remote Sensing   2½:0:3
Remote sensing is one of the important technological spin-offs of space exploration. This course presents an overview of the basic physics, the techniques and the practical applications of remote sensing.

IM 990   Project in Imaging Science   0:5:3
Experimental and theoretical investigation of a problem in imaging science under the guidance of a faculty adviser. A comprehensive written report is required, to be submitted to the adviser one week before the last day of classes. Prerequisite: Degree status and project adviser's approval.

FACULTY

Arnost Reiser, Professor of Chemistry; Director, Institute of Imaging Sciences
Formerly Head of Photochemistry Laboratory, Kodak, England; Dr. Ing. (Prague); D. Sc. (London); 1981 Henderson Medal of Royal Photographic Society
Photochemistry, Image Science

Isreal Abramov, Professor of Psychology, Brooklyn College of CUNY; Professor of Psychophysics, Rockefeller University
B.A., University College, London; Ph.D., Indiana University
Developmental studies of vision, visual perception

Leo Beiser, Consultant in Laser Technology; Formerly Director of Dennis Gabor Laboratory of CBS; Governor of Society of Photo-Optical Instrumentation Engineers
B.S. and M.S. (Physics), Hofstra University
Laser scanning, image displays

Leonard Bergstein, Professor of Electro-Optical Sciences
Ph.D., Polytechnic Institute of New York
Fiberoptics, electro-optics

Henry L. Bertoni, Professor Electrophysics
B.S., Northwestern University; M.S., Ph.D., Polytechnic Institute of Brooklyn
Electromagnetics, acoustics

George R. Bird, Professor of Chemistry, Rutgers University
Formerly head of Physcial Chemistry Laboratory, Polaroid Corporation
B.A., M.A. and Ph.D., Harvard University
Spectroscopy; fundamental photographic science

J. Warren Blaker, Head, Department of Electrical Engineering, Fairleigh-Dickenson University; Formerly Head of Physics Department, Vassar College
Ph.D., Massachusetts Institute of Technology.
Optics

Michael Bruno, Founder and first president of the Technical Association of Graphic Arts (TAGA); 1983 Gold Medal of Institute of Printing (England)
Printing and graphic arts

Irving Cadoff, Professor of Metallurgy
B.M.E., City College of New York; M.M.E., D. Eng. Sc., New York University
Microlithography

Patrick T. Cahill, Professor of Physics, Professor of Radiology, Cornell University Medical School
B.S. and M.S., University of New Hampshire; Ph.D., Harvard University
Medical imaging, radiation physics

Philip Chu, Associate Professor, Mechanical Engineering
B.S., National Cheng Kung University (Taiwan); M.S., Auburn University; Ph.D., University of South Carolina
Imaging in stress analysis

Jesse F. Crump, Associate Professor of Bioengineering
B.S., M.D., University of Nebraska
Bioengineering, medical imaging

Douglas A. Davids, Associate Professor of Electrophysics
B.S., M.S., Newark College of Engineering; Ph.D., Johns Hopkins University
Microwaves, acoustic imaging, thermal imaging

Bruce A. Garetz, Associate Professor of Physical Chemistry
B.A., Harvard University; Ph.D., Massachusetts Institute of Technology
Lasers and non-linear optics

Roy S. Freedman, Associate Professor of Computer Science
B.S., M.S. (EE), M.S. (Math), Ph.D., Polytechnic Institute of New York
Expert systems, artificial intelligence

Phillip A. Grieve, Head, Electrophysics Laboratory, Grumman Corporate Research Center
B.S., Cornell University; M.S. and Ph.D., UCLA
Radar and remote sensing

William J. Heacock, Senior Consulting Engineer, Fairchild Weston Systems
B.E.E., Pratt Institute; M.E.E., Polytechnic Institute of New York
Image processing

Irving Hirschberg, Director Technology Developments, Fairchild Weston Systems
B.E.E., Cornell University; M.S.E.E., Columbia University
Image acquisition and focal planes

Aaron Kershenbaum, Associate Professor of Computer Science
B.S. and M.S., Polytechnic Institute of Brooklyn; Ph.D., Polytechnic Institute of New York
Computer architecture

T.K. Kwei, Professor of Polymer Chemistry
M.S., National Chiao-Tung University (China); M.S., University of Toronto; Ph.D., Polytechnic Institute of Brooklyn
Polymer physical chemistry, polymer blends

Said Nourbakhsh, Assistant Professor of Metallurgy
B.S., Arya-Mehr University of Technology (Iran); Ph.D., Leeds University (England)
Phase transformations, electron microscopy

Eli M. Pearce, Professor of Polymer Chemistry, Dean of Arts and Sciences
B.S., Brooklyn College; M.S., New York University; Ph.D., Polytechnic Institute of New York
Polymer synthesis and degradation

S. Unnikrishna Pillai, Assistant Professor of Electrical Engineering
B.Tech., M.Tech., Indian Institute of Technology (Bombay); Ph.D., University of Pennsylvania
Signal processing, image reconstruction

Leonard Shaw, Professor and Head of Dept. of Electrical Engineering
B.S., University of Pennsylvania; M.S. and Ph.D., Stanford University
Image transmission and coding

Rodney Shaw, Director, Center of Imaging Science, Rochester Institute of Technology
Ph.D., Cambridge University; Journal Award and 1976 Charles E. Ives Award of The Society of Photographic Scientists and Engineers (SPSE); Editor, Journal of Imaging Science
Image analysis

Giuliana Tesoro, Research Professor of Polymer Chemistry
Ph.D., Yale University
Fiber science, polymers for electronic applications

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B.M.E., City College of New York; M.M.E. and Ph.D., New York University
Computer graphics

IMAGING SCIENCES AND ENGINEERING

Richard Van Slyke, Professor of Electrical Engineering
and Computer Science; Director, Center for Advanced
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B.S., Stamford University; Ph.D., University of California
(Berkeley)
Image communications

Edward K. Wong, Assistant Professor of Computer
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University; Ph.D., Purdue University
Pattern recognition, computer vision, artificial intelligence

Dante C. Youla, Professor of Electrical Engineering
B.E.E., City College of New York; M.S., New York University;
Member of the National Academy of Engineering
Image reconstruction, adaptive filtering
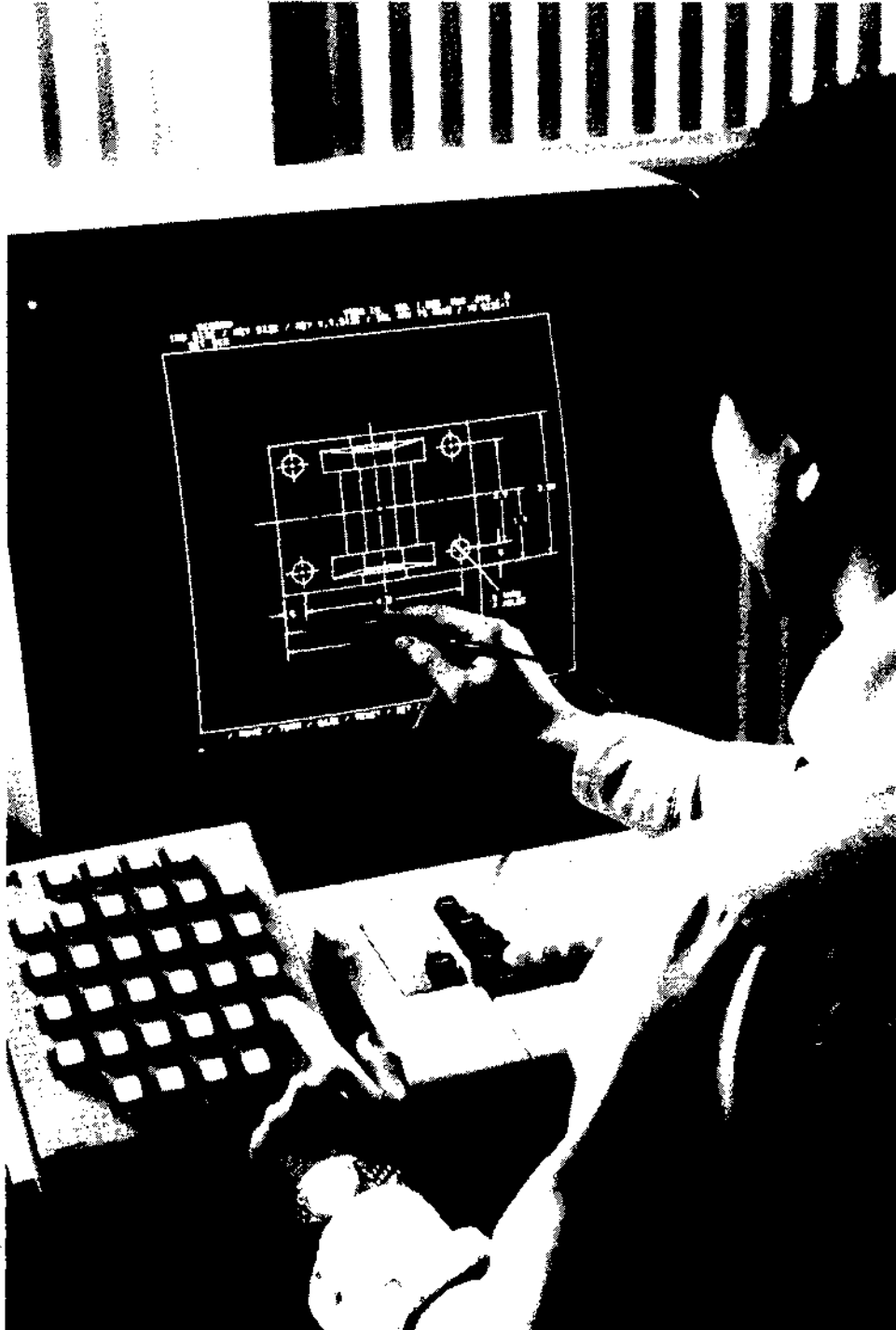
INDUSTRIAL ENGINEERING

The Department of Mechanical and Industrial Engineering offers programs in industrial engineering at the bachelor's, master's, engineer's, and doctor's levels.

Industrial engineering deals with the analysis, design and utilization of modern, large-scale systems, ranging from completely automated processing plants through urban systems—transportation, justice and health care, for example—to managerial systems composed solely of human beings. It concerns itself with those areas in which the systems approach, engineering knowledge and analytical techniques are applied directly to the urgent problems of society.

As noted in a career statement by the Institute of Industrial Engineers, "Industrial engineers deal with people as well as things. They look at the 'big picture' of what makes society perform best—the right combination of human resources, natural resources and man-made structures and equipment. Industrial engineers bridge the gap between management and operations, dealing with and motivating people as well as determining what tools should be used and how they should be used."

There are opportunities in many diverse areas. For example, industrial engineers are called upon to:
- Analyze and plan production schedules and inventories
- Devise ways of maximizing the effectiveness of hospitals and other health care facilities
- Diagnose and correct causes of poor quality in production
- Study the feasibility of equipment replacement
- Evaluate proposed traffic control procedures
- Locate new plants and design their physical layout
- Develop computer simulations of man-machine systems
- Study the effects of feedback and automation on society and industry

Industrial engineers apply engineering and operations research techniques to the analysis and solution of actual problems in industry, government and nonprofit service organizations. While there is considerable overlap of industrial engineering with operations research, a few differences may be noted. Operations researchers tend to emphasize analysis and prefer analytical models. Industrial engineers solve specific problems and design new man-machine configurations. They make heavy use of computers, frequently employing heuristic rather than analytic approaches.

Industrial engineers seek to allocate limited resources in an optimal manner. A unifying theme focusing this body of knowledge and methods into a coherent entity is the systems point of view. The search for similarity among concepts, laws and models of different disciplines, the emphasis on the adaptation, integration and exploitation of existing techniques in areas other than their fields of origin, and, above all, a unique point of view dealing with relationships rather than with components—these characterize industrial engineering.

These techniques are applied in a very wide range of organizations. There are industrial engineers in banks, hospitals, government, transportation and communications, construction, social service, facilities design, manufacturing, warehousing and information processing.

Many industrial engineers eventually move from the analysis and design of productive systems to their administration. While engineering and management are different fields, both require the ability to make decisions based on valid information. Industrial engineers are especially trained to obtain and evaluate such information.

LABORATORIES AND COMPUTING FACILITIES

The Department operates laboratories in the areas of work design and measurement, human factors, plant layout, robotics, automation, and noise measurement; these laboratories are equipped with the latest equipment, including numerically-controlled machine tools and a Fischerteck automated production line model. Besides direct experimentation, students engage in simulated experimentation and decision making using a broad range of computers.

In addition to the Polytechnic-wide computing facilities described elsewhere in this catalog, the Department maintains its own bank of IBM and compatible microcomputers and graphic workstations computers, as well as direct access and UNIX terminals connecting with the Polytechnic's IB 4341 and DEC-11 computers. Students use existing software packages or they may write their own.

UNDERGRADUATE PROGRAM

The undergraduate program leads to the degree of bachelor of science in industrial engineering, which is accredited by the Accreditation Board for Engineering and Technology.

The undergraduate program requires 136 credit-hours of work, including mathematics, chemistry, physics, humanities, social science, required departmental courses and technical and free electives. The humanities, technical and free electives permit a flexible program of study in which students have the opportunity to pursue individual interests that build on the core requirements.

While all engineers work primarily toward the creation of better products, industrial engineers are also concerned with the economic and human effects of changing technology. The undergraduate curriculum therefore provides a strong background not only in engineering, mathematics and physical sciences, but also in economics and psychology. In addition, the industrial engineering courses emphasize applications of these disciplines in industry, government and service institutions such as

hospitals, banks and schools. Industrial engineers are thus in a strategic position to bring about the best integration of people, materials, machines, time and money in any endeavor.

Senior Project

An important part of the program is the capstone senior design project course. In the senior year, students in small groups tackle a real-life problem under the guidance of a faculty advisor. The problems may be provided by industry or other outside sources, and may have a practicing industrial engineer as co-advisor. Oral and written reports help prepare the students for similar activities required in their professional lives.

Graduate Courses

Graduate courses may be taken as electives by qualified juniors and seniors with at least a B average, who obtain their advisers' approval. If the total number of credits exceeds those required for bachelor's degree, these graduate credits may be credited toward a graduate degree in accordance with current Polytechnic policy, if the student is admitted to graduate study.

Transfer Students

Transfer students who have completed two years of study at a college of liberal arts and science or a community college, may ordinarily complete requirements for bachelor's degrees in two additional years of study. Assuming that a student has completed 64 credits equivalent to MA 101-104, PH 104-106, PH 115-116, CM 101-102, CM 111-112, CS 112, HU 101, HU 200, SS 104, SS 189, SS 251, plus 16 credits of acceptable courses, the student can complete the requirements shown on page 164.

Evening Study

Many of the courses in the industrial engineering program are available in the evening or late afternoon for the convenience of part-time students. Part-time students can usually finish the program in eight years, without summer work, by averaging eight and a half credits per semester. However, students can change loads readily to suit their

See footnotes on following page.

educational needs, provided they do not violate prerequisites and Polytechnic time limits.

Suggested Elective Sequences

Students often seek guidance in using permitted electives to develop a meaningful sequence for concentration. Suggested groupings from which students may select electives are shown in the Operations Research section of this catalog; these are merely suggestions, not required sequences of study.

Requirements for the Degree of Bachelor of Science in Industrial Engineering

		Credits
Mathematics:	MA 101, MA 102, MA 103, MA 104, MA 223, MA 224	20
Science:	CM 101, CM 102, CM 111, CM 112, CS 112[1], PH 104, PH 105, PH 106, PH 115, PH 116	1$
Humanities:	HU 101, HU 200[1], SS 104[1], SS 189, SS 251	1:
Physical Ed:	PE 101, PE 102, PE 103, PE 104	(
Engineering:	EE 370, EE 374, ME 101, ME 111, ME 121	12
Management:	MG 304	3
Major:	IE 254[1], IE 300, IE 306, IE 311, IE 319, IE 321, IE 327, IE 328, IE 340, IE 365, IE 380, IE 389, IE 390	37
Electives:	Chosen by student in consultation with department adviser[2]	30
	Total	136

For detailed information on humanities and social sciences requirements, consult the catalog section on "Humanities and Social Sciences Requirements for Engineering and Computer Science Majors."

Typical Course of Study for the Degree of Bachelor of Science in Industrial Engineering

A typical program sequence is shown below covering eight semesters. Students may rearrange courses and increase or decrease loads per semester to suit their educational needs, provided prerequisites are not violated.

Freshman Year

First Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
CM	101	General Chemistry I	2½	0	2½
CM	111	General Chemistry Lab I	1½	0	½
CS	112[1]	Programming in Pascal	3	0	3
HU	101[1]	Writing & the Humanities I	3	0	3
MA	101	Calculus I	4	0	4
SS	104	Contemporary World History	3	0	3
SL	101	Student Survival	0	1	0
PE	101[3]	Physical Education	0	2	0
					16

Second Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
CM	102	General Chemistry I	2½	0	2½
CM	112	General Chemistry Lab I	1½	0	½
HU	200[1]	Writing & the Humanities II	3	0	3
MA	102	Calculus II	4	0	4
PH	104	Introductory Physics I	3	0	3
SS	189	Introduction to Psychology	3	0	3
PE	102[3]	Physical Education II	0	2	0
					16

Sophomore Year

			Cl.	Lab.	Cr.
IE	254	Intro. to Industrial Engineering	3	0	3
MA	104	Appl. Differential Equations	3	0	3
IE	101	Graphics	1	3	2
IE	111	Mechanics I	3	0	3
PH	105	Introductory Physics II	3½	0	3½
PH	115	Physics Laboratory I	0	1½	½
SS	251	Microeconomics	3	0	3
PE	103[3]	Physical Education III	0	2	0
					18

			Cl.	Lab.	Cr.
MA	103	Calculus III	3	0	3
ME	121	Mechanics of Materials	3	0	3
MG	304	Accounting Fundamentals	3	0	3
PH	106	Introductory Physics III	2½	0	2½
PH	116	Physics Laboratory II	0	1½	½
PE	104[3]	Physical Education IV	0	2	0
		Electives[2]			6
					18

Junior Year

			Cl.	Lab.	Cr.
IE	306	Work Design & Measurement	2½	1½	3
IE	327	Operations Research I	3	0	3
IE	340	Manufacturing Processes	2½	1½	3
MA	223	Introduction to Probability	3	0	3
		Electives[2]			6
					18

			Cl.	Lab.	Cr.
EE	370	Princ. of Electrical Engrg.	3	0	3
EE	374	Instrumentation Laboratory	0	3	1
IE	300	Engineering Economy	3	0	3
IE	328	Operations Research II	3	0	3
IE	365	Hum. Factors in Engrg. Design	2½	1½	3
MA	224	Intro. to Math Statistics	3	0	3
					16

Senior Year

			Cl.	Lab.	Cr.
IE	311	Statistical Quality Control	3	0	3
IE	319	Production Planning & Control	3	0	3
IE	380	System Simulation	2	3	3
IE	389	Project Laboratory I	1	3	2
		Electives[2]			6
					17

			Cl.	Lab.	Cr.
IE	321	Facility Planning & Design	3	0	3
IE	390	Project Laboratory II	1	3	2
		Electives[2]			12
					17

Total credits required for graduation: 136

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[1]Students may substitute IS 140, IS 141 for HU 200, SS 104. Students may substitute CS 100 for CS 112, and make up the missing credit with an additional credit of technical elective. This substitution is not recommended for students who expect to take additional CS courses; students who have taken a course in a high-level language (e.g., Pascal, FORTRAN, PL/1, BASIC) may apply to their adviser for permission to substitute 3 credits of technical elective.

If scheduling of transfer students necessitates taking principal IE courses before IE 254 can be taken, then an approved IE elective may be substituted for IE 254.

[2]The 30 credits of electives are to be distributed as follows. All require adviser's approval.
   6 credits of industrial engineering courses
   6 credits of engineering science selected from courses below (excess credits count as technical electives):

CS 236 Switching Circuit & Digital Syst.
ME 112 Mechanics II
ME 201 Thermodynamics
MT 301 Mechanical Behavior of Materials
or
MT 305 Mechanical Properties of Materials
MT 407 Transport Methods in Metallurgy
3 credits of technical electives—engineering or science
9 credits of humanities and social sciences; see catalog section on "Humanities and Social Sciences Requirements for Engineering & Computer Science Majors" for HU/SS requirements.
6 credits of free electives

[3]ROTC freshmen and sophomores may substitute zero-credit military science courses for PE 101-104 (physical education); juniors and seniors may substitute three of the following two credit courses: MS 301, 303, 401 or 403 for six credits of technical and/or free electives.

Typical Course of Study for Transfer Students

Junior Year

First Semester			Hours/Week			Second Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.	No.		Subject	Cl.	Lab.	Cr.
IE	254	Intro. to Industrial Engineering	3	0	3	IE	300	Engineering Economy	3	0	3
IE	306	Work Design & Measurement	2½	1½	3	IE	328	Operations Research II	3	0	3
IE	327	Operations Research I	3	0	3	IE	365	Hum. Fact. in Engrg. Design	2½	1½	3
IE	340	Manufacturing Processes	2½	1½	3	MA	224	Intro. to Math. Statistics	3	0	3
MA	223	Introduction to Probability	3	0	3	ME	121	Mechanics of Materials	3	0	3
ME	111	Mechanics I	3	0	3	MG	304	Accounting Fundamentals	3	0	3
					18						18

Senior Year

IE	311	Statistical Quality Control	3	0	3	EE	370	Princ. of Electrical Engrg.	3	0	3
IE	319	Production Planning & Control	3	0	3	EE	374	Instrumentation Laboratory	0	3	1
IE	380	System Simulation	3	0	3	IE	321	Facility Layout & Location	3	0	3
IE	389	Project Laboratory I	1	3	2	IE	390	Project Laboratory II	1	3	2
		Electives[2]			7	ME	101	Graphics	1	3	2
					18			Electives[2]			7
											18

Total credits required for graduation: 136

See four-year program for notes.

MANUFACTURING ENGINEERING CONCENTRATION

The industrial engineering profession originally dealt mostly with manufacturing. Over the years, industrial engineers have enlarged their expertise to include much wider ranges of applications, from hospital management to banking information systems. As a consequence industrial engineering education de-emphasized manufacturing engineering.

Today, manufacturing enterprises must operate with greater efficiency and precision to compete in international markets. To help American industry, Polytechnic has developed a concentration to emphasize manufacturing in its industrial engineering program.

The manufacturing engineering concentration was prepared by an interdisciplinary committee, aided by a select industrial advisory group and an extensive national survey. The concentration is designed to educate students in productivity, computer-aided design and computer-aided manufacturing (CAD/CAM), robotics, factory automation and computer-integrated manufacturing (CIM).

All courses required for the standard degree are also required in the manufacturing engineering concentration. The 30 credits of electives are satisfied as follows:

6 credits industrial engineering courses
    IE 342 Robotics Applications
    IE XXX Elective
6 credits engineering science
    MT 407 Transport Methods in Metallurgy
    CS 236, ME 111 or ME 201
3 credits technical elective
    AM 331 Comput. Meth. in Computer-Aided Design
9 credits humanities and social science
    Selected in consultation with adviser
6 credits free elective
    AM 332 Computer Graphics in CAD
    One more course selected in consultation with adviser

TRANSPORTATION CONCENTRATION

The academic preparation of industrial engineers is a very good basis for graduate study and careers in transportation planning and engineering. These fields, as described under the Transportation heading of the catalog, rely heavily on industrial engineering methodology as presented in the engineering economics, human factors, system simulation, facility planning, work design, statistical quality control, and operations research modelling courses.

Polytechnic's faculty and research programs in transportation provide unique opportunities for industrial engineering students to obtain a grounding in these fields. To this end, a transportation concentration is offered wherein students choose appropriate elective courses, as shown in the table below, and select transportation-related projects for the senior IE 389-390 laboratory courses.

All courses required for the standard degree are also required in the Transportation concentration. The 30 credits of electives are satisfied as follows:

6 credits of industrial engineering courses
    IE 350 Logistics
    IE 346 Operational Design of Public Systems
6 credits engineering science: select from
    CS 236, ME 111, ME 201, or MT 407
6 credits technical elective
    TR 360 Traffic Engineering
    TR 362 Public Transportation
9 credits humanities and social science
    Selected in consultation with adviser
6 credits of free electives

GRADUATE STUDIES

The department offers graduate programs in industrial engineering leading to degrees of master of science in industrial engineering, engineer in industrial engineering and doctor of philosophy.

Students may specialize in manufacturing systems, system simulation, quality control, experimental design, man-machine systems, production engineering, production and inventory models, reliability and maintainability, among other areas. Certificate programs are available for more limited graduate studies in specialized topics.

Graduate students come with diverse academic training. Many professionals in this area of specialization receive the major part of their training at the graduate level. Common to all our students is the desire to develop techniques for problem-solving and decision-making in a technical world.

MASTER OF SCIENCE DEGREE

The general Polytechnic requirements for master of science degree are stated in this catalog under "Degree Requirements." Detailed requirements for this degree are shown below.

Admission to the master of science program requires a bachelor's degree in an engineering discipline, from an accredited institution, with a superior undergraduate academic record. A student not meeting these requirements is considered for admission on an individual basis, and may be admitted subject to the completion of appropriate undergraduate courses to remove deficiencies in preparation.

Knowledge of computer programming in a high level language, such as FORTRAN, Pascal, BASIC or PL/I, is assumed. Students without this knowledge must take CS 530 or CS 531 without credit.

Students are encouraged to seek waivers for all required courses in which they can demonstrate competence, so that they can use their time most effectively.

Applications should be made to the department with industrial engineering indicated as the area of specialization.

Requirements for Degrees of Master of Science in Industrial Engineering

A. Basic Required Courses[1]
   IE 600 Engineering Economy
   IE 606 Work Design & Measurement
   MA 561 Elements of Probability
   IE 608 Statistics
   IE 627 Op. Res.: Deterministic Models[4]
   IE 628 Op. Res.: Stochastic Models[4]

B. Required Courses   12 units
   IE 611 Statistical Quality Control
   IE 619 Production Planning & Control
   IE 621 Facility Planning & Design
   IE 680 Discrete System Simulation

C. Major Electives: Select three courses[2]   9 units

   {IE 614 Modeling of Social & Mngrl. Systems
   {IE 682 Factory Simulation

   {IE 645 Productivity Management
   {IE 765 Human Factors in Engrg. Design
   {IE 775 Industrial Safety Engineering

   {IE 620 Project Management & Control
   {IE 776 Manufacturing Resource Planning
   {IE 778 Advanced Production Planning

   {IE 777 Manufacturing Improvement Curves
   {IE 779 Advanced Work Systems Design

   {IE 852 Applied Regression & ANOVA
   {IE 853 Design of Experiments

D. Other Relevant Electives[3]   15 units
                           Minimum total: 36 units

ENGINEER DEGREE

The degree of engineer in industrial engineering is a professional degree intended for engineers who desire to advance their professional development and training beyond the master's level but without the original research required of doctoral students. General requirements for the engineer degree are stated in this catalog under "Degree Requirements." Detailed requirements for this degree are given here.

Admission to the engineer degree program assumes possession of a master's degree substantially equivalent to the Polytechnic M.S. in I.E. The engineer degree requires a minimum of 72 units beyond bachelor's degree or 36 units beyond master's degree, including at least 6 units of a design project. On completion of the design project, the candidate will be required to make a final oral presentation before a faculty committee. The project may be waived by the guidance committee for professionally mature candidates who have previously completed work in their major areas judged to be of exceptional caliber, and for those students who have completed suitable master's theses or projects.

Requirements for Degree of Engineer in Industrial Engineering

The student with the adviser, will work out an approved program of study having at least 36 units, including the following (groups A, B, C and D refer to M.S. in I.E. requirements):

A.   All group A courses   (No credit)

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[1]All group A courses are required unless they are specifically waived by the adviser because the student either (a) has taken equivalent undergraduate or graduate courses or (b) passes a validation examination for the course. Up to three group A courses actually taken may be credited toward the degree requirements; if more than three must be taken, degree requirements are increased accordingly

[2]Only one of each bracketed set of courses is counted in the group in which it is listed; the other courses may be counted under group D

[3]Group D electives are to be chosen with the adviser's approval to bring total units to 36 plus any excess of group A courses beyond 9 units. They

may include thesis, additional courses from group C, or other graduate courses in this or other disciplines. For students interested in taking management electives, most MG courses will be approved however, because of substantial overlap with IE courses, no credit will be given for MG 502, MG 503, MG 505, and MG 630.

[4]Certain introductory courses will be waived if a student takes specified advanced courses, for which full credits will be given· For IE 627: IE 631 and IE 632. For IE 628: IE 650.

B/C.	All group B and C courses; only one of each bracketed set is required. No more than 7 of these courses may be credited toward the 36 units.	0-21 Units
D.	Any group E courses taken for the M.S. under group D, reduce group E requirements and increase group G.	
E.	Advanced Major Electives	9 units

Select 3 of the Following:
IE 612 Advanced Quality Control
IE 618 Inventory Models
IE 631 Linear Programming
IE 650 Queuing Systems I
IE 778 Advanced Production
    Planning
IE 779 Advanced Work Systems
    Design

F.	Project: IE 998 (unless waived by adviser)	6-12 units
G.	Other relevant electives	0-21 units
	Minimum total	36

DOCTOR OF PHILOSOPHY DEGREE

The Department offers a program leading to the degree of doctor of philosophy in operations research and industrial engineering. Students concentrating in industrial engineering must have bachelor's degrees in engineering disciplines from an accredited institution. The general Polytechnic requirements for the doctor of philosophy degree are stated in this catalog under "Degree Requirements." Specific requirements for the doctoral program may be found in the department's doctoral brochure.

Entrance to the doctoral program is contingent upon passing the program's qualifying examination. This consists of the Part I preliminary written examination and the Part II major field written examination; an oral examination may also be required.

The doctoral program requires a minimum of 90 units beyond bachelor's degree including a minimum of 24 units of dissertation; no more than 30 units of dissertation may be counted in the minimum total. After passing the written qualifying examination, the candidate selects a thesis adviser and prepares a formal proposal for the dissertation research. A thesis committee will be appointed to judge the merits of the proposed research. After approval of this proposal, the doctoral candidate registers for research. On completion of the dissertation, the candidate must pass an examination in its defense.

CERTIFICATE PROGRAMS

The department offers certificate programs designed for the professional with work experience. A certificate program requires five courses, which are selected in accordance with the needs of the individual. Applicants for a certificate program must hold a bachelor's degree. On completion of the sequence with a B average or better, the student is issued a certificate. Students who later are admitted to study for a master's degree are usually able to apply all certificate courses toward the master's degree.

If a student has taken the equivalent of any required courses as an undergraduate, or more than one as a graduate student, then substitute courses must be selected in consultation with the adviser. Additional information may be obtained from the department.

The certificate programs are shown below. Additional certificates are shown in the Operation Research section of this catalog.

Basic Industrial Engineering
IE 600 Engineering Economy
IE 606 Work Design & Measurement
MA 561 Elements of Probability
IE 608 Statistics
IE 627 Op. Res.: Deterministic Models

Advanced Industrial Engineering
IE 611 Statistical Quality Control
IE 619 Production Planning & Control
IE 621 Facility Planning & Design
IE 628 Op. Res.: Stochastic Models
    One of the following:
IE 778 Advanced Production Planning
IE 779 Advanced Work System Design

Quality Control & Reliability
MA 561 Probability
IE 608 Statistics
IE 611 Statistical Quality Control
IE 686 Component Reliability
    One of the following:
IE 612 Advanced Quality Control
IE 685 System Reliability
YY XXX Approved Elective

Production & Inventory Control
IE 627 Op. Res.: Deterministic Models
IE 618 Inventory Models
IE 619 Production Planning & Control
IE 776 Manufacturing Resource Planning
    One of the following:
IE 671 Business & Economic Forecasting
IE 680 Discrete System Simulation
IE 778 Advanced Production Planning

UNDERGRADUATE COURSES

Note: Junior or senior standing is required for all undergraduate IE courses except IE 254.

IE 254   Introduction to Industrial Engineering   3:0:3
Basic principles of industrial and manufacturing engineering. Introduction to work design, manufacturing processes, inventories and modeling in industrial engineering.

IE 300   Engineering Economy   3:0:3
Economic and financial consideratiosn in engineering decisions. Decision criteria under certainty, risk, uncertainty. Cost concepts, financial calculations, capital sources, accounting data, depreciation. Comparison of alternatives by annual cost, present worth and discounted cash flow methods. Minimum cost and maximum profit determination, replacement and economic life, breakeven analysis, effect of taxes, intangible factors. Prerequisite: junior standing.

IE 302   Legal and Ethical Responsibilities of Engineers*3:0:3
Responsibilities of engineers in design, operation and maintenance. Liabilities as brought out in court cases. Moral and ethical decision making, tradeoffs, and cost-benefit analysis in deciding for more safety versus more reliability, speed, efficiency or profit. Specific areas of concern include safety, health, and ethical dilemmas in the work place, the products and services produced therein, the environmental fallout, and the operation of engineered systems for transport, communications, the home and other institutions of modern society. Prerequisite: junior standing.

IE 306   Work Design and Measurement   2½:1½:3
Principles and techniques of designing work methods and work simplification programs. Theory and techniques of work measurement, including time study, work sampling and standard data systems. Laboratory sessions in methods analysis, rating, work allowances and stopwatch time study. Prerequisite: junior standing.

IE 311   Statistical Quality Control   3:0:3
Process control: concept of statistical stability—operational randomness, control charts for variables and attributes. Product control: design and analysis of attributes sampling plans, concept of producer's and consumer's risks, AOQL, AQL, and LQ of sampling plans, military sampling plans. Introduction to variable sampling plans. Cost of quality. Zero defects and related concepts. Prerequisite: MA 224.

IE 314   Simulation of Continuous Systems*   3:0:3
Modeling and simulation of high order engineering, physical, managerial and social systems. Linear and non-linear models as interrelated positive and negative loops with emphasis on structure, feedback and delays. Exploration of various control algorithms as related to quickness of response and avoidance or attenuation of oscillation, using DYNAMO. Applications to manufacturing and social systems. Prerequisite: Knowledge of calculus and computer programming, and junior standing.

IE 319   Production Planning and Control   3:0:3
Analytical techniques for designing and operating production systems. Assembly-line balancing, job sequencing, inventory control, project planning with PERT and CPM. Applications of linear programming algorithms to shop loading and production scheduling of single and multiple products. Prerequisite: IE 327.

IE 320   Project Planning and Control*   3:0:3
Network planning techniques for project management and resource allocation. Emphasis on PERT, CPM, and probabilistic generalized networks. Heuristic models for multi-project scheduling and resource leveling. Other topics include network development, computer adaptation, progress reports and project monitoring. Prerequisite: knowledge of computer programming and junior standing.

IE 321   Facility Planning and Design   3:0:3
Development of quantitative models for analysis of facility layout and location problems. Solutions by both mathematical optimization and heuristic algorithms. Locations of single and multiple facilities in existing and new layout design. Other topics include computerized layout planning, materials handling systems, evaluation and improvement of facility productivity. Prerequisites: IE 306 and IE 327.

IE 327   Operations Research I   3:0:3
Development of mathematical models for solving decision problems of deterministic nature. Classical optimization, Lagrange multipliers, linear programming, transportation method, network procedures, games. Dynamic programming. Prerequisite: MA 103 and junior standing.

IE 328   Operations Research II   3:0:3
Mathematical models for solving decision problems of stochastic nature. Queuing, Markov processes, Inventory models, reliability, probabilistic dynamic programming. Prerequisites: IE 327 and MA 223.

IE 340   Manufacturing Processes   2½:1½:3
Properties of materials relating to fabrication methods. Casting. Metal cutting mechanics, cutting fluids, thermal and vibrational aspects of machining. Machinability criteria. Deformation processing, hot and cold, mechanics of deformation. Joining and welding. Unconventional processing. Electrochemical and electrodischarge machining. Numerical control. Metrology. Prerequisite: junior standing.
Also listed under MT 340

IE 342   Robotics Applications*   2½:1½:3
Applied robotics and integration of robots into manufacturing processes. The course will cover robotic work space design and selection of robot types to suit each phase of industrial engineering. Laboratory experiments will include construction and use of robots and scaled models. Plant visits, field trips and case studies. Prerequisite: Junior standing.

IE 346   Operational Design of Public Systems*   3:0:3
Description, analysis and optimization of public systems. Population, economy, resource allocation, land use, transportation networks and facility location. Case studies of pollution control, criminal justice system, library management, fire fighting strategies and public health. Prerequisites: IE 327 and IE 328.

IE 350   Logistics*   3:0:3
Analysis of logistic problems and procedures applied to inventory control, materials handling systems, packaging, warehousing, transportation, facility location, information/communications, and customer service. Cost tradeoffs between the various components in optimization of the total logistics system. Logistics systems design and productivity measures. Business and military cases and applications. Prerequisite: IE 328.

IE 365   Human Factors in Engineering Design   2½:1½:3
Study of research techniques that yield information important in man-machine systems design. Man's learning, problem-solving, physiological and information processing capacities, performance under various environmental conditions. Prerequisite: SS 189 and junior standing.

IE 375   Industrial Safety Engineering*   3:0:3
Analysis and design of industrial accident prevention, control and management systems. Effect of OSHA, Workmen's Compensation and environmental factors in implementing safety programs. Project work involves safety inspection, detection and control of hazards. Prerequisite: junior standing.

IE 376   Manufacturing Resource Planning*   3:0:3
Quantitative models for analysis of production and inventory management systems. Topics covered include bill of material structures, time-phased parts requirements, shop loading and capacity constraints, priority planning and control, and schedule regeneration. Development of computer-based MRP systems. Prerequisites: IE 319, or permission of instructor, and knowledge of computer programming.

IE 380   System Simulation   2:3:3
Modeling and simulation of discrete stochastic systems, including random variables and statistical phenomena. Study of SIMSCRIPT II.5; introduction to PC-based simulation software packages. Students develop, code, run, and experiment with several simulation models. Prerequisite: MA 224 and knowledge of computer programming.

IE 389-390   Project Laboratory I, II   IE 389—1:3:2
IE 390—credit arranged
Independent project combining elements of theory, experimentation, design and construction used to learn methods of approach, design of experiments, modeling, validation and utilization of results which are common to undertaking of project development. Student-faculty seminars discuss individual projects to encourage student's exchange of ideas and methods, and to enhance each student's abilities in oral and written communication in engineering endeavors. Prerequisite: senior standing.

**IE 391-392 Selected Topics in Industrial
Engineering and Operations
Research I, II*   each 3 credits**
Areas not covered in other courses. Specific topics vary according
to instructor, who may be a visiting professor. Topics and prerequi-
sites announced during term prior to offering.

**IE 393-394 Guided Studies in Industrial
Engineering and Operations
Research I, II   each 3 credits**
Individual reading of selected papers and current literature in spe-
cialized areas of study, guided by faculty member. Prerequisite:
approval of adviser, instructor and department chairman.

IE 396 Industrial Engineering Internship*   credit arranged
Supervised, creative engineering experience of at least two months'
duration culminating in written and oral report presented to industrial
and faculty supervisors. Faculty visits and conferences during in-
ternship. Arrangements to be made prior to beginning internship
experience. Prerequisite: completion of junior year and departmen-
tal approval.

**IE 399 Senior Honors Work in
Industrial Engineering and
Operations Research   credit arranged**
Independent work undertaken by qualified honors students in indus-
trial engineering or operations research under faculty guidance.
Prerequisites: senior standing and adviser's approval.

GRADUATE COURSES

IE 600 Engineering Economy   2½:0:3
Economic and financial considerations in engineering decisions.
Decision criteria under certainty, risk, uncertainty. Cost concepts,
financial calculations, capital sources, accounting data, deprecia-
tion. Comparison of alternatives by annual cost, present worth and
discounted cash flow methods. Minimum cost and maximum profit
determination, replacement and economic life, breakeven analysis,
effect of taxes, intangible factors. (Not open to students who have
taken IE 300.)

IE 606 Work Design and Measurement   2:1:3
Principles and techniques of designing work methods and work
simplification programs. Theory and techniques of work measure-
ment, including time study, work sampling and standard data sys-
tems. Laboratory sessions in methods analysis, rating, work al-
lowances and time studies. (Not open to students who have taken IE
306.)

IE 608 Statistics   2½:0:3
Estimation, confidence limits, tests of hypothesis, regression analy-
sis. Applications to engineering problems. (Not open to students
who have taken MA 224.) Prerequisite: MA 561.
Also listed under MA 562.

IE 611 Statistical Quality Control   2½:0:3
Process control: concept of statistical stability—operational ran-
domness, control charts for variables and attributes. Product con-
trol: design and analysis of attributes sampling plans, concept of
producer's and consumer's risks, AOQL, AQL, and LQ of sampling
plans, military sampling plans. Introduction to variables sampling
plans. (Not open to students who have taken IE 311.) Prerequisite: IE
608.

IE 612 Advanced Quality Control*   2½:0:3
Continuation of IE 611. Theoretical basis of variable sampling plans.
Emphasis on recently developed techniques: cumulative sum
charts, theory of runs, evolutionary operations, non-normal variables
sampling plans, treatment of outliers in industrial data. Prerequisite:
IE 611

**IE 614 Modeling of Social and Managerial
Systems*   2½:0:3**
This course introduces the student to general systems theory as it
applies to managerial and social phenomena. Systems are viewed
as irrelated positive and negative feedback loops whose behavior is
governed by structure, amplification, and delays. Using the
DYNAMO language, students prepare, analyze, and restructure
several models in ecology, management, economics, and areas
related to their individual interest.
Also listed under MG 714.

IE 618 Inventory Models*   2½:0:3
Study of inventory systems. Deterministic and probabilistic models.
Fixed versus variable reorder intervals. Dynamic and multistage
models. Statistical forecasting of demands and lead times. Control
of dynamic inventory systems with lead times. Prerequisites: MA 561
and either IE 627 or IE 631.

IE 619 Production Planning and Control   2½:0:3
Analytical techniques for designing and operating production sys-
tems. Assembly-line balancing, job sequencing, inventory control,
project planning with PERT and CPM. Applications of linear pro-
gramming algorithms to shop loading and production scheduling of
single and multiple products. (Not open to students who have taken
IE 319.) Prerequisite: IE 627 or IE 631.

IE 620 Project Planning and Control   2½:0:3
Network-planning techniques for project management and resource
allocation. Emphasis on PERT, CPM, and probabilistic generalized
networks. Heuristic models for multi-project scheduling and re-
source leveling. Other topics include network development, com-
puter adaptation, progress reports and project monitoring. (Not
open to students who have taken IE 320.) Prerequisite: knowledge of
computer programming.
Also listed under MG 810 and CE 828.

IE 621 Facility Planning and Design*   2½:0:3
Development of qualitative models for analysis of facility layout and
location problems. Solutions by both mathematical optimization and
heuristic algorithms. Location of single and multiple facilties in ex-
isting and new layout design. Other topics include computerized
layout planning, materials handling systems, evaluation and im-
provement of facility productivity. (Not open to students who have
taken IE 321.) Prerequisites: IE 606 or permission of instructor and
either IE 627 or IE 631.

**IE 627 Operations Research:
Deterministic Models   2½:0:3**
Development of mathematical models of solving decision problems
of deterministic nature. Classical optimization, Lagrange multipliers.
Linear programming, transportation method, network procedures,
games. Dynamic programming. (Not open to students who have
taken IE 327 or equivalent.) Prerequisite: Calculus.

**IE 628 Operations Research:
Stochastic Models   2½:0:3**
Mathematical models for solving decision problems of stochastic
nature. Queuing, Markov Processes, inventory models, reliability,
probabilistic dynamic programming. IE 628 and IE 627 constitute
standard one-year survey course in operations research. (Not open
to students who have taken IE 328 or equivalent.) Prerequisite: MA
561.

IE 631 Linear Programming   2½:0:3
Theory and application of linear programming techniques. Simplex
and revised simplex algorithms. Duality theory, dual simplex
method, postoptimality analysis. Degeneracy. Transportation and
assignment problems. Applications, problem formulation, computer
solutions. Prerequisite: MA 153.
Also listed under MA 813.

**IE 997 Thesis for Degree of
Master of Science** **each 3 units**
Original investigation in topic chosen by student. Conferences and progress reports required during work and final written report required; oral examination may be requested by department. Registration and degree credit beyond first six units require separate approval. Prerequisites: degree status and approval of supervising professor, adviser and department head.

IE 998 Project for Degree of Engineer **each 3 units**
Post-master's investigating of significant problem, utilizing modern techniques of analysis and design. Project to be selected and developed in consultation with faculty member. Written report required, after which student is examined orally. Six units must be accumulated. Prerequisites: degree status and supervising professor's approval.

**IE 999 Dissertation for Degree of
Doctor of Philosophy** **each 3 units**
Doctoral dissertation must give evidence of and embody results of extended research in specific field of industrual engineering, constituting original contribution. Candidate required to take oral examination on subject of thesis and on related topics. Minimum of 24 units required. Prerequisite: completion of qualifying examination and guidance committee's approval.

FACULTY

William R. McShane, P.E., Professor of Transportation and Industrial Engineering: Head, Department of Mechanical and Industrial Engineering; Director, Transportation Training and Research Center
B.E.E., Manhattan College, M.S., Ph.D., Polytechnic Institute of Brooklyn; Professional Engineer (N.Y., CA. (Traffic))
Traffic engineering, highway capacity, expert systems in transportation, PC applications and models, economics and finances.

Edmund J. Cantilli, P.E., Professor of Transportation Planning
B.A., B.S.C.E., Columbia University, Cert. in Highway Traffic Engineering, Yale University; Ph.D., Polytechnic Institute of Brooklyn; Professional Engineer (N.Y., N.J., CA. (Traffic))
Transportation and industrial safety, environmental impacts of transportation urban planning, pedestrian, bicycle planning, and human factors.

Norbert Hauser, Professor of Industrial Engineering and Management Science
B.M.E., Cooper Union; M.I.E., Eng.Sc.D., New York University
Modeling of social systems, computer simulation, quality control, factory simulation

Walter Helly, Professor of Operations Research
B.A., Cornell University; M.S., University of Illinois; Ph.D., Massachusetts Institute of Technology
Stochastic modeling, tele- and vehicular traffic, urban systems

Joachim I. Weindling, P.E., Professor of Operations Research and System Engineering and Director of Operation Research Program
B.M.E., City College of New York; M.S., Ph.D., Columbia University; Professional Engineer (N.Y., PA.)
Mathematical programming, optimum design, economic evaluation

Herman Grau, Associate Professor of Industrial Engineering and Director of Manufacturing Engineering Program
B.M.E., Polytechnic Institute of New York; M.I.E., New York University
Methods, work measurement, project management, manufacturing engineering, robotics

Ravinder Nanda, Associate Professor of Industrial Engineering and Operations Management,
B.Sc., Banaras Hindu University (India); M.S., Ph.D., University of Illinois
Production and operations planning, productivity analysis, project control

John S. Zuk, Instructor in Industrial and Manufacturing Engineering
B.M.E., Union College; M.S. (IE), Polytechnic University
Modeling of manufacturing systems, computer simulation, robotics

ADJUNCT FACULTY

James Browne, Adjunct Professor
B.A., St. John's University; M.A., Brooklyn College

Johnson Edosomwan, Adjunct Professor
B.S., M.S., University of Miami; D.Sc., George Washington University; P.Engr., Columbia University

Owen Hill, Adjunct Professor
B.S., Texas A & M University;
M.S., Ph.D., University of California at Berkeley

John. H.K. Kao, Adjunct Professor
B.S., National Central University (China); M.S., Eng.Sci.D., Columbia University

Sambhu Mukho, Adjunct Professor
B.S., Jadav Pau University; M.S., City University of New York; M.B.A., New York University

Maureen Dolan, Adjunct Assistant Professor
B.A., Molloy College; M.S., Stevens Institute of Technology; M.S., Polytechnic Institute of New York

Lois Engel, Adjunct Lecturer
B.S., M.B.A., Hofstra University

Fred Fenster, Adjunct Lecturer
B.S., Drexel University

Margaret Gaudet, Adjunct Lecturer
B.S., Polytechnic University

Peter Martino, Adjunct Lecturer
B.E.E., Manhattan College; M.S., Stevens Institute of Technology; Engineer, Polytechnic University

William Ronai, Adjunct Lecturer
B.S., City College of New York; M.S., C.W. Post College

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INFORMATION MANAGEMENT

Information Management is an interdisciplinary program dealing with the design, operation and maintenance of systems which serve the information needs of business and manufacturing organizations.

Currently, there is a great demand for graduates in this field. Industries in the metropolitan New York area such as banking, finance, retailing, utilities and hospitals, as well as manufacturing have been unable to meet employment requirements in information management for several years. A typical position calls for technical competence and the ability to work closely with computer operations personnel, auditors, consultants, and user department representatives, and other project team members.

Polytechnic educates information management professionals who, after graduation, are usually assigned individual or team tasks, which they are able to complete independently and with minimal supervision.

Cooperative Program & Internships

A four to five year cooperative education program is available which permits students to integrate academic courses and career preparation. While earning the B.S. degree, students are able to earn up to 75% of their college expenses. Students who wish a less intensive work experience as part of their education may wish to enroll in a summer internship with advisors' permission.

UNDERGRADUATE PROGRAM

Polytechnic offers a program of study, administered by the Division of Management, leading to the Bachelor of Science degree in Information Management. Students are offered both day and evening courses on a full or part-time basis.

The program's objectives are to provide students with the educational background and skills to qualify for entry level positions as application programmers or analysts in the business world. Unlike computer science, where mathematics, science and software development are emphasized, information management is business oriented. Students must be aware of problems encountered by management which require timely information.

This in-depth program enables interested students to move into project leadership positions within one to five years after entering industry without additional courses. Finally the program provides a solid foundation for the student who wishes to pursue graduate study.

Requirements for Degree of Bachelor of Science in Information Management

The curriculum, requiring 128 credits for graduation, consists of four components: computing, management/system analysis, arts and sciences, and electives.

	Credits
Computing: CS 112, CS 212, CS 204, CS 211, CS 308, MG 202	18
Management/System Analysis: IE 254, IE 300, IE 314, IE 320, IE 380, MG 300, MG 301, MG 304, MG 316, MG 390, MG 401	33
Humanities/Social Science: HU 101, HU 110, HU 200, LA 110, LA 130, LA 131, LA 132, LA 140, LA 142, LA 143, LA 150, SS 104, SS 251, SS 252	45
Mathematics: MA 101-102, MA 231	11
Freshman Seminar: SL 101	0
Physical Education: PE 101-104	0
Electives	21
Total	128

ROTC students should note that freshmen and sophomores may substitute zero-credit military science courses for PE 101-104 (physical education); juniors and seniors may substitute three of the following two-credit courses for six credits of electives: MS 301, 303, 401 or 403.

Graduate courses may be taken as electives by qualified juniors and seniors with at least a B average who obtain advisors' approval. If the total number of credits exceeds those required for the bachelor's degree, these graduate courses may be credited toward a graduate degree in accordance with Polytechnic policy.

Four-Year Programs

A typical program sequence is shown covering eight semesters. Students may rearrange courses and increase or decrease load per semester to suit their educational needs, provided prerequisites are not violated.

Cooperative Program & Internships

A five-year cooperative education program is available which permits students to integrate academic courses and career preparation. While earning the B.S. degree, students are able to earn up to 75% of their college expenses. Students who wish a less intensive work experience as part of their educational may wish to enroll in a summer internship with advisers' permission.

Transfer Students

Transfer students from other accredited schools are accepted into the B.S. program after evaluations of their transcripts by faculty advisers. Graduates of technology programs may fulfill bachelor's degree requirements in two to three-and-one-half years, depending upon the scope and level of their previous education.

Typical Course of Study for the
Bachelor of Science Degree in Information Management

Freshman Year

First Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
HU	101	Writing and the Humanities	3	0	3
LA	110	Technol. & Society in Historical Perspective	3	0	3
MA	101	Calculus I	4	0	4
MG	202	Computers in Mgt.	2	3	3
SS	104	Cont. World History	3	0	3
SL	101	Student Survival	0	1	0
PE	101	Phys. Ed. I	0	2	0
					16

Second Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
CS	112	Programming in Pascal	3	0	3
HU	200	Writing and the Humanities II	3	0	3
LA	130	The Physical World	4	0	4
MA	102	Calculus II	4	0	4
MG	304	Accounting Fund.	3	0	3
PE	102	Phys. Ed. II	0	2	0
					17

Sophomore Year

CS	211	COBOL Programming	3	0	3
IE	254	Intro. to Ind. Eng.	3	0	3
LA	131	The Biological World	3	3	4
LA	132	The Behavioral World	3	3	4
SS	251	Microeconomics	3	3	3
PE	103	Phys. Ed. III	0	2	0
					17

MG	300	Management Process	3	0	3
CS	204	Data Structures	3	0	3
HU	110	Basic Report Writing	3	0	3
LA	140	Ethics and Technology	3	0	3
SS	252	Macroeconomics	3	0	3
PE	104	Phys. Ed. IV	0	2	0
					15

Junior Year

CS	212	C,UNIX and Software Development	3	0	3
IE	320	Project Planning & Control	3	0	3
LA	142	Machines: Extension of Man	3	0	3
		Elective			6
					15

LA	143	Info., Comm., and Society	3	0	3
CS	308	Intro. to Database Systems	3	0	3
IE	300	Engineering Economy	3	0	3
IE	314	Modeling of Social Systems	3	0	3
LA	143	Info., Comm. & Society	3	0	3
		Electives			3
					18

Senior Year

IE	380	System Simulation	3	0	3
LA	150	Making of Connections	3	0	3
MG	301	Organizational Behavior	3	0	3
		Electives			6
					15

MG	316	Commercial Data Proc. Systems Design	3	0	3
MG	390	Decision Making Lab.	2	3	3
MG	401	Senior Project			3
		Electives			6
					15

Total credits required for graduation: 128

FACULTY

This interdisciplinary program is administered by the Division of Management. The faculties of industrial engineering, computer science, humanities, social sciences, and mathematics participate in delivering the program.

INFORMATION SYSTEMS ENGINEERING (NEW OFFERING)

The Computer Science Division of Polytechnic University supported by the Electrical Engineering and Computer Science Department offers a Master of Science degree program in Information Systems Engineering.

The development of the curriculum was sponsored by the New York State Center for Advanced Technology in Telecommunications (CATT) at Polytechnic University which continues to coordinate the program.

The programs development was supported by a private sector advisory board. The board's current functions are to

(i) monitor the effectiveness of the program
(ii) help keep the detailed course syllabi current
(iii) propose changes in the program in light of experience.

The philosophy of the program is to provide rigorous education in the component disciplines of computers and telecommunications with emphasis on the unified field of information systems engineering. The focus is the application of theoretical insights to practical problems. The program combines courses from electrical engineering, computer science, social science and management.

ADMISSION REQUIREMENTS AND APPLICATION FOR INFORMATION

Admission to the program requires a bachelor's degree from an accredited institution with a superior undergraduate academic record and demonstrated proficiency in calculus, probability and a programming language.

Currently this program is offered in special format where all students are working professionals in telecommunications or computers and are sponsored by their employers who pay an all inclusive fee that covers tuition, textbooks and special services.

Applications for admission are accepted throughout the year but admission is for Fall semester only. Because enrollment is limited, early application is recommended.

DEGREE REQUIREMENTS

The general requirements for the Master of Science Degree are stated elsewhere in this catalog.

CURRICULUM

The curriculum consists of 13 courses (39 academic units), which are offered in a structured program over a two-year period.

The courses in the curriculum are

1st Semester (Fall)
CS 613 Computer Architecture
EL 635 Principles of Communications Networks
CS 676 Mathematical Techniques for Information Systems

2nd Semester (Spring)
CS 623 Operating Systems I
EL 735 Communication Networks I
CS 606 Software Engineering I

3rd Semester (Fall)
EL 736 Communications Networks II
MG 654 Economics of Information Systems
SS 907 Human Factors in Information Systems

4th Semester (Spring)
CS 630 Input and Output Systems
MG 820 Project Management
CS 608 Principles of Data Base Systems
CS 996 Advanced Project in Computer Science

FACULTY

Robert R. Boorstyn, Professor of Electrical Engineering and Computer Science
B.E.E., CCNY; M.S., Ph.D., Polytechnic Institute of Brooklyn
Telecommunications

Ivan T. Frisch, Professor of Electrical Engineering and Computer Science and Director of the Center for Advanced Technology in Telecommunications
B.S. (Physics), Queens College; B.S., M.S., Ph.D. (EE), Columbia University
Information systems, computer networks and network control

Aaron Kershenbaum, Professor of Computer Science
B.S., M.S., Ph.D., Polytechnic Institute of New York
Computer communications and algorithms

Martin L. Shooman, Professor of Electrical Engineering and Computer Science
S.B., S.M., Massachusetts Institute of Technology; D.E.E, Polytechnic Institute of Brooklyn
Software engineering, reliability, fault-tolerant systems

Richard Van Slyke, Professor of Electrical Engineering and Computer Science and Director of CATT
B.S., Stanford University; Ph.D., University of California at Berkeley
Director of Center for Advanced Technology in Telecommunications

Basil Maglaris, Associate Professor of Electrical Engineering and Computer Science
Dipl. EE, National Technical University of Athens (Greece); M.S., Polytechnic Institute of New York; Ph.D., Columbia University
Computer communications

Michael J. Post, Assistant Professor of Computer Science
A.B., Columbia University; M.S., Ph.D., Polytechnic Institute of New York
Coding, operating systems

Richard Wener, Assistant Professor of Environmental Psychology
B.A., University of Wisconsin; M.S., Ph.D., University of Illinois, Chicago
Human computer interaction, environment behavior relations

Industry Professors

Robert J. Flynn, Industry Professor of Computer Science
B.S. (Physics), Manhattan College; M.S. (Math), Ph.D. (Math), Polytechnic Institute of Brooklyn
Computer architecture and operating systems

Nancy J. Needham, Academic Director of Telecommunications Management Program and Industry Professor of Management
B.A., Wellesley College; M.B.A., D.B.A., Harvard University
International telecommunications and financial services

Adjunct Faculty

Ruven Brooks, Adjunct Professor of Computer Science
B.A., University of Michigan; M.S., Ph.D. (Psychology), Carnegie-Mellon University
Man-Machine systems

E. Hart Rasmussen, Director of Westchester Graduate Center and Adjunct Professor of Management
M.S. (Chem Eng.), Polytechnic University of Denmark
Project management

Sheila Lehman, Adjunct Assistant Professor of Environmental Psychology
B.A. (English Literature), Barnard College; M.A. (English Literature), Columbia University; M.A. (Environmental Psychology), Graduate School, C.U.N.Y.

MANAGEMENT

The Division of Management offers one undergraduate degree:

Bachelor of Science in Information Management*

and four graduate degrees:

Master of Science in Management
Master of Science in Organizational Behavior
Master of Science in Operations Management*
Master of Science in Telecommunications Management.*

The master of science in management degree (MSM) is recognized, along with the master of business administration (MBA), by the Graduate Management Admission Council as graduate professional management degrees. Most MSM programs are offered by leading engineering schools. Polytechnic's MSM is designed to prepare working professionals for increasing responsibility in management positions. The program is aimed at developing competence in planning and decision-making and in the selection, allocation and direction of human, financial, physical, technological and organizational resources.

These management skills can be applied in a broad range of professional settings both in the private and the public sector; in labor-intensive and in capital-intensive industries; in production-oriented and in service-oriented activities; and in traditional as well as in high-technology environments.

Polytechnic's graduate program in management takes a pragmatic, results-oriented approach that emphasizes management of technology, production management, and strategic planning to achieve long term productivity and profitability. Traditional subjects such as accounting, economics, finance, and marketing are taught, not as special areas of expertise but as basic tools for managerial decision-making.

After completing the core courses, degree candidates build further managerial skills in their choice of 7 concentrations:

• Construction Management
• Economics and Finance
• Human Resources Management
• Information Management
• Management and Administration
• Management Science
• Technology Management

The program concludes with a course in Business Policy and Strategy which integrates the functional disciplines studied throughout the program. Through case studies the students acquire an understanding of top management's perspective, how organizations set goals, establish policies, and implement strategies to gain competitive advantage.

Polytechnic's students are working professionals, typically engineers and scientists with managerial responsibility. Small classes (averaging 15 or fewer students) enable the students to receive close individual attention from the faculty.

Admission — Criteria for admission include having a bachelor's degree with at least a B average from an accredited college or university and demonstrated evidence of motivation, maturity, and the ability to benefit from and contribute to professional graduate studies. An applicant who does not meet all the criteria may be admitted as a non-degree student with the opportunity subsequently to become a degree candidate. Satisfactory scores on the Graduate Management Admission Test (GMAT) or an acceptable equivalent test may be used as support for admission to degree studies.

Degree Requirements — The MSM requires completion of a minimum of 12 courses, or 36 units, with a B average or better. Students who lack prerequisites may be required to take up to 4 additional courses, or 12 units, as described in the next paragraph. Transfer credits of 9 units may be granted for graduate courses in management taken previously, as evaluated by advisers.

The Curriculum

1. **Basic and Core Courses.** A management base and core curriculum form nine required courses upon which students can build a variety of specializations within the degree programs. Basic and core courses provide intensive introductions to the several disciplines basic to professional management. Students who have taken these courses elsewhere or previously at Polytechnic, or who have had equivalent experiences may be excused from them. Upon proof of competence, advisers can waive any corresponding basic or core courses. Students must then substitute electives, or basic courses as required by advisers, to complete the minimum of 36 units (12 courses) for the master's degree. If one or more basic courses are required, these must be taken in addition to the 12 courses required for the degree, except if one or more core courses are waived.

The Basic Courses:

MG 502 Computers in Management
MG 503 Economic Environment of Management
MG 504 Managerial Accounting
MG 505 Statistical Analysis

The Core Courses:

MG 600 Management Process
MG 601 Organizational Behavior
MG 606 Managerial Finance
MG 607 Marketing Management
MG 608 Managerial Economics

2. **Areas of Concentration.** Students must choose areas of concentration. These may be one of those listed below or, with the adviser's approval, a set of courses designed to meet students' special needs. A minimum of four

courses must be selected in any one area of concentration. Courses in all the available options are shown below.

3. **Free Electives.** Two graduate courses may be chosen from those offered by any programs of Polytechnic with the adviser's consent.

4. **Business Policy and Strategy, with Project (MG 970).** This required integrating course is recommended for students' final semester. It includes a project normally in the area of students' specialization. In special cases, MG 997, Thesis for Degree of Master of Science, may be substituted for students who wish to produce a major dissertation in a specialty.

Concentration Course Requirements

Each concentration sequence consists of a minimum of four courses. Students who take more than the minimum number of required coures may count additional courses as electives. Substitutions may be made with advisers' approval in any concentration areas.

Construction Management
Select four:
MG 631 Organizational Theories
MG 664 Management and the Legal System
MG 810 Project Planning and Control
MG 820 Project Management
MG 825 Construction Administration
MG 826 Construction Estimates and Costs
MG 827 Specifications and Contracts
MG 830 Formulation and Analysis of Public Works

Economics and Finance
Required:
MG 766 Financial Institutions

Electives — Select three:
MG 615 Labor Economics
MG 640 Resource Economics
MG 671 Business and Economic Forecasting
MG 860 Financial Planning, Internal Reporting and Operational Control
MG 912 Seminar in Investment Analysis
MG 963 Seminar in Financial Planning and Control

Human Resources Management
Required:
MG 612 Human Resources Management
MG 633 Research Methods

Electives — Select two:
MG 611 Career Management
MG 613 Industrial Relations
MG 622 Personnel Psychology
MG 623 Training in Organizations
MG 624 Organization Development
MG 625 Seminar in Career Management
MG 626 Human Resource Information Systems
MG 627 Human Resources and Technological Change
MG 631 Organizational Theories
MG 664 Management and the Legal System

Information Management
Select four:
MG 612 Human Resources Management
MG 626 Human Resources Information Systems
MG 650 Management of the Information Function
MG 654 Economics of Information Systems
MG 664 Management and the Legal System
MG 716 Commercial Data Processing Systems and Design
MG 736 Management Information Systems
MG 810 Project Planning and Control
MG 820 Project Management
CS 603 Design and Analysis of Algorithms I
CS 681 Information Privacy and Security

Management and Administration
Required:
MG 630 Operations Management

Select three:
MG 612 Human Resources Management
MG 624 Organization Development
MG 633 Research Methods
MG 645 Productivity Management
MG 664 Management and the Legal System
MG 700 New Enterprise and Small Business Mgmt.
MG 705 Managerial Planning Process
MG 850 Cost Systems
MG 868 Strategic Management of Productivity

Management Science

Students electing this option should substitute MA 551 for MG 505 in the basic courses.

Note that IE 624 has several prerequisites.

Select four:
MG 714 Modeling of Social and Managerial Systems
MG 810 Project Planning and Control
IE 624 Computer-Augmented Case Studies in Management Science
IE 627 Operations Research: Deterministic Models
IE 628 Operations Research: Stochastic Models
IE 680 System Simulation

Technology Management
Required:
MG 866 Technology, Management and Policy

Select three:
MG 624 Organization Development
MG 627 Human Resources and Technological Change
MG 630 Operations Management
MG 634 Applied Research Methods
MG 645 Productivity Management
MG 664 Management and the Legal System
MG 672 Technological Forecasting
MG 714 Modeling of Social and Managerial Systems
MG 820 Project Management
MG 865 Research Development and Management of Innovation
MG 867 Corporate Strategy for Technology Intensive Industries
MG 868 Strategic Management of Productivity

MASTER OF SCIENCE PROGRAMS IN ORGANIZATIONAL BEHAVIOR

Program — A graduate evening program is offered to students who wish to specialize in organizational behavior, a field concerned with solving human problems in modern organizations. The program includes both theoretical and practical courses relevant to organizational behavior.

Admission — Applicants must meet the basic admission requirements of the graduate programs in Management. Those without undergraduate courses in psychology will be required to remove this deficiency.

The Curriculum

1. **Required Core courses.** An organizational behavior base consists of three core courses upon which the student can build a variety of specializations within the degree program. Core courses provide an introduction to several areas basic to organizational behavior. Students who have previously completed courses in any of these areas, or who have had substantial equivalent experience may be excused from taking them by presenting proof of competence and receiving waivers from advisers.

Students who have not completed an undergraduate course in statistics will be required to enroll in MG 505, Statistical Analysis. Those with little or no background in computers must make up the deficiency by enrolling in MG 502, Computers in Management. These courses are in addition to degree requirements.

The core courses are:
MG 601 Organizational Behavior
MG 631 Organization Theory
MG 633 Research Methods

2. **Areas of Concentration.** Students must choose three areas of concentration, each consisting of two courses. These may be three of the concentrations listed below or, with adviser's approval, may consist of a series of six courses designed to meet students' special needs.

Courses in each of the following available areas of concentration are shown below:

Career Management
MG 611 Career Management
MG 625 Seminar in Career Management

Labor Relations
MG 613 Industrial Relations
MG 614 Collective Bargaining

Industrial Relations
MG 613 Industrial Relations
MG 614 Collective Bargaining

Information and Technological Change
MG 626 Human Resource Information Systems
MG 627 Human Resources and Technological Change

Performance and Motivation Management
MG 616 Job and Work Place Design
MG 617 Performance Measurement and Reward Systems

Personnel and Human Resources
MG 612 Human Resources Management
MG 622 Personnel Psychology

Training and Development
MG 623 Training in Organizations
MG 624 Organization Development

3. **Free Electives.** Two appropriate graduate courses may be chosen from any program at Polytechnic. These could include courses from any concentration not required in students' programs, other courses in management, or courses in computers, psychology and social sciences.

4. **Research Projects**
MG 634 Applied Research Methods

All students are required to submit an independent research project. In special cases, MG 997, a thesis for degree of master of science, may be substituted for students who wish to produce a major research project.

CERTIFICATE PROGRAMS

The Division of Management offers several certificate programs designed for professionals with work experience. A certificate program requires five courses, which are selected according to individual needs. Applicants for certificate programs must hold bachelor's degrees. On completion of a sequence with an average grade of B or better, students are issued certificates. Those who choose to work towards the master's degree are able to apply all courses taken toward a certificate, upon admission, toward fulfillment of a degree program. Additional information may be obtained from the Division.

Management Certificate — This program is designed to foster professional and personal growth through intensive studies of the latest advances in management processes and the newest quantitative techniques, ranging from management information systems to decision models. Management certificates are offered in the following fields:

Construction Management
Economics and Finance
Human Resources Management
Information Management
Management & Administration
Operations Management
Technology Management

Organizational Behavior Certificate — This program involves intensive studies of the latest knowledge and techniques for dealing with human problems in organizations. Individualized programs make it highly appropriate for specialists as well as generalists to improve and update their knowledge and skills in areas ranging from individual motivation to organizational development.

,NDERGRADUATE COURSES

,AG 202   Computers In Management   2:3:3
Introduction of basic computer hardware and software concepts. Survey of operating systems and programming languages. Heavy emphasis on personal computer applications and management-oriented application packages in word processing, database management, spreadsheets, communications, and business graphics.
Also listed under LA 125.

MG 300   Management Process   3:0:3
Introductory management course for undergraduates. Primary focus is the management process: planning, organizing, staffing, controlling, directing and decision making. Attention is given to the roles of various disciplines within management as well as to the traditional business functions of marketing, accounting, finance, production, engineering, research and development.

MG 301   Organizational Behavior   3:0:3
Study of behavior in industrial settings. Emphasis on informal and formal group dynamics: interpersonal relationships; supervision; leadership; communication theory; attitude measurement; creativity. Analyses of administration problems by case studies and simulated situations.
Also listed under SS 299

MG 304   Accounting Fundamentals   3:0:3
Managerial approaches to problems of cost determination and analysis. Job order, process and standard cost systems. Analysis of indirect manufacturing expenses, preparation and analysis of balance sheets, income and manufacturing statements. Relations between accounting and engineering functions.

MG 316   Commercial Data Processing
Systems Design   3:0:3
Functional relationships of information across the commercial environment and their relevance in the design of Management Information Systems. Also covered are the present and future roles of personal computers and terminals in information interchange. The necessary communication techniques and protocols to accomplish mainframes to personal computer connections are included. Prerequisite: MG 202.

MG 390   Management Decision Making
Students integrate specialized areas of economics and management previously studied by analyzing and making decisions in environments based upon a computer-processed management simulations. Students are organized into competing companies making quarterly decisions on production, price, research, marketing, etc. Periodic oral and written reports: final oral and written reports presented to Board of Directors. (Note: Normally, this is a three-credit course. However a two-credit version, omitting written reports, may be offered to non-IM students). Prerequisite: SS 251, IE 300, MG 304, or permission of instructor.

MG 401   Senior Project   3 credits
Independent work integrating students' knowledge under faculty guidance. Students design systems required to manage information regarding specific management functions. Prerequisite: senior standing in information management.

GRADUATE COURSES

MG 502†   Computers in Managemenet   2½:0:3
Computer literacy for managemenet problem-solving, information systems, computer technology, software and vocabulary. Advantages and disadvantages of alternatives ranging from large mainframes to time-sharing networking, batch processing, personal computers and programmable ca' Jlators. Survey of software, compilers, interpreters, assemblers and language important to managers. Examples and cases of decision-support systems and their operation in office automation, financial analysis and other business applications.

MG 503†   Economic Environment of Management   2½:0:3
Central problems of economic society, supply and demand analyses, structures of industrial markets, factors of production, profits and incentives, national income accounting, income determination, business cycles, monetary and banking systems, governmental influences on the economy, international trade and finance.

MG 504†   Managerial Accounting   2½:0:3
Aspects of accounting of practical use to the manager. Stress on understanding of financial statements rather than on bookkeeping procedures. Internal management usage of accounting data: job orders, process and standard costing; relations among accounting, economic and financial perspectives.

MG 505†   Statistical Analysis   2½:0:3
Fundamental statistical models and their uses in decision-making. Emphasis on alternative techniques, their assumptions and limitations. Topics include descriptive statistics; probability-concepts of probability, probability distributions both discrete and continuous; sampling methods, estimation, hypothesis testing, regression and correlation analysis; time series, chi-square testing.

MG 600   Management Process   2½:0:3
Establishment of conceptual perspectives of major schools of management thought, including scientific management, classical administrative theory, human relations, behavioral system theories.

MG 601   Organizational Behavior   2½:0:3
Integration of behavioral science theories, concepts, research and techniques for understanding of human behavior in organizations. Motivation and job satisfaction, personality and conflict, group dynamics, interpersonal relationships, supervision and leadership, communications, organization structures and processes, impacts of technology, career development.

MG 606   Managerial Finance   2½:0:3
Analyses of principles and practices of finance function and its application in organizations. Survey of uses of financial instruments, sources and uses of short- and long-term funds available to business; capital budgeting under certainty and uncertainty; cost of capital and dividend policy; working capital management. Prerequisite: MG 504 or equivalent.

MG 607   Marketing Management   2½:0:3
Foundation course in marketing processes and institutions. Consumer motivation and behavior, pricing determination and policies, product planning and development, promotion management, channels and means of distribution, influences of government. Cases and managerial aspects stressed. Co/Prerequisite: MG 503.

MG 608   Managerial Economics   2½:0:3
The development of micro-economic analysis and its application to business decision-making. Quantitative techniques, profit measurement, competition, oligopoly and monopoly, multiple product analysis, demand analysis and demand forecasting, cost analysis, pricing analysis, capital budgeting. Prerequisite: MG 503.

MG 611   Career Management   2½:0:3
An examination of careers from the perspectives of both management and individuals. Specific issues include career stage models, organizational entry, career pathing, mid-career crisis, career change, continuing education and retraining, professional obsolescence, career re-entry, tokenism, job loss and underemployment. Existing career planning/development programs used by organizations will be evaluated. Prerequisite: MG 601 or permission of instructor.

MG 612   Human Resources Management   2½:0:3
Personnel functions are investigated from the perspectives of individual managers and the total organization. Topics include manpower characteristics, recruitment and development, motivation, performance evaluation and rewards, effects of government policy on legislation and the changing labor force. Prerequisite: MG 601 or permission of instructor.

MANAGEMENT

MG 616   Job and Workplace Design   2½:0:3
An examination of the interaction among individual, job design and work environment characteristics. Topics include work analysis; task and workspace design; impact on communication; job satisfaction; motivation and productivity; implications of and responses to new technologies; skills obsolesence and retraining; job and work environment redesign; socio-technical design approaches; emerging role of artifical intelligence.

MG 617   Performance Measurement and Reward Systems   2½:0:3
An introduction to practical approaches in the establishment of a performance appraisal system that includes theoretical and applied issues. Reasons for implementing a performance appraisal system in organizations are addressed. Other topics include coaching, feedback, and performance evaluation. The role of compensation and other rewards in attracting, retaining and motivating employees.

MG 622   Personnel Psychology   2½:0:3
Examination of theory, research and practice concerning individual differences relating to organizational behavior with emphasis on the personnel selection process, measurement of predictors, criteria for validation and decision-making strategies. Prerequisites: MG 601 and MG 505 or permission of instructor.

MG 623   Training in Organizations   2½:0:3
The roles of training in organizations, focusing on department and line managers. Subjects addressed include need analysis, preparation of employees for jobs, management development, training program design, evaluation and employee obsolescence. Prerequisite: MG 601 or permission of instructor.

MG 624   Organization Development   2½:0:3
Applied theory and research related to process of managing change in organizations. Practical application of group, intergroup and individual changes. Planned structural revisions in formal organizations. Dynamics of organizational change processes. Experimental techniques and seminar approaches emphasized. Prerequisite: MG 601.

MG 625   Seminar in Career Management   2½:0:3
Examination of the latest concepts, research and practices pertaining to professional and managerial careers in organizations. Emphasis is on current issues and problems in career management. Experts and resource materials are utilized in examining research findings as well as in studying career developments and planning practices and programs which have been established in organizations. Prerequisite: MG 611 or permission of instructor.

MG 626   Human Resource Information Systems   2½:0:3
Design, selection, implementation, enhancement and operation of Human Resources Information Systems (HRIS) in organizations. Organizational, legal and political issues as well as hardware, software, applications and communications in HRIS. The uses of time-sharing, personal and minicomputers and mainframes. Focus on design and use of HRIS to facilitate objectives of human resource functions, as well as to support entire organizations.
Also listed under SS 678.

MG 627   Human Resources and Technological Change   2½:0:3
Examination of the impact of technological changes on human resources and their management. An overview of technological changes and their effects on the work force, focusing on changes in supply and demand as well as the obsolescence of knowledge and skills. Topics include utilization, human resources planning, job redesign, resistance to change, organizational change, continuing education and retraining, productivity and innovation, inter-organizational cooperation, roles of government, and international issues. Corequisite: MG 601 or permission of the insstructor.
Also listed under SS 679.

MG 630   Operations Management   2½:L
Analytic techniques for designing and operating production ar service systems, including facility layouts and locations, assembl, line balancing, job sequencing, inventory control, and project planning. Introductory linear programming and other formal methods Cases and managerial perspective.

MG 631   Organization Theory   2½:0:3
Analyses of theories of large-scale organizations focusing on characteristics of bureaucracy, suboptimization, human dynamics and informal systems, influence and control systems, planned change. Examination of both formal and information organizations through varieties of research studies. Prerequisite: MG 601 or permission of instructor.

MG 633   Research Methods   2½:0:3
An introduction to theories and techniques of research methods. Primary objectives are to provide understanding and appreciation of why and how organizationl research is carried out. Survey of research methods. Research projects are designed and analyzed. Prerequisite: MG 505 or permission of instructor.

MG 634   Applied Research Methods   2½:0:3
Integration and application of advanced research techniques utilized in studies of organizations. Students develop and carry out individual applied research projects. Prerequisite: MG 633 or permission of instructor.

MG 645   Productivity Management   2½:0:3
Modern approaches to productivity measurement, evaluation, planning and improvement in manufacturing and service industries. Participants develop productivity models for various types of organizations. Prerequisite: Graduate standing or permission of instructor.
Also listed under IE 645

MG 650   Management of the Information Function   2½:0:3
Structures of information processing, storage, transport and user services within organizations. Relations of distributed processing, distributed databases, and telecommunication network topology to organizationsl structures. Management of voice and data integration. Hardware and software evaluation and acquisition; benchmarking; information systems contracting; pricing of information services. Operation of information systems.

MG 654   Economics of Information Systems   2½:0:3
Concepts of market supply and demand as they apply to markets for information services and products; rationales for, and nature of, emerging applications of information systems; availabilities and pricing of services; methods of economic decision making and justification of business information systems.

MG 664   Management and the Legal System   2½:0:3
Impacts of the legal system on corporate strategy, managerial decisions and planning processes. Issues covered include: protection of intellectual and technological properties; consumer, contract, commercial and secured financing laws; employer liability to, and for, employees; negligence and risk-management from legal and corporate viewpoints, and constitutional and regulatory aspets of conducting business on a multi-state basis. The legal system from the perspective of individual managers as agents, contract-makers, etc.

MG 671   Business and Economic Forecasting   2½:0:3
Forecasting for managerial decision and control. Statistical vs. judgmental methods. Smoothing and analyses of trends, seasonal factors, cycles and random variations. Econometric forecasting. Economic indicators and sources of information. Applications to the national economy, industry sales, corporate profits, financial institutions, government expenditures, etc. Prerequisite: IE 608 or equivalent.
Also listed under IE 671

MG 672   Technological Forecasting   2½:0:3
Introduction to problems of technological forecasting. Morphological analyses, extrapolation of trends, heuristic and intuitive forecasts. Consideration of rational directing of technological changes. Students prepare forecasts on topics of choice.
Also listed under SS 672

**MG 700   New Enterprise and Small Business
               Management   2½:0:3**
Characteristics, opportunities, and hazards of new and small business firms with special attention given to technology, engineering and manufacturing concerns. A variety of operating problems in different stages of a small company's life cycle are considered. Actual business cases involving opportunity-finding and decision-making are utilized for students to gain insights into their attitudes towards risk-taking and in developing their own action-taking skills. Prerequisite: Advanced Standing.

MG 705   Managerial Planning Processes   2½:0:3
Introduction to strategic management and to formal planning as methods for translating business goals into procedures or actions. Tactical planning at operating levels. Development of foresight and classical methods for gathering information essential to decision-making in large-scale organizations. Prerequisites: MG 600 and MG 601.

**MG 716   Commercial Data-Processing
               Systems Design   2½:0:3**
Functional relationships of information across the commercial environment and their relevance in the design of management information systems. Present and future roles of personal computers and terminals in information interchange. Necessary communication techniques and protocols to accomplish mainframes to personal computer connections. (Not open to students whohave taken MG 316.) Prerequisite: MG 502.

**MG 736   Analyses and Design of
               Management-Information Systems   2½:0:3**
Roles of information systems in management decision-making processes. Detailed development of management-information systems through planning, design and implementation, introduction to information theory, the value of information. The information system and changes in the organization, examples and applications. Prerequisite: MG 502.

MG 766   Financial Institutions   2½:0:3
Financial institutions and their importance in the economy. Capital and money markets, commercial banking systems, federal banking systems, investment banks, insurance companies, savings and loan associations, mutual funds, brokerage companies, international banking.

MG 800   Policy Analysis and Planning   2½:0:3
Systems analyses of policy choices in areas facing federal and regional governments. Cost-benefit methods and related analytical techiques. Analyses and planning in urban contexts. Future-oriented studies. Economic and technological projects. New technologies and their cultural and ecological implications.

MG 810   Project Planning and Control   2½:0:3
Network planning techniques for project management and resource allocation. Emphasis on PERT, LOB, CPM and probabilistic generalized networks. Heuristic models for multi-project scheduling and resource leveling. Network development, computer adaptation, progress reports and project monitoring. Prerequisite: knowledge of computer programming.
Also listed under IE 620 and CE 828.

MG 820   Project Management   2½:0:3
Specific managerial concepts and techniques related to management of projects in research and development, construction, engineering, and data processing. Functional and administrative structures, coordination of activities, manpower planning, feasibility analyses, negotiations and contracts.

MG 825   Construction Administration   2½:0:3
Management techniques of construction are discussed in relation to alternate means of project execution. Organizational structures, management systems, and controls are examined from the points of view of owners, the constructors, and the professional construction managers.
Also listed under CE 825.

MG 826   Construction Estimates and Costs   2½:0:3
Techniques for estimating costs of capital projects and methods for effective cost control during project execution are taught with emphasis on principles of good management. Class project.
Also listed under CE 826.

MG 827   Specifications and Contracts   2½:0:3
Principles of contract law applied to construction; legal problems in preparing and administering construction contracts. Prerequisite: MG 825.
Also listed under CE 827

MG 850   Cost Systems   2½:0:3
Methods used in industry for predicting and recording costs. Design and operation of standard and direct cost-accounting systems. Prerequisite: MG 504.

MB 863   Market Research   2½:0:3
An overview of the accepted methodology for identifying and sizing an existing or emerging market for a specific product so as to guide management action in research and development, manufacturing or marketing. Techniques appropriate to collecting, analyzing and reporting marketplace information to management are explored. Prerequisities: MG 605 and MG 607.

MG 864   Product Planning   2½:0:3
Systematic studies of processes followed by successful companies in creating commercially viable products from technology deeloped by or available to them. Steps involved up to market entry are reviewed sequentially: initial search; preliminary evaluation; organizing the new product venture; manufacturing preparation; market testing; etc. Financial aspects of product development. Prerequisites: MG 600 and MG 607.

**MG 865   Research, Development and
               Management of Innovation   2½:0:3**
Introduction to the environment of technological growth with reference to the economy, to companies and to management of the R and D function. Examination of policies and factors which affect innovation in industry. Methods for assessing and forecasting technology, delphi, cross-impacting scenarios, parameter extrapolation, enveloping, etc. Problems in managing research and development by private enterprise during rapid technological changes. Prerequisite: MG 600.

MG 866   Technology Management and Policy   2½:0:3
Topics and issues in private and public management; considerations of technology in strategic planning for high-technology corporations; government's roles in directing technology, defense, space, and energy. Managing large-scale technological enterprises. Science and technology in international relations.

**MG 867   Corporate Strategy for
               Technology-Intensive Industries   2½:0:3**
Corporate Strategy for Technology-Intensive Industries is designed as a general management course. It focuses on the emerging technology-strategy relationship in the large technology-based corporation. This relationship is treated from three different perspectives: the corporate strategy of the individual firm, the competitive structure of an entire industry, and the "industrial policy" of a national government. The strategic management of technology in several different countries and industries is studied and compared. The course employs conceptual and empirical readings and relevant case studies.

MG 868   Strategic Management of Productivity   2½:0:3
Issues relating to U.S. productivity relative to that of its trading partners and competitors in international trade. Analyses of American management strategies. Current controversies and their theoretical and empirical foundations. Time horizons for research and development, for market forecasting and new product development, for financial controls and portfolio analyses, and for valuation of managerial performance. Efforts to define long-term, strategic roles for productivity in manufacturing and in providing services within the firm or to the market. Reassessment of the strategic function of the management of production. Cases and Readings. Prerequisite: Advanced standing.

MG 912   Seminar in Investment Analysis   2½:0:3
Financial markets and individual and corporate investment decisions. Study of theories of market efficiency and investment strategy. Risk analysis, portfolio theory, technical and fundamental assessments. Implications of national and international economic forces, such as business cycles, currency markets, and profit repartriation restrictions, for individual and corporate investment decisions.

MG 970   Business Policy and Strategy   2½:0:3
Integration of functional disciplines studied in the master's program to understanding how organizations are managed strategically. The "top management" perspective is the focus. Setting organizationsl goals, establishing policies that assure realization of objectives, devising and implementing strategies to gain competitive advantage or capitalize on corporate opportunities. Cases, research paper. Prerequisite: advanced standing.

MG 975   Selected Topics in Management   2½:0:3
Current topics in various fields analyzed and discussed. Prerequisites: advanced standing and permission of instructor.

MG 976-977   Readings in Management   each 3 units
Directed individual study of supervised readings in advanced areas of management. Prerequisite: permission of dean.

**MG 985   Selected Topics in
Organizational Behavior   2½:0:3**
Discussion and analysis of current topics in organizational behavior. Prerequisities: advanced standing and permission of instructor.

**MG 986-987   Readings In
Organizational Behavior   each 3 units**
Directed individual study or supervised readings in advanced areas of organizational behavior. Prerequisite: permission of dean.

**MG 997   Thesis for Degree of
Master of Science   each 3 units**
Original investigation in topic chosen by student. Conferences and progress reports required during work, and final written report required at completion; oral examination may be requested by department. Registration and degree credit beyond first six units require separate approval. Prerequisites: degree status and approval of supervising professor, adviser and division dean.

Infrequently Offered Courses

The following courses are offered infrequently and, in most cases, only at the Brooklyn campus.

MG 613   Industrial Relations   2½:0:3
Policies and philosophies of management, organized labor and government with regard to solution of labor problems. Evaluation of industrial relations problems, particularly those of collective bargaining, emphasizing interrelationships with social, economic and legal trends. Co/Prerequisite: MG 600 or permission of instructor.

MG 614   Collective Bargaining   2½:0:3
Analysis of nature of the collective bargaining process, its major issues and points of contention. Major trends examined with consideration given to broad economic and social implications. Prerequisite: MG 613 or permission of instructor.

MG 615   Labor Economics   2½:0:3
Analysis of the character and operation of labor markets through economic theory and empirical studies. Supply and demand, wages and employment, "scientific manager.ent," job opportunities, governmental micropolicy, collective bargaining and internal markets. Discrimination, unemployment and inflation, poverty and income distribution. Prerequisite: MG 608 or permission of instructor.

MG 632   Business and Its Environment   2½:0:3
Discussion of various environments of business (economic, political, legal, social), together with conflicting values in these environments. Prerequisite: MG 600

MG 640   Resource Economics   2½:0:3
Theories of exhaustible natural resources with special emphasis on fossil fuels. Theories of extraction logistics and resource exhaustion. Theories of pricing and allocation of exhaustible resources under economic conditions of competition, monopoly and oligopoly. Present-day behavior of the world oil market and the domestic markets for natural gas and coal will be discussed, as well as policy problems. Prerequisites: SS 251 and MA 103, or IE 665, or permission of instructor.

**MG 714   Modeling of Social and
Managerial Systems   2½:0:3**
This course introduces the student to general systems theory as it applies to managerial and social phenomena. Systems are viewed as interrelated positive and negative feedback loops whose behavior is governed by structure, amplification, and delays. Using the DYNAMO language, students prepare, analyze, and restructure several models in ecology, management, economics, and areas related to their individual interests
Also listed under IE 614.

MG 727   Case Studies in Management Science   2½:0:3
Application of scientific and analytic methods to solving management decision-making problems, drawn from current practice and literature. Prerequisite: permission of the instructor.
Also listed under IE 727.

MG 740   Process of Policy Formation   2½:0:3
Situations faced by practitioners and alternative techniques employed to define issues, formulate policy goals and objectives, bargain over priorities, define implementation procedures and garner support.

MG 744   Social Forecasting   2½:0:3
How institutional, economic, social and cultural changes affect both private and public sector organizations in divergent—and sometimes dramatic—ways. Evaluation of methods employed to formulate forecasts and of how implicit beliefs and values of forecasters can subtly bias forecasts. Assessment of alternative forecasts. Prerequisite: MG 600.

MG 746   Public Sector Management   2½:0:3
Management in the public sector is distinguished by the political setting in which it occurs. It goes beyond technical canons of economy and efficiency to involve issues of social equity and political viability. This course is designed to show how these considerations alter the management decision-making process.

MG 760   International Development:
                Management and Technology   **2½:0:3**
The course provides a framework for development issues of particular significance to students in engineering and management. Economics of science and technology, appraisal and management of development projects and programs, appropriate technology and mechanisms of technology transfer. Political criteria and the impact of technological decision on social and economic change in developing countries

MG 763   National Economic Models
                and Forecasting   **2½:0:3**
Measures of aggregate economic activity, national income accounting, simple and complex national and regional macroeconomic models, the firm's position relative to the economic environment, introductory econometrics, econometric models of the national economy and their estimation, and the use of the analysis in the profit planning and strategic management of the firm and in the formulation of public policy. Prerequisites: MG 503 and MG 505.

MG 830   Formulation and Analysis of Public Works
                Projects   **2½:0:3**
Methods for the identification, formulation, preliminary appraisal, and detailed analysis of individual projects and systems of civil engineering projects. Different approaches appropriate for government agencies, public utilities, industrial firms, and private entrepreneurs. Planning considers projects that satisfy single and multiple purposes and objectives, meet local and regional needs, and take advantage of opportunities for development. Financial and economic analyses, including sensitivity and risk analysis. Mathematical models for evaluation of alternatives and optimization. Impacts of projects: environmental, social, regional economic growth, legal and institutional, and public involvement.
Also listed under CE 781.

MG 840   Financial Aspects of Public Policy   **2½:0:3**
Politics of fiscal policy and the social welfare principles. Optimality of public policy with regard to social goods, supported research and development, and different taxation methods. Effect of external economies and diseconomies on the Pareto Optimum conditions; public regulation of social resources allocation. Prerequisite: approval of instructor.

MG 860   Financial Planning, Internal Reporting
                and Operational Control   **2½:0:3**
The techniques of planning and control at various levels within the enterprise with emphasis on system analysis and quantifiable aspects of individual or corporate productivity. Applications in the public and private sectors. Budgeting, monitoring and evaluation of performance, "expense and investment centers," transfer pricing, relationship between control systems and organizational goals. Prerequisites: MG 504 and MG 606.

MG 862   Industrial Marketing   **2½:0:3**
Problems concerning the marketing of industrial products, particularly those of high technological content. Projecting consumer demand, establishing channels of distribution, sales and customer training, advertising and promotion, technical support of the marketing program and budgeting for these activities of the firm. Prerequisites: MG 600 and MG 607

MG 963   Seminar in Financial
                Planning and Control   **2½:0:3**
Capital budgeting and investment valuation under certainty and uncertainty. Application of portfolio theories and mathematical programming to corporate investment alternatives. Management of alternative sources of capital and cash flow. Short- and long-term financial management and control. Implications of national and international political and economic forces, such as interest rates, transfer prices, tariffs, business cycles, currency markets, and profit repatriation restrictions, for corporate decisions about sources and uses of capital. Prerequisites: MG 503 and MG 606, or permission of instructor.

FACULTY

Ernest Racz, Dean of Management
B.A., Franklin & Marshall College; M.Div. Lancaster Theological Seminary; M.A. Ed.D., Teachers College, Columbia University

A. George Schillinger, Professor of Management
B.E.E., City College of New York; M.S., Eng. Sc.D., Columbia University
General management, technology management, corporate strategy

Anthony J. Wiener, Professor of Management
A.B., J.D., Harvard University
Corporate strategy, forecasting and planning, technology management, public policy

Nancy Needham, Industry Professor of Management, Associate Director of CATT
B.A., Wellesley College; M.B.A., D.B.A., Harvard University
International telecommunications and financial services

Seymour Kaplan, Associate Professor of Operations Research and Management Science
B.S., Newark College of Engineering; M.S., Ph.D., New York University
Economic modeling, linear programming

Harold G. Kaufman, Program Director, Organizational Behavior and Associate Professor of Management
B.M.E., Cooper Union; M.I.E., Ph.D., New York University
Career management, science and engineering manpower obsolescence and continuing education

Byron David, Assistant Professor, Program Director, Operations Management
B.A., Queens College of City University of New York; M.S., Polytechnic Institute of New York; M.B.A., Baruch College
Operations management

Thomas Conoscenti, Academic Associate, Program Director, Farmingdale Campus
B.S., M.A., New York University
Economics, statistics, public policy

Madhuri Kadiyala, Academic Associate
B.A., M.A., Andhra University; M.S., Polytechnic Institute of New York

E. Hart Rasmussen, Program Director, Westchester Graduate Center; Adjunct Professor; Licensed Professional Engineer in New York and New Jersey
M.S. (Chem. Eng.) Polytechnic University of Denmark
Project management, control systems

ADJUNCT FACULTY

Robert R. Goodman, Adjunct Professor
B.S.E.E., City University of New York; M.B.A., Harvard University
Business administration

Jerry M. Rosenberg, Adjunct Professor
B.S., City College of New York; M.A., Ohio State College; Ph.D., New York University

Siegfried Altscher, Adjunct Associate Professor
B.A., Brooklyn College; M.S., Ph.D., Polytechnic Institute of New York

Richard Buda, Adjunct Associate Professor
B.A., Iona College; BA/MA, John Jay College of Criminal Justice; Ph.D., Stevens Institute of Technology

Ernest Cilenti, Adjunct Associate Professor
B.B.A., Hofstra University; MBA, Hofstra University

Michael Cortegiano, Adjunct Associate Professor
B.S., Fairfield University

Matthew De Luca, Adjunct Associate Professor
B.A., Fairfield University; MPA, University of Pittsburgh

Judith Katz Geschwind, Adjunct Associate Professor
B.A., Brandeis University; M.A., Harvard Graduate School of Education; M.S., MIT, Sloan School of Management

Edward Greenbaum, Adjunct Associate Professor
B.S., Arnold College; M.A., Cornell University; M.S., New York University

Robert Hawks, Adjunct Associate Professor
B.A., Syracuse University; MPA, Baruch College; M.A., Fordham University

Stanley J. Jacoby, Adjunct Associate Professor
B.S., Polytechnic Institute of New York; M.S., Columbia University; M.M.S., Stevens Institute of Technology; Professional Engineer

John Keane, Adjunct Associate Professor
A.B., Fordham University; M.A., St. John's University

Patrick McNelis, Adjunct Associate Professor
B.E.E., Manhattan College; M.S.E.E., Polytechnic Institute of New York

John Merson, Adjunct Associate Professor
B.A., University of North Carolina - Chapel Hill; MBA, Harvard Business School

Ary Mossiman, Adjunct Associate Professor
B.S., Pratt Institute; M.S., Long Island University; M.S.M., Polytechnic Institute of New York

Sam Mukhopadhyay, Adjunct Associate Professor
B.S., Jadavpur University, India; M.S., City University of New York; MBA, New York University

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B.S., St. Peter's College; MBA, City College of New York

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Kenneth Walden, Adjunct Associate Professor of Management
B.S., City College of New York; M.S., New York Institute of Technology

Steven Azzaro, Adjunct Assistant Professor
B.S., Rutgers University; M.B.A., New York Institute of Technology

Robert Fitzgerald, Adjunct Assistant Professor
B.A., St. John's University; M.A., St. John's University

Girdhar Gopal, Adjunct Assistant Professor
B.A., Loyola College, Madras, India; M.A., Madras University, Madras, India; MBA, Syracuse University

Mark Kurman, Adjunct Assistant Professor
B.A., New York University; M.A., Bowling Green State University

James Philbin, Adjunct Assistant Professor
B.S., Manhattan College; M.S., Polytechnic Institute of New York

Robert Schiffer, Adjunct Assistant Professor
B.S., M.B.A., Adelphi University

Richard N. Walton, Adjunct Assistant Professor
B.S., Columbia University; M.B.A., New York University

Benjamin Karan, Adjunct Instructor
B.A., Brooklyn College of City College of New York

MANUFACTURING ENGINEERING

Polytechnic has an active interest in manufacturing engineering, and diverse curricula leading to degrees or concentrations related to manufacturing. These include:

- Graduate and undergraduate degrees in industrial engineering, the historical focus of manufacturing engineering. Within these degrees, students may take a range of courses including manufacturing processes, manufacturing resource planning, robotic applications, and simulation;

- Course sequences related to manufacturing within most of the engineering programs, including metallurgy & materials science, electrical engineering, industrial engineering, mechanical engineering;

- Degree programs leading to the M.S. degree in manufacturing engineering of electronic materials, jointly administered by the metallurgy and materials science program and industrial engineering program;

- Opportunities to pursue Ph.D. dissertations on topics related to manufacturing engineering in any of the programs named herein.

This section of the catalog describes only the M.S. (manufacturing engineering of electronic materials) in detail. All other concentrations and courses sequences are shown under the catalog sections for the respective programs. The range of available courses is also indicated in this section, with course descriptions found in the individual catalog sections.

MANUFACTURING ENGINEERING: AN OVERVIEW

Manufacturing engineering holds great opportunities because its challenges are so vast. New technology in materials, optics, imaging, robotics, flexible automation, computer aided engineering (CAE), and computer integrated manufacturing systems (CIMS) provide new means of accomp. shing tasks. New techniques, including enhanced inventory and quality control, add new dimensions to technology. Key industries—electronics, computers, automotive—are at the forefront of national capability and/or are infusing new capital into plant rennovation.

The future holds massive changes in national manufacturing capabilities. Engineering, combined with management practices and capital, provides many new opportunities.

UNDERGRADUATE CONCENTRATIONS IN MANUFACTURING

All undergraduate engineering programs at Polytechnic have ABET accreditation. The BS in industrial engineering, BS in metallurgical engineering, and BS in mechanical engineering degree programs explicitly allow students to use their electives to form concentrations in manufacturing.

THE MS IN MANUFACTURING ENGINEERING

The M.S. program in manufacturing engineering of electronic materials prepares engineers and scientists working in industry who have diverse academic backgrounds to meet the challenges and unique complexities of the electronic device manufacturing industries. The industries represented include those processing complex materials and those using these materials for the manufacture of complete assemblies of packaged integrated circuits and products. The curriculum develop understanding of the submicron world of integrated circuits, specialized fabrication techniques, computer integrated manufacturing systems, and exceptional quality control requirements. Upon graduation, students are prepared to use these new skills and to respond to the rapid changes in design, materials, specifications, and fabrication which are found in the electronic industries.

Students enrolled in the M.S. program may elect courses in CAD, lasers, robotics, and other areas. Special to this M.S. degree is the emphasis on the processes, materials, facility design and CIMS aspects related to electronic materials manufacturing.

Background of Applicants

Applicants for the degree may have an undergraduate degree from any of the engineering disciplines, physics, or chemistry. The curriculum is not designed for materials specialists or manufacturing engineers only. It is oriented for other engineers and scientists working in industry who are unfamiliar with the concepts and skills required to increase productivity, and the reliability and quality of devices.

In order to provide a common basis for students in the program, certain courses or the equivalent content are required. This may be established by prior formal education examinations or by interviews to review industrial experiences or other training.

Up to six units of these courses may be applied for credit toward the degree, if taken as formal graduate courses and not counted toward an undergraduate degree.

The prerequisite requirements are:

1. Course in probability and statistics.
2. IE 627 or equivalent.
3. MT 540 - Survey of Metallurgical Principles.
4. CM 515 - Polymer Organic Chemistry.
5. EL 540 - Solid State Devices & Circuits.

A course in linear programming can be substituted for the system modeling requirement.

Requirements for the Degree Program

The degree requirements are divided as follows:

a. **Core courses** include materials, industrial engineering, and computer integrated manufacturing.

b. **Electives** may be used to obtain concentrations in electronic materials, industrial engineering, mechanical engineering, computer science, and electronics.

c. **Project or Thesis** - An experimental project or thesis is generally required. For part-time students, projects which demonstrate proficiency in handling processing, analytical equipment, and CIMS are substituted for formal laboratory coursework. Full-time students complete theses under direct supervision of the faculty. Oral presentations or project/thesis proposals followed by a second presentation at the completion of the project/thesis are required.

The specific requirements are:

Core		Units
MT 707	Thin Film Technology	3
MT 709	Integrated Circuits (VLSI) Manufacturing Techniques	3
IE 611	Statistical Quality Control	3
IE 619	Production Planning and Control	3
CH 695/ MT 625	Design of Clean Facilities	3
IE 785	Computer Integrated Manufacturing Systems (CIMS)	3
MT 788/ IE 788	Case Studies in Electronics Manufacturing	3
MT 996	Master's Report	3
		24
Electives (4 courses, or courses plus thesis)		12
Total		36

The concepts of just-in-time inventory, real time process control, advantages of robotics, and modifying a production line based upon yield data are introduced in "Statistical Quality Control" and/or "Production Planning and Control".

Electives

The electives may be selected from a number of disciplines; they must support the student's professional goals and be approved by the advisor. Courses in computer aided design, interactive computer graphics, facility planning and design, polymer processing, fabrication technology, factory simulation, and productivity management are among the electives which may be selected.

The courses listed below represent the usual selections from which these concentrations are drawn. With the approval of the academic advisers, other courses can be used, or transfer credit or waivers based upon other graduate studies given. For each course shown, the appropriate prerequisites (if any) must be taken.

MT 603   Introduction to Electron Microscopy I

MT 720	Advances in Materials Analyses & Characterizations
IE 606	Work Design & Measurement
IE 776	Manufacturing Resource Planning
IE 620	Project Planning & Control
IE 621	Facility Planning & Design
IE 642	Robotics Applications
MT 772	Computer-Aided Design
EL 617	System Reliability
EL 618/IE 686	Component Reliability
EL 645	Integrated Circuit (VLSI) System Design

Master's Report

The M.S. Report, usually 3 units, may be expanded to a 6 unit project by use of some elective credits.

The M.S. Report is to be done in an industrial lab setting wherever possible, with the cooperation of employers and program sponsors.

OTHER GRADUATE COURSES RELATED TO MANUFACTURING

The manufacturing engineering orientation of several engineering programs is described in this section.

Industrial Engineering

Manufacturing is one of the natural application areas of industrial engineer, and the entire curriculum can be considered as oriented to this.

The Department's highest priority of laboratory growth relates to materials handling, production and assembly, flexible automation, and robotics.

Illustrative courses in industrial engineering related to manufacturing engineering include the following:

* Work Design and Measurement
* Production Planning and Control
* Project Planning and Control
* Facility Planning and Control
* Systems Simulation
* Robotic Applications
* Industrial Safety Engineering
* Manufacturing Resource Planning
* Manufacturing Improvement Curves

Mechanical Engineering

Mechanical Engineering is, by its nature, involved in the design and implementation of man-made systems—machines, vehicles, tools, spacecraft, and reactor vessels. It logically extends to the manufacturing of these systems.

At Polytechnic, mechanical engineering undergraduates may elect a minor in manufacturing through a program which includes courses in:

* Synthesis of Mechanical Systems
* Computer-Aided Design
* Analysis/Design of Machine Elements

- Computer Graphics in CAD
- Instrumentation and Control
- Robotics

Appropriate focus in manufacturing can also be provided at the graduate level by course selection and by theses and dissertation work.

Chemical Engineering

Chemical engineers are involved in the manufacture of a wide variety of materials ranging from semiconductors and plastics to pharmaceuticals and chemicals. Chemical engineering courses which could relate to manufacturing include the following:

- Design of Clean Rooms
- Fundamentals of Biochemical Engineering
- Chemical Process Kinetics I & II
- Polymer Processing

Metallurgy and Materials Science

The Department of Metallurgy and Materials Science is the operation most directly concerned with the materials and techniques of manufacturing. It has the most significant interest in such special programs as electronic materials fabrication.

Existing courses of direct relevance to manufacturing include:

- Mechanical Metallurgy
- Fabrication Technology
- Process Metallurgy
- Metallurgical Failure Analysis
- Ceramic Refractory Materials
- Materials Selection
- Welding Metallurgy
- Powder Metallurgy
  Mechanical Behavior of Materials
  Engineering Materials

Courses in semiconductor technology are also cross-listed with electrical engineering.

Electrical Engineering and Computer Science

The manufacturing aspects of EE/CS have to do with the control, communications, and computer applications of the manufacturing process. A wide range of courses in computer systems, signal processing, systems theory, control theory, computer graphics, artificial intelligence, data base systems, distributed processing, VLSI design, and software reliability are thus directly relevant.

The following courses illustrate the subjects available:

- Semiconductor Technology
- Systems Reliability
- VLSI Systems Design and Fabrication
- Computer Architecture
- Software Designs and Engineering
- Data-Base Management Systems

- Microprocessors
- Data Communication Networks
- Computer Graphics and Image Processing
- Interactive Computer Graphics
- Artificial Intelligence
- Pattern Recognition

These encompass both graduate and undergraduate offerings.

FACILITIES AT THE POLYTECHNIC

Metallurgy and Materials Science

The laboratories in metallurgy and materials science include complete mechanical testing, optical and electron microscopy facilities as well as fabrication welding and heat treating equipment.

Robotics

The Industrial Engineering laboratories include industrial and educational robots, and a scale materials handling facility.

INDUSTRIAL LAISION

The nature of the MS (MEEM) program requires visits to industrial laboratories, and cooperative efforts with industry. These have been established.

COURSE DESCRIPTIONS OF THE MS (MEEM)

Only the courses central to the MS (Manufacturing Engineering of Electronic Materials) degree are described in this section. For various other electives, see the section of the catalog for the respective programs within which the electives fall.

MT 707   Thin Films Technology   2½:0:3
Preparation, structure, evaluation and properties of thin films: metallic, semiconductor and dielectric film techniques, nucleation and growth considerations, epitaxy, and metastable configurations. Prerequisite: Instructor's Consent.

**MT 709   Integrated Circuits (VLSI) Fabrication
                Techniques   3:0:3**
Study of the process technology used to produce semiconductor devices and itegrated circuits. Emphasis is on silicon technology: bipolar, MOS, and VSLI processes. The process requirements are first defined in terms of the circuit structure, i.e., concentration profiles, topographical layout as through diffusion, ion implantation, oxidation, photolithography, metallization, interconnection, and packaging to final test are analyzed. The impact of process on design rules are pointed out. Prerequisite: MT 708 or Permission of Instructor.
Also listed under EL 646

IE 611   Statistical Quality Control   2½:0:3
Process control: concept of statistical stability - operational randomness, control charts for variables and attributes. Product control: design and analysis of attributes sampling plans, concept of producer's and consumer's risks, AOQL, AQL, and LQ of sampling plans, military sampling plans. Introduction to variables sampling plans. (Not open to students who have taken IE 311) Prerequisite: IE 608.

IE 619   Production Planning & Control   2½:0:3
Analytical techniques for designing and operating production systems. Assemblyline balancing, job sequencing, inventory control, project planning with PERT and CPM. Applications of linear programming algorithms to shop loading and production scheduling of single and multiple products. Prerequisite: IE 608.

CH 625   Design of Clean Rooms   2½:0:3
Critical nature of purity; starting purity, during processing. Starting materials; etchants, solvents, photoliths, gases. Piping and monitoring; circulation, inert gases. Clean room; interlocks, temperature, humidity, ambient light. Cascading of solvents and etchants. Deionized water; containers, generation and monitoring. Safety of handling. Waste disposal. Toxicity. Vacuum systems; inert atmosphere. Clean room fatigue; dress, human factors.

IE 785   Computer Integrated Manufacturing Systems 2½:0:3
CIMS encompasses all activities from planning and design of a product to its manufacture and shipping. This course will offer several perspectives on the manufacturing system. It will also describe the elements of the system and their interfaces. This conceptual structure will be reinforced by discussion of system planning and performance projection through simulation.

IE/MT 788   Case Studies in Electronics
Manufacturing   2½:0:3
Contemporary techniques for product design and manufacturing. Topics include robust design of product and processes using orthogonal array techniques, simulation, partitioning and scale-up JIT/TQC, "pull" and flexible manufacturing processes. Financial and other performance metrics pertinent to these new processes will be given. Corporate cultural changes necessary to effect their successful introduction will be discussed. Applications will be illustrated by case studies of successes and anatomy of disasters drawn from a wide variety of design and manufacturing situations.

MT 996   Report Project for the Degree of Master of
Science   3-6 units
Independent project demonstrating professional maturity and graduate-level knowledge completed under guidance of departmental advisor. Report includes critical analysis and interpretation of pertinent literature and should represent worthwhile contribution to the field. Oral final examination and project report required.

FACULTY

George Fischer, Professor of Metallurgy and Head of Metallurgy and Materials Science
B.Met.E., M.Met.E., Polytechnic Institute of Brooklyn
Corrosion and welding metallurgy

William R. McShane, Professor of Transportation and Industrial Engineering; Head of the Department of Mechanical and Industrial Engineering; Director of Transportation Training and Research Center
B.E.E., Manhattan College; M.S., Ph.D., Polytechnic Institute of Brooklyn
PC applications; software development.

Allan S. Myerson, Professor of Chemical Engineering and Head of Chemical Engineering
B.S., Columbia University; M.S., Ph.D., University of Virginia
Crystallization, mass transfer and biochemical engineering

Ephraim Banks, Professor of Inorganic Chemistry
B.S., City College of New York; Ph.D., Polytechnic Institute of Brooklyn
Chemistry and physics of crystals, solid state reactions and phase transitions

Irving Cadoff, Professor of Metallurgy
B.M.E., City College of New York; M.M.E., D.Eng.Sc., New York University
Electronic materials; liquid metal embrittlement; thin film epitaxy

Chang Dae Han, Professor of Chemical Engineering and Director of Polymer Science and Engineering Program
B.S., Seoul National University (Korea); M.S., Newark College of Engineering; M.S., New York University
Rheology; polymer processing; process control

L. Owen Hill, Adjunct Professor of Manufacturing Engineering
Manufacturing Modeling; Artificial Intelligence; Image Processing

Norbert Hauser, Professor of Industrial Engineering
B.M.E., Cooper Union; M.I.E., Eng.Sc.D., New York University
Modeling of manufacturing systems; computer simulation; quality control

Charles W. Hoover, Jr., Professor of Manufacturing Engineering
Physical Design; manufacturing processes; electronic device assembly

Yoshiyuki Okamoto, Professor of Chemistry
B.S., Osaka University of Science and Engineering (Japan); Ph.D., Purdue University
Polymer synthesis, characterization, and applications

Joachim I. Weindling, Professor of Operations Research and System Engineering; Director of the Graduate Operations Research Program
B.M.E., City College of New York; M.S., Ph.D., Columbia University
Mathematical programming, optimum design and economi evaluation

Herman Grau, Associate Professor of Industrial Engineering
B.M.E., Polytechnic Institute of Brooklyn; M.I.E., New York University
Methods; work measurement; project management; manu facturing engineering; industrial management

Jovan Mijovic, Associate Professor of Chemical Engineering
B.S., University of Belgrade (Yugoslavia); M.S., Ph.D., University of Wisconsin at Madison
Polymer morphology; fracture properties of polymers; adhesives and composites

Ravinder Nanda, Associate Professor of Industrial Engineering and Operations Management
B.Sc., Banaras Hindu University (India); M.S., Ph.D., University of Illinois
Production and operations planning; productivity analysis; project control

Said Nourbakhsh, Assistant Professor of Metallurgy
B.S., Arya-Mehr University of Technology (Iran); Ph.D., Leeds University (England)
Phase transformations, electron microscopy and mechanical behavior

Ernest Levine, Adjunct Professor of Metallurgy
B.Met.E., Rensselaer Polytechnic Institute; Ph.D., New York University
Electron microscopy

John S. Zuk, Instructor of Industrial and Manufacturing Engineering
B.S., Union College; M.S., Polytechnic University
Modeling of Manufacturing Systems, Computer Simulation, Robotics

STEERING COMMITTEE FOR MANUFACTURE OF ELECTRONICS MATERIALS

A Presidential Advisory Committee on Electronic Materials Manufacturing, consisting of high-level industrial experts, provides guidance and advice to the degree program and to the departments which oversee it. The members are:

H. Fridrich	Vice President, International Business Machines, East Fishkill
S. Weinig	President, Materials Research Corporation, Orangeburg, New York
H. Fialkov	President, Aleph Null Corporation
R. Nafis	President, Grumann Electronic Systems Division
F. Blecher	Executive Director, Integrated Circuit Design Division (Bell Labs)

The President, the Vice President for Educational Development, and the heads of the departments which oversee the program attend the meetings of the committee.

MATHEMATICS AND STATISTICS

Mathematics is devoted to the solution of problems by the use of symbolic language and formal logical operations. It serves as a foundation for other scientific disciplines and is an indispensable tool for engineering. Today mathematicians find employment not only in schools and colleges but in every branch of industry and government.

A complete spectrum of mathematics courses is offered at Polytechnic, ranging from first-year courses to the doctoral level and covering all branches of abstract and applied mathematics.

In addition, a sequence of elective courses is available in theoretical and applied statistics which enable students to prepare themselves for careers in statistics or in a field utilizing statistical theories and techniques. The graduate curriculum is more specialized. Courses, thesis work and informal departmental activities are designed to familiarize students with mathematics in general while they become specialists in their particular areas of choice.

UNDERGRADUATE PROGRAM

The undergraduate program in mathematics provides both a background for advanced study or subsequent research in abstract or applied mathematics and training for those students who expect to terminate their formal education with a bachelor's degree. In addition, a sequence of elective courses in theoretical and applied statistics prepares students for careers in statistics or in fields utilizing statistical theories and techniques.

For science and engineering majors, mathematics provides the theory and methods essential for comprehension of the mathematical aspects of their respective fields.

With these objectives, the Department of Mathematics offers courses in abstract and applied mathematics and, for the mathematics major, specific programs leading to the degree of bachelor of science.

Students wishing to pursue the bachelor's degree in mathematics may elect to follow one of three courses of study. Students wishing to focus their studies within mathematics itself may elect course of study I, emphasizing abstract mathematics (see page 000). Students particularly interested in applying mathematics knowledge and techniques to other fields may elect course of study II, emphasizing applied mathematics (see page 000). Students wishing to incorporate computer science into their mathematical training may elect course of study III, the computer science option. All three programs provide basic grounding in mathematical knowledge. Details of each follows.

Requirements for the Bachelor of Science Degree

MA 111-114 or MA 101**-104, 153, 154, 217, 223, 333	29
CS 112, PH 101-103, CM 101, 102, 111, 112	19
HU 101; and HU 200, SS 104 or IS 140, IS 141	9
Two years (or equivalent) of French, German, Russian or Spanish*	12
Major specialty†	18
Minor specialty‡	12
Humanities/Social Science electives	9
Free electives	20
	128

*If less than 12 credits are needed, the remaining credits should be taken in the humanities/social science areas.
**MA 100-110 is an alternative to MA 101-102 with adviser's approval.
†Major specialty. Students must elect coherent courses of study in their major field. Three typical selections follow:***

Course of Study I	Course of Study II	Course of Study III
MA 570	MA 224	Course of Study II
MA 211, 212	MA 201, 202	plus CS 203, 204,
Math electives — nine credits	MA 358	205, 206, 306, 308
	IE 327, 328	

Note: If course of study III is elected, the minor specialty is eliminated.

‡Minor specialty: at least twelve credits beyond required courses in any single area of study outside the Department of Mathematics, except for statistics, which may include mathematical statistics courses. The sequence must be well integrated and consistent, thereby enabling the student to gain knowledge in an area outside the Department of Mathematics. The faculty adviser of the department of interest should be consulted.

***In addition, a program of studies leading to the bachelor of science degree in mathematics (actuarial science) appears in the section titled actuarial science section.

Minor Specialties — To achieve depth of understanding in a field other than mathematics, students are asked to choose a 12-credit sequence from other disciplines. This work must be in addition to courses taken under other categories of the programs, e.g., required courses in physics do not count toward a minor in physics nor do French courses in fulfillment of language requirements count toward a minor in French. With the exception of applied statistics and computing courses, all minor courses must be completed outside the department. Education courses are not accepted toward a minor specialty, nor are the first two years of a second foreign language.

Courses of minor specialties are chosen in consultation with advisers. In appropriate cases, advisers for minor sequences may be from departments other than mathematics. The following are possible minor concentrations:

Aerospace	AM 111, 112, 311, 312
Statistics	MA 232, 555, 556, 557

IE 632   Nonlinear Programming*   2½:0:3
Optimization of nonlinear functions. Classical methods. Constraints and Lagrangian methods. Kuhn-Tucker theory. Duality and economic interpretation. Separable programming, feasible directions, gradient projection. Quadratic and convex programming. Industrial and engineering applications. Prerequisite: IE 631.
Also listed under MA 818.

IE 633   Integer Programming*   2½:0:3
Solution techniques for integer and mixed-integer linear programming problems. Cutting plane methods, zero-one programming, branch and bound methods. Surrogate constraints. Quadratic programming. Applications to combinatorial analysis. Prerequisite: IE 631.
Also listed under MA 814.

IE 634   Dynamic Programming*   2½:0:3
Application of principle of optimality to solution of deterministic and stochastic systems as multistage decision processes. Relationship to variational methods. Nonserial problems. Howard's algorithms. Applications, problem formulation, computational procedures. Prerequisites: MA 561 and either IE 627 or IE 631.

IE 635   Advanced Linear Programming*   2½:0:3
Parametric programming. Primal-dual algorithm. Upper bounds and generalized upper bounds. Decomposition principle. Network flows. Stochastic and chance-constrained programming. Applications to large-scale systems. Construction of computer programs. Recent algorithms, e.g., Khatchian and Karmarkar. Prerequisites: MA 561 and IE 631.

IE 636   Network Flows and Application*   2½:0:3
Introduction to graphs and networks. Definition and fundamental principles of networks. Maximum flow and minimum cost models in static and dynamic networks. Stochastic and activity networks. Applications include production-inventory problems, plant location-allocation problems, regional transportation and traffic assignments, manufacturing processes. Prerequisites: MA 561 and either IE 627 or IE 631.

IE 642   Robotics Applications*   2:1:3
Applied robotics and integration of robots into manufacturing processes. The course will cover robotic work space design, selection of robot types to suit each phase of industrial engineering, flexible manufacturing and work cells. Laboratory experiments will include construction and use of robots and scaled models, Plant visits, case studies. (Not open to students who have taken IE 342.)

IE 645   Productivity Management*   2½:0:3
Modern approaches to productivity measurement, evaluation, planning and improvement in both manufacturing and service industries. Participants will develop productivity models for various types of organizations.
Also listed under MG 645.

IE 650   Queuing Systems I   2½:0:3
Development of elements of queuing and loss theory. Single and multiple servers, Markovian and non-Markovian arrival and service time distributions, various queue disciplines. Applications to inventory control, maintenance, transportation, communication. Model building and basic solution techniques stressed rather than formal theoretical development. Prerequisite: MA 561.

IE 651   Queuing Systems II*   2½:0:3
Applications of queuing theory with emphasis on communications and vehicular traffic. Customer behavior, switching networks, overflow traffic, alternate routing, feedback, priorities, control. Formulation of standards based on cost-benefit view-point. Prerequisite: IE 650 or MA 815.

IE 671   Business and Economic Forecasting   2½:0:3
Forecasting for managerial decision control. Statistical vs. judgmental methods. Smoothing and analyses of trends, seasonal factors, cycles and random variations. Econometric forecasting. Economic indicators and sources of information. Applications to the national economy, industry sales, corporate profits, financial institutions, government expenditures, etc. Prerequisite: IE 608.
Also listed under MG 671.

IE 680   Discrete System Simulation   2½:0:3
Modeling and simulation of discrete stochastic systems. Generation of pseudo-random numbers, variates from discrete, continuous, theoretical and empirical distributions. Extensive study of SIM-SCRIPT II.5, introduction to other languages. Students program, code and run several simulation models. (Not open to students who have taken IE 380.) Prerequisite: knowledge of computer programming and IE 608 or equivalent.

IE 682   Factory Simulation*   2½:0:3
Modeling and simulation of complex industrial, commercial, and service systems, such as factories and hospitals. Students develop, run, and experiment with several simulation models using different software packages. Prerequisites: knowledge of computer programming and MA 561 or equivalent.

IE 685   System Reliability*   2½:0:3
Structural reliability, redundancy, bounds on reliability of complex systems. Repairable systems: Markov models, maintainability and availability. Optimization of spare parts inventories, inspection intervals and replacement times. Failure models: accumulated shocks and stress-strength-time. Marginal failures, dependent failures. Prerequisite: EL 531 or MA 561 or equivalent.
Also listed under EL 617.

IE 686   Component Reliability*   2½:0:3
Failure models for industrial components: exponential, Weibull, lognormal, gamma, Gumbel and other distributions. Failure and hazard rates, graphical probability plots and maximum-likelihood parameter estimation and testing. Sampling plans based on life tests and accelerated life tests. Serial and parallel analysis on component reliability. Prerequisite: EL 531 or MA 561 or equivalent
Also listed under EL 618.

IE 720   Optimum Seeking Methods*   2½:0:3
Algorithm construction and applications of computer-implemented search procedures. One-dimensional searches, including Fibonacci and golden section search; quadratic and cubic convergent search. Multivariate methods, including gradients, conjugate directions and variable metric (e.g., DFP) methods. Constraints, penalty functions, SUMT. Sensitivity, convergence and program efficiency. Prerequisites: computer programming and either IE 627 or IE 631.

**IE 727   Case Studies In Industrial Engineering
           and Operations Research***   2½:0:3
Application of scientific and analytical methods to solving management decision-making problems, drawn from current practice and literature. Prerequisite: instructor's permission.

IE 754   Logistics*   2½:0:3
Analysis of logistic problems and procedures applied to inventory control, materials handling systems, packaging, warehousing, transportation, facility location, information/communications, and customer service. Cost trade offs between the various components in optimization of the total logistics system. Logistics systems design and productivity measures. Business and military cases and applications. (Not open to students who have taken IE 350.) Prerequisites: IE 627 and IE 628, or instructor's permission.
Also listed under TR 754.

IE 757 Technology Transfer to Developing Countries*   2½:0:3
Mechanisms of technology transfer. Ecological, social and economic factors in technology selection and utilization. Local efforts to adapt technology to local needs. National and international means to stimulate or block technology transfer. Technology and political influence. Case studies of technology transfer to newly industrializing countries.
Also listed under SS 675.

IE 765 Human Factors in Engineering Design*   2:1:3
Study of research techniques that yield information important in man-machine systems design. Man's learning, problem-solving, physiological and information processing capacities, performance under various environmental conditions. (Not open to students who have taken IE 365.) Prerequisite: SS 189, or permission of instructor.

IE 775 Industrial Safety Engineering*   2½:0:3
Analysis and design of industrial accident prevention, control and management systems. Effect of OSHA, Workmen's Compensation and environmental factors in implementing safety programs. Project work involves safety inspection, detection and control of hazards. (Not open to students who have taken IE 375.)

IE 776 Manufacturing Resource Planning*   2½:0:3
Quantitative models for analysis of production and inventory management systems. Topics covered include bill of material structures, time-phased parts requirements, shop loading and capacity constraints, priority planning and control, and schedule regeneration. Development of computer-based MRP systems. (Not open to students who have taken IE 376.) Prerequisites: IE 619 or instructor's permission, knowledge of computer programming.

IE 777 Manufacturing Improvement Curves*   2½:0:3
Development of learning-curve theory, analysis of various improvement curve models and estimation of parameters. Applications of improvement curves are incorporated in evaluating work standards, wage incentives, training and labor turn-over cost, inventory control, price policy and production schedules. (Not open to students who have taken IE 377.) Prerequisite: IE 606.

IE 778 Advanced Production Planning*   2½:0:3
Quantitative analysis of aggregate planning models using optimal, heuristic and search decision rules. Explosion and netting models for material and resource requirements. Algorithms for scheduling manpower for continuous operations. Selected topics in operational planning from recent research literature and assigned independent study. Prerequisite: IE 619.

IE 779 Advanced Work Systems Design*   2½:0:3
Study of work design with emphasis on parameters affecting installation of overall system. Advanced work sampling, work-force balancing, ergonomic work loads, incentive for machine-controlled operations, computer-assisted planning of systems. Prerequisite: IE 606.

IE 785 Computer Integrated Manufacturing Systems (CIMS)*   2½:0:3
CIMS encompasses all activities from planning and design of a product to its manufacture and shipping. This course will offer several perspectives on the manufacturing system. It will also describe the elements of the system and their interfaces. This conceptual structure will be reinforced by discussion of system planning and performance projection through simulation.

IE 788 Case Studies in Electronics Manufacturing   2½:0:3
Contemporary techniques for product design and manufacturing. Topics include robust design of product and processes using orthogonal array techniques, simulation, partitioning and scale-up JIT/TQC, "pull" and flexible manufacturing processes. Financial and other performance metrics pertinent to these new processes will be given. Corporate cultural changes necessary to effect their successful introduction will be discussed. Applications will be illustrated by case studies of successes and anatomy of disasters drawn from a wide variety of design and manufacturing situations.

IE 846 Urban Systems Analysis*   2½:0:3
The overall urban system. Modeling for prediction and management of major components: population, economy, land use, transportation network, facility location, government service systems. Cost-benefit viewpoint in social welfare context. (Not open to students who have taken IE 346, except with instructor's permission.) Prerequisite: IE 627 or equivalent.

IE 851 Stochastic Processes*   2½:0:3
Random variables and stochastic processes. Moment generating and characteristic functions. Conditional expectations. Homogeneous and nonhomogeneous Poisson processes. Waiting and interarrival times. Renewal processes. Integral equation, age, and excess life. Discrete parameter Markov chains. Classification and decomposition. Continuous parameter Markov chains. Backward and forward differential equations. Birth and death processes. Applications to business, industry, and sciences. Prerequisite: MA 561.

IE 852 Applied Regression and Analysis of Variance*   2½:0:3
Analysis of observed data by means of regression and analysis of variance and covariance. Multiple regression in matrix notation. Systematic treatment of analysis of multiple classifications involving fixed and random effects and crossed and nested variables of classification. Regression analysis and its relation to analysis of variance. Use of BMD and SPSS program packages. Prerequisites: MA 153 and IE 608.

IE 853 Design of Experiments*   2½:0:3
Basic designs for scientific and industrial experiments: single-factor and multiple-factor completely randomized designs, randomized blocks, incomplete blocks, orthogonal contrasts, general regression approach, Latin and higher squares, quantitative factors—orthogonal polynomials, complete and fractional factorial experiments including confounding methods. Use of BMD and SPSS program packages. Prerequisite: IE 608.

IE 870 Games and Decisions*   2½:0:3
Rectangular games and strategies, payoffs, values and the minimax theorem. Continuous games. Relationships to linear programming. Statistical decision functions. Bayes, minimax, admissible and complete class of decision functions. Behavioral decision models and bounded relationality. Utility and choices. Group decisions and multiple objectives. Applications to statistics, managerial decisions and public affairs. Prerequisite: IE 608.

IE 911-912 Selected Topics in Operations Research and Industrial Engineering I, II*   each 2½:0:3
Areas not covered in other courses. Specific topics vary according to instructor, who may be a visiting professor. Topics and prerequisites announced during term prior to offering.

IE 920 Research Seminar in Operations Research and Industrial Engineering*   2½:0:3
Examination of selected advanced topics at research frontiers of department's graduate program areas. Presentations by graduate students, faculty, visiting scientists. Prerequisite: candidacy status for a graduate degree or permission of the course coordinator.

IE 930-931 Readings in Industrial Engineering I, II   each 3 units
Individual reading of selected papers and current literature in specialized area of study, guided by faculty member. Prerequisite: approval of adviser, instructor and department head.

IE 935 Engineering Projects Related to Public Administration   each 3 units
See Cooperative Program with New York University's Graduate School of Public Administration for details.

Biology	LS 105, 115, 106, 116, 103
Chemistry	CM 122, 123, 161, 162
Computers	CS 203, 205, 236, 237
Industrial Engineering	IE 300, 306, 327, and one of IE 311, 319, 321
Operations Research	IE 300, 327, 328, and one of IE 319, 346, 380
Management	MG 300, SS 199, MG 304 and either SS 251 or SS 252
Physics	PH 210, 321, 313, 314
Psychology	SS 189, 190, 192, 193, 195, 197
Economics	SS 251, 252, 730, IE 300
Electrical Engineering Systems	EE 101, 102, 103, 104
English Literature	HU 211, 212, 222, 241, 251, 258, 262, 272, 295
French	ML 135, 235, 236, 237, 238
Transportation	TR 360, 361, 362, 840, 842, 845

Advanced Placement — Advanced placement credits may be given for the first year of calculus. Students receiving grades of 4 or 5 on advanced placement examinations in calculus, conducted by the College Entrance Examination Board, may be granted a maximum of eight credits to be applied toward the 128-credit requirement for bachelor's degrees in mathematics.

ACTUARIAL SCIENCE

The actuarial profession has always been a lucrative field for those at ease with numbers and mathematical theories. Actuarial science combines mathematics, statistics, and business economics. It provides the educational background for a range of careers in business, industry, and government. Typical areas include: insurance, human resources and benefit planning, and contract negotiation.

Actuaries are responsible for calculating premiums on life insurance, casualty insurance, retirement and pension plans. Their duties cover deciding how much money must be set aside periodically to provide future payment of benefits; analyzing sources of earnings under policy contracts to determine proper rates of dividends, and investigating factors related to payments of various types of policies. In life insurance, they consider effects on mortality of physical impairments, hazardous occupations, and other unusual risks; in pension and casualty fields, they are concerned with changing life styles and demographic effects on policy incomes and payments. Actuaries usually play important parts in developing executive policies of companies. Although *these actuaries cannot operate without thorough knowledge of the mathematical bases of finance*, they are more business men and women than mathematicians. They explain complicated problems to colleagues and policyholders in clear language.

The development of health, pension, and accident insurance have posed many new problems in mathematical and statistical theory and practical administration. It is largely actuaries who solve these problems. Though not restricted to insurance, many actuaries are found in insurance companies. Business and industry provide opportunities for consulting actuaries; actuaries are also employed by federal and state governments.

The profession is not crowded. Large companies, particularly those engaged in writing industrial insurance, group

insurance, and pension plans, need large staffs of actuaries. Many people initially trained as actuaries move on to other spheres, particularly the investment, administration, underwriting, accounting, and other executive positions.

In actuarial careers, adequate salaries are paid even during training periods. Later, salaries depend upon responsibilities assumed; average salaries are high.

Qualification is attained by passing examinations required for membership in the Actuarial Society of American or the American Institute of Actuaries. Salaries for actuarial trainees depend on the number of examinations passed. It is anticipated that students in this program are able to take and pass three or four of these examinations before graduating. For this reason, these studies are well-suited to the Cooperative Education Program, especially if students plan to work the year between their junior and senior year.

The program is similar to others in the mathematics department. Course requirements, typical courses of study, and course descriptions for actuarial science follow.

Requirements for the Bachelor of Science Degree in Mathematics (Actuarial Science)

	Credit
MA 101**-104, 153, 217, 223	23
CS 111; PH 101-103; CM 101, 102, 111, 112	19
HU 101, 200; SS 104, 251, 252	15
Two years* (or equivalent) of French, German, Russian or Spanish	12
Major specialty: MA 201, 202, 224, 358; AC 301, 302, 401, 402, 501-503; IE 300, 327, 328	38
Humanities/Social Sciences elective	3
Free electives	18†

*If less than 12 credits are needed, remaining credits should be taken in the HU/SS areas.
**MA 100-110 is an alternative to MA 101-102 with adviser's approval.
†It is suggested that some of these be CS courses.

JOINT MATHEMATICS AND PHYSICS MAJOR

A joint major for the BS degree in Mathematics and Physics is offered at the Polytechnic.

The purpose of the Joint Major is to offer a student an opportunity to gain competence in two different and substantial fields of science, to such an extent that upon earning a Bachelor's degree, they are able to qualify for industrial positions in two distinct areas, or to go on to graduate studies in either of the two subjects.

Requirements for the Joint Bachelor of Science Degree in Mathematics and Physics

	Credit
MA 101*-104, 153, 201-2, 217, 223, 224, 333, 358	38
PH 104-06, 115-6, 210, 234, 236, 302, 311, 323-4, 335-6, 347, 373-5, 390	43
CM 101-2, 111-2, CS 112	9
HU 101, 200; SS 104	9
Language (or equivalent)	12
Humanities/Social Sciences electives	9
Free electives	8†
	128

**MA 100-110 is an alternative to MA 101-102 with adviser's approval.

Typical Course of Study I for the Bachelor of Science Degree in Mathematics (Abstract)‡

Freshman Year

First Semester			Hours/Week			Second Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.	No		Subject	Cl.	Lab.	Cr.
MA	111	Calculus Ia	4	0	4	MA	112	Calculus IIa	4	0	4
PH	101	General Physics I	3	0	3	PH	102	General Physics II	3½	1½	4
CS	112	Programming in Pascal	3	0	3	HU	200	Writing and the Humanities II	3	0	3
HU	101	Writing and the Humanities I	3	0	3	MA	153	Elem. Linear Algebra	3	0	3
		Language courses	3	0	3			Language course	3	0	3
SL	101	Student Survival	0	1	0	PE	102	Phys. Ed.	0	2	0
PE	101	Physical Education	0	2	0						17
					16						

Sophomore Year

MA	113	Calculus IIIa	3	0	3	MA	114	Differential Equations	3	0	3
MA	154	Elem. Abstract Algebra	3	0	3	MA	570	Intro. Geometry	3	0	3
PH	103	General Physics III	2½	1½	3	CM	102	General Chemistry II	2½	0	2½
		Language course	3	0	3	CM	112	General Chemistry Lab. II	0	1½	½
CM	101	General Chemistry I	2½	0	2½			Language course	3	0	3
CM	111	General Chemistry Lab. I	0	1½	½			Electives*			3
PE	103	Physical Education	0	2	0	PE	104	Phys. Ed.	0	2	0
					15						15

Junior Year

MA	211	Analysis I	3	0	3	MA	212	Analysis II	3	0	3
MA	217	Complex Variables	3	0	3	MA	333	Partial Diff. Equations	3	0	3
MA	223	Intro. to Probability	3	0	3			Minor specialty†			3
SS	104	Contemp. World History	3	0	3			Electives*			7
		Minor Specialty†			3						16
		Electives*			2						
					17						

Senior Year

		Minor specialty			3			Minor specialty†			3
		Electives			13			Electives*			13
					16						16

Total credits required for graduation: 128

*Electives total 45 credits, of which at least nine must be in the courses with MA labels and at least nine in courses with HU, SS or ML labels. Remaining elective may be freely chosen from the catalog.

†See minor specialty.
‡This is a sample program. Students should consult with an adviser before embarking on a specific course of study.

Typical Course of Study II for the Bachelor of Science Degree in Mathematics (Applied)‡

Freshman Year

First Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
MA	101	Calculus I**	4	0	4
PH	101	General Physics I	3	0	3
CS	112	Programming in Pascal	3	0	3
HU	101	Writing and the Humanities I	3	0	3
		Language courses	3	0	3
SL	101	Student Survival	0	1	0
PE	101	Physical Education	0	2	0
					16

Second Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
MA	·102	Calculus II**	4	0	4
PH	102	General Physics II	3½	1½	4
HU	200	Writing and the Humanities II	3	0	3
SS	104	Contemp. World History	3	0	3
		Language course	3	0	3
PE	102	Phys. Ed.	0	2	0
					17

Sophomore Year

			Hours/Week		
MA	103	Calculus III	3	0	3
PH	103	General Physics III	2½	1½	3
MA	223	Intro. Probability	3	0	3
		Language course	3	0	3
CM	101	General Chemistry I	2½	0	2½
CM	111	General Chemistry Lab. I	0	1½	½
PE	103	Physical Education	0	2	0
					15

			Hours/Week		
MA	104	Appl Diff. Equations	3	0	3
MA	224	Intro. to Math. Stat.	3	0	3
MA	153	Elem. of Linear Algebra	3	0	3
		Language course	3	0	3
CM	102	General Chemistry II	2½	0	2½
CM	112	General Chemistry Lab. II	0	1½	½
PE	104	Phys. Ed.	0	2	0
					15

Junior Year

			Hours/Week		
MA	201	Applied Analysis I	3	0	3
MA	217	Complex Variables	3	0	3
MA	333	Partial Diff. Equations	3	0	3
IE	327	Operations Res. Models I	3	0	3
		Minor Specialty*			3
		Electives			2
					17

			Hours/Week		
MA	202	Applied Analysis	3	0	3
MA	358	Intro. Numerical Anal.	3	0	3
IE	328	Operations Res. Models II	3	0	3
	·	Minor specialty			3
		Electives			4
					16

Senior Year

			Hours/Week		
MA	154	Elem. of Abstract Algebra	3	0	3
		Minor specialty*			3
		Electives			10
					16

Minor specialty				3
Electives				13
				16

Total credits required for graduation: 128

*See minor specialty.
**MA 100-110 is an alternative to MA 101-102 with adviser's approval.

‡This is a sample program. Students should consult with an adviser before embarking on a specific course of study.

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Typical Courses of Study III for the Bachelor of Science Degree in Mathematics (Computer Science)‡

Freshman Year

First Semester			Hours/Week			Second Semester			Hours/Week		
No		Subject	Cl.	Lab.	Cr.	No		Subject	Cl.	Lab.	Cr.
MA	101	Calculus I**	4	0	4	MA	102	Calculus II**	4	0	4
PH	101	General Physics I	3	0	3	PH	102	General Physics II	3½	1½	4
CS	112	Programming in Pascal	3	0	3	HU	200	Writing and the Humanities II	3	0	3
HU	101	Writing and the Humanities I	3	0	3	CS	204	Data Structures and Algorithms	3	0	3
		Language course	3	0	3			Language course	3	0	3
SL	101	Student Survival	0	1	0	PE	102	Physical Education	0	2	0
PE	101	Physical Education	0	2	0						17
					16						

Sophomore Year

			Cl.	Lab.	Cr.				Cl.	Lab.	Cr.
MA	103	Calculus III or	3	0	3	MA	104	Appl. Diff. Equations	3	0	3
PH	103	General Physics III	2½	1½	3	MA	224	Intro. to Math. Stat.	3	0	3
MA	223	Intro. Probability	3	0	3	MA	153	Elem. of Linear Albebra	3	0	3
		Language course	3	0	3			Language course	3	0	3
CS	236	Theory and Logic Design	3	0	3	SS	104	Contemporary World History	3	0	3
PE	103	Physical Education	0	2	0	PE	104	Physical Education	0	2	0
					15						15

Junior Year

			Cl.	Lab.	Cr.				Cl.	Lab.	Cr.
MA	201	Applied Analysis I	3	0	3	MA	202	Applied Analysis	3	0	3
MA	217	Complex Variables	3	0	3	MA	358	Intro. Numerical Anal	3	0	3
CS	212	C, UNIX, and Software Development	3	0	3	IE	328	Oper. Res. Models II	3	0	3
IE	327	Operations Res. Models I	3	0	3	CS	205	Assembly Language and Systems Programming	3	0	3
CM	101	General Chemistry I	2½	0	2½	CM	102	General Chemistry II	2½	0	2½
CM	111	General Chemistry Lab I	0	½	½	CM	112	General Chemistry Lab II	0	1½	½
					15			Elective	3	0	3
											18

Senior Year

			Cl.	Lab.	Cr.				Cl.	Lab.	Cr.
MA	154	Elem. of Abstract Algebra	3	0	3	CS	275	Theory of Computation	3	0	3
CS	337	Computer Architecture and Organization	3	0	3			Electives*	13	0	13
MA	333		3	0	3						16
		Electives	7	0	7						
					16						

Total credits required for graduation: 128

**MA 100-110 is an alternative to MA 101-102 with adviser's approval.
‡This is a sample program. Students should consult with an adviser before embarking on a specific course of study.

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Typical Course of Study for the Bachelor of Science Degree in Mathematics (Actuarial Science)‡

Freshman Year

First Semester			Cl.	Lab.	Cr.	Second Semester			Cl.	Lab.	Cr.
No		Subject	Hours/Week			No		Subject	Hours/Week		
MA	101	Calculus I**	4	0	4	MA	102	Calculus II**	4	0	4
PH	101	General Physics	3	0	3	PH	102	General Physics II	3½	1½	4
CS	112	Programming in Pascal	3	0	3	HU	200	Writing and the Humanities II	3	0	3
HU	101	Writing and the Humanities I	3	0	3	SS	104	Main Themes in Contemp. World History	3	0	3
		Language course	3	0	3			Language course	3	0	3
SL	101	Student Survival	0	1	0						
PE	101	Physical Education	0	2	0	PE	102	Physical Education	0	2	0
					16						17

Sophomore Year

			Cl.	Lab.	Cr.				Cl.	Lab.	Cr.
MA	103	Calculus III or	3	0	3	MA	104	Appl. Diff. Equations	3	0	3
PH	103	General Physics III	3½	1½	3	MA	224	Intro. to Math. Stat.	3	0	3
MA	223	Intro. Probability	3	0	3	MA	153	Elem. of Linear Algebra	3	0	3
		Language course†	3	0	3			Language course†	3	0	3
CM	101	General Chemistry I	2½	0	2½	CM	102	General Chemistry II	2½	0	2½
CM	111	General Chemistry Lab. I	0	1½	½	CM	112	General Chemistry Lab. II	0	1½	½
PE	103	Physical Education	0	2	0	PE	104	Physical Education	0	2	0
					15						15

Junior Year

			Cl.	Lab.	Cr.				Cl.	Lab.	Cr.
MA	201	Applied Analysis I	3	0	3	MA	202	Applied Analysis	3	0	3
MA	217	Complex Variables	3	0	3	MA	358	Intro. Numerical Anal.	3	0	3
IE	327	Oper. Res. Models I	3	0	3	IE	328	Oper. Res. Models II	3	0	3
AC	301	Actuarial Science Workshop I	1½	1½	2	AC	302	Actuarial Science Workshop II	1½	1½	2
		Elective	3	0	3	AC	501	Actuarial Science I	2½	0	3
IE	300	Engineer. Economy	3	0	3			Elective	3	0	3
					17						17

Senior Year

			Cl.	Lab.	Cr.				Cl.	Lab.	Cr.
AC	401	Actuarial Science Workshop III	1½	1½	2	AC	402	Actuarial Science Workshop IV	1½	1½	2
AC	502	Actuarial Sci. II	2½	0	3	AC	503	Actuarial Sci. III	2½	0	3
SS	251	Microeconomics†	3	0	3	SS	252	Macroeconomics†	3	0	3
		Electives*			9			Electives*			6
					17						14

Total credits required for graduation: 128

†If only 6 language credits are required because foreign languages were begun in high school, they should be taken in freshman year and SS 251, 252 should be taken in sophomore year. Language requirement in sophomore year may then be replaced by 6 other credits of HU/SS in senior year.
*Electives total 21 credits, of which at least 3 must be in courses with HU/SS labels
**MA 100-110 is an alternative to MA 101-102 with adviser's approval.
‡This is a sample program. Students should consult with an adviser before embarking on a specific course of study

Typical Course of Study for the Bachelor of Science Degree with a Joint Major in Mathematics and Physics‡

Freshman Year

First Semester

No.		Subject	Cl.	Lab	Cr.
CS	112	Programming in Pascal	3	0	3
CM	101	Gen. Chemistry I	2½	0	2½
CM	111	Gen. Chem. Lab I	0	1½	0½
MA	101	Calculus I*	4	0	4
		Hum./Soc. Sci. elective	6	0	6
SL	101	Student Survival	0	1	0
PE	10x	Physical Education	0	2	0
					16

Second Semester

No.		Subject	Cl.	Lab.	Cr.
CM	102	Gen. Chemistry II	2½	0	2½
CM	112	Gen. Chem. Lab II	0	1½	0½
MA	102	Calculus II*	4	0	4
PH	104	Intro. to Physics I	3	0	3
		Hum./Soc. Sci. elective	6	0	6
PE	10x	Physical Education	0	2	0
					16

Sophomore Year

First Semester

No.		Subject	Cl.	Lab.	Cr.
MA	103	Calculus III	3	0	3
MA	223	Probability	3	0	3
PH	105	Intro. to Physics II	3½	0	3½
PH	115	Physics Lab I	0	1½	0½
PH	210	Analyt. Mechanics	3	0	3
		Hum./Soc. Sci. elective	3	0	3
PE	10x	Physical Education	0	2	0
					16

Second Semester

No.		Subject	Cl.	Lab.	Cr.
MA	104	Appl. Diff. Eqns.	3	0	3
MA	224	Statistics	3	0	3
PH	106	Intro. to Physics III	2½	0	2½
PH	116	Physics Lab II	0	1½	0½
PH	234	Intro. to Mod. Phys.	2	0	2
PH	236	Physics Lab III	0½	1½	1
		Hum./Soc. Sci. elective	3	0	3
PE	10x	Physical Education	0	2	0
					15

Junior Year

First Semester

No.		Subject	Cl.	Lab.	Cr.
MA	201	Appl. Analysis I	3	0	3
MA	333	Part. Diff. Eqns.	3	0	3
MA	153	Elem. Lin. Algebra	3	0	3
PH	323	El. & Magnetism I	2	0	2
PH	335	Quantum Physics II	3	0	3
		Hum./Soc. Sci. elective	3	0	3
					17

Second Semester

No.		Subject	Cl.	Lab.	Cr.
MA	202	Appl. Analysis II	3	0	3
MA	358	Numerical Analysis	3	0	3
PH	302	Advanced Lab	1	3	2
PH	324	Elect/ & Magnetism II	2	0	2
PH	336	Quantum Mechanics	3	0	3
		Hum./Soc. Sci. Electives	3	0	3
					16

Senior Year

First Semester

No.		Subject	Cl.	Lab.	Cr.
MA	217	Complex Variables	3	0	3
PH	311	Thermodynamics	3	0	3
PH	373	Intro. Theor. Ph. I	3	0	3
PH	347	Modern Optics	3	3	4
		Hum./Soc. Sci. elective	3	0	3
					16

Second Semester

No		Subject	Cl.	Lab	Cr.
PH	374	Intro. Theor. Ph. II	3	0	3
PH	390	Senior Seminar	2	0	2
		Hum./Soc. Sci. elective	3	0	3
		Free elective	8	0	8
					16

Total credits required for graduation: 128

**MA 100-110 is an alternative to MA 101-102 with adviser's approval.
‡This is a sample program. Students should consult with an adviser before embarking on a specific course of study.

GRADUATE PROGRAMS

The Department of Mathematics offers graduate-level courses in foundations and logic, analysis, geometry and topology, algebra and number theory, applied mathematics, probability and statistics. These courses form a major portion of the work for advanced degrees in mathematics. They may also be taken by students in other departments to satisfy minor and elective requirements and by qualified pre-degree students who desire further study in graduate-level mathematics.

The department offers master's degrees in abstract mathematics, industrial and applied mathematics and applied statistics. Doctor's degrees are offered in abstract mathematics, applied mathematics and applied statistics. Departmental requirements for these degrees are supplemented by certain general requirements for advanced degrees set forth elsewhere in this catalog.

Outstanding students are advised to apply for research fellowships, teaching fellowships or partial tuition remission.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE IN MATHEMATICS

Bachelor's degrees in mathematics are required for admission to this program. Students with degrees in other fields may be admitted, possibly with undergraduate deficiencies, at the discretion of deparmental advisers.

Before beginning graduate studies, students are expected to have completed a year's course in advanced calculus. In case of acceptance without these credits, students are asked to take the sequence MA 619-620 at Polytechnic in addition to other requirements listed below for master's degrees.

Thirty-six units are required, including 21 units of required courses. Six units may be devoted to a thesis.

No.	Required Subjects	Units
MA 621-622	Real and Complex Analysis	6
MA 705-706	Linear and Modern Algebra	6
	Elective courses	18
	Additional electives or thesis	6
		36

The thesis option includes an examination of the thesis material by faculty advisers and certification that the work is satisfactory. Students offering only course work must pass comprehensive oral examinations before degrees are awarded. Examinations cover students' programs of study and are scheduled toward the end of the semester in which work is completed.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE (INDUSTRIAL AND APPLIED MATHEMATICS)

The industrial and applied mathematics option is offered to students interested in certain areas of applied mathematics rather than in pure mathematics. By selecting appropriate sequences of courses, students can major in mathematical statistics or in mathematical operations research. Department advisers aid students in selections of programs of study. Students who elect this option may continue toward the Ph.D. in mathematics.

Bachelor's degrees in some quantitative field, with at least a minor in mathematics, are required for admission to this program. Students who enter without a year's course in advanced calculus are asked to take the sequence MA 619-620 at Polytechnic for which no graduate credit is given. Students who enter without undergraduate courses in linear algebra or complex variables are asked to take one from the graduate program; for each such course successfully completed, three units are allowed toward degrees.

No.	Required Subjects	Units
MA 813	Linear Programming	3
MA 821	Numerical and Approximate Analysis	3
MA 853	Probability I	3
MA 861	Principles of Statistical inference	3
Applied electives — chosen from MA 812, 814, 815, 817, 822, 823, 854, 855, 862		9
Other electives		9
Additional electives or thesis		6
		36

Regulations governing the thesis option or final examination for degrees are the same as for master's degrees in mathematics.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE (STATISTICS)

Bachelor's degrees are required in some quantitative field with at least a minor in mathematics, which should include a six-credit course in probability and statistics equivalent to MA 233-224 or MA 561-562. Students may be admitted with undergraduate deficiencies after consulting with departmental advisers. Such students are required to take the courses necessary to remove deficiencies.

Required Courses		Units
MA 619-620	Advanced Calculus	6
At least 3 of		9-12
MA 554	Applied Decision Theory	
MA 555	Design of Experiments	
MA 556	Correlation and Multivariate Models	
MA 557	Sampling	
MA 853	Probability	3
MA 854	Probability II	3
MA 861-862	Principles of Stat. Inference I, II	6
		27-30

Electives: Project ST 995 (3 units),
Thesis ST 997 (6 units) — 3-9 / 36

Regulations governing the thesis option for final examination fo this degree are the same as for master's degrees in mathematics.

The thesis or project option includes an examination of the material by faculty advisers and certification that the work is satisfactory. Students offering only course work must

pass comprehensive oral examinations before degrees are awarded. Examinations cover students' programs of study and are scheduled toward the end of the semester in which work is completed.

REQUIREMENTS FOR THE DOCTOR OF PHILOSOPHY DEGREE IN MATHEMATICS

Requirements for doctor's degrees are primarily qualitative rather than quantitative. All students' programs must have the approval of the guidance committee.

The number of graduate units of course work usually associated with doctoral programs is 72. These are normally selected to form well-balanced programs in one major and two minor fields. One minor field may be outside the Department of Mathematics, selected from such fields as applied mechanics, electrophysics, circuit theory, physics, industrial engineering, industrial management, etc.

Doctoral candidates must pass a qualifying oral examination, which is divided into two parts. Part 1, taken early in the students' careers, covers real and complex variables and algebraic structures. Part 2, covering three elective topics, may be taken only after part 1 has been passed. Final examinations, which follow the submission of acceptable dissertations, are also oral.

In addition to 72 units of course materials, students must devote at least 24 units to dissertations, reporting original research under the direction of faculty advisers.

Students must satisfy doctoral language requirements in one language (selected from French, German or Russian).

Additional details are contained in brochures which may be obtained from the departmental office.

REQUIREMENTS FOR THE DOCTOR OF PHILOSOPHY DEGREE IN STATISTICS

Within the Department of Mathematics, Polytechnic offers graduate studies in the field of statistics leading to Ph.D. degrees. A full range of courses is offered in the areas of applied and mathematical statistics, supported by a range of elective courses in probability and all areas of abstract and applied mathematics. Students may also take elective courses from other departments, selected under the supervision of graduate advisers.

A bachelor's degree with at least a minor in mathematics, which should include a one-year course in advanced calculus, is required for admission.

No.	Required Subjects	Units
MA 630	Elements of Complex Variables	3
MA 703	Linear Algebra	3
MA 621	Real Analysis	3
MA 853,854,855	Probability, Stochastic Processes	9
MA 861-862	Principles of Statistical Inference	6
MA 863-864	Multivariate Analysis	6
MA 865-866	Regression and Analysis of Variance	6
		36

At least 3 of		9-12
MA 555	Design of Experiments	
MA 557	Sampling	
MA 867	Nonparametric Methods in Statistics	
MA 881	Statistical Analysis of Time Series	
Electives, approved by departmental adviser		24-27
	Subtotal	72
Dissertation ST 999 (3 units each)		24
	Total	96

Students must satisfy the doctoral language requirements in one language (selected from French, German or Russian).

REQUIREMENTS FOR THE CERTIFICATE PROGRAMS

The department offers certificate programs in the areas of applied statistics, mathematical statistics, computer mathematics and mathematical programming. Requirements for the certificate program are 15 units.

Applied Statistics
MA 223   Introduction to Probability
MA 224   Introduction to Mathematical Statistics

Choice of three
MA 554   Applied Decision Theory
MA 555   Design of Experiments
MA 556   Correlation and Multivariate Models
MA 557   Sampling

Mathematical Statistics
MA 861   Statistical Inference I
MA 862   Statistical Inference II

Choice of three
MA 863   Multivariate Analysis I
MA 864   Multivariate Analysis II
MA 865   Regression and Analysis of Variance I
MA 866   Regression and Analysis of Variance II
MA 881   Statistical Analysis of Time Series I
MA 882   Statistical Analysis of Time Series II
MA 867   Nonparametric Methods in Statistics

Computer Mathematics
MA 821   Numerical and Approximate Analysis I
MA 822   Numerical and Approximate Analysis II

Choice of three
MA 823   Special Topics in Numerical Analysis I
MA 825   Numerical Linear Algebra
MA 837   Applied Matrix Theory
MA 838   Linear Algebra and Differential Equations

Mathematical Programming
MA 812   Theory of Games
MA 813   Linear Programming

Choice of three
MA 814   Integer Programming
MA 817   Graph Theory
MA 818   Nonlinear Programming
MA 844   Optimal Control Theory

REVIEW COURSES

MA 001   Pre-Collegiate Algebra   2:0:nc
For students who have not taken this subject in preparatory school or who need review work in algebra. Exponents and radicals, factoring and fractions, logarithms, systems of equations, ratio, proportion, variation, quadratic equations, inequalities.

MA 005   Pre-Collegiate Trigonometry   2:0:nc
For students who have not taken this subject in preparatory school or who need review work in trigonometry. Definitions of trigonometric functions, reduction formulas, radian measure and curve plotting, addition and subtraction formulas, inverse trigonometric functions, solutions of trigonometric functions, solutions of trigonometic equations, polar coordinates.

MA 011   Review of Calculus   ·   2:0:nc
For graduate students who are insufficiently prepared for subsequent required courses in differential equations. Fundamental concepts and applications of calculus and infinite series. Course is remedial, and admission required recommendation of departmental adviser.

UNDERGRADUATE COURSES

MA 091-092   Principles of Mathematics I, II   each 4:0:4
Logic, sets, mathematical induction, geometry, trionometry, functions, limits, differentiation, integration and some applications, probability. First course in mathematics for students in Departments of Humanities and Social Sciences.

MA 100   Introductory Calculus I   4:0:4
Basic algebraic operations, including absolute value. Equations and inequalities. Functions and their graphs. Systems of equations including determinants and Cramer's rule. Trigonometric functions: definitions, graphs, identities, and equations. Law of Sines, law of Cosines. Solution of triangles. Complex numbers. Limits and continuity of functions, including trigonometric functions. Derivatives and differentiation, including trigonometric functions. Emphasis is placed on solving word problems.

MA 110   Introductory Calculus II   4:0:4
Applications of differentiation, including related rates and maximum-minimum problems. Definition of the integral. The fundamental theorem of calculus. Applications of the definite integral, including area and volume. Derivatives and integrals of logarithmic, exponential, inverse trigonometric and hyperbolic functions. Techniques of integration, Improper integrals. L'Hospital rule, Sequence, series, and tests for convergence. Polar coordinates and applications. Parametric equations. Prerequisite: MA 100 or MA 101.

MA 101   Calculus I   4:0:4
Standard first course in calculus for beginning students. Function concepts, trigonometric functions, limits of algebraic and trigonometric functions, differentiation, maximization, applications to geometry and physics. The integral, elementary techniques of integration of algebraic and trigonometic functions.

MA 102   Calculus II   4:0:4
Applications of integration, logarithmic and exponential functions, advanced techniques of integration, hyperbolic functions, inverse trigonometric and hyperbolic functions, areas in polar coordinates, conic sections, indeterminate forms, infinite series and power series. Prerequisite: MA 101

MA 103   Calculus III   3:0:3
Solid geometry and vectors, partial derivatives. Multiple integrals. Parametric equations. Prerequisite: MA 102 or equivalent.

MA 104   Applied Differential Equations   3:0:3
Ordinary differential equations: separable variables, linear equations with constant coefficients, series solutions. Systems of differential equations. Prerequisite: MA 102 or equivalent.

MA 111   Calculus Ia   4:0:4
First course in calculus with emphasis on definitions and proofs. Standard operations of calculus of one variable, differentiation formulas, applications. The integral, methods of integration, applications. Polar coordinates, parametric equations, plane curves. Elementary transcendential functions. Prerequisite: department's permission.

MA 112   Calculus IIa   4:0:4
Sets and sequences of real numbers, properties of a real number system. Theory of limits and continuity. Definition of Riemann integral and Reimann-Stieltjes integral. Vectors on plane and space. Determinants. Introduction of matrices. Prerequisite: MA 111 or MA 101 and department's permission.

MA 113   Calculus IIIa   3:0:3
Standard operations of calculus of several variables. Partial derivatives. Multiple integrals. Infinite series, power series, uniform convergence. Interchange of order of limits, derivatives, integrals, series. Introduction to differential equations. Prerequisite: MA 112 or MA 102 and department's permission.

MA 114   Differential Equations   3:0:3
Existence and uniqueness theorems. Systems of ordinary differential equations. Series solutions. Nonlinear differential equations. Prerequisite: MA 112 or MA 102 and department's permission.

MA 143   Introduction to Number Theory   3:0:3
Properties of integers and prime numbers, congruences, theorems of Fermat, Euler, Wilson, quadratic residues, diophantine equations. Prerequisite: MA 102 or equivalent.

MA 153†   Elements of Linear Algebra   3:0:3
Linear transformations, matrices and determinants, characteristic roots, diagonalization, introduction to vector spaces. Prerequisite: MA 102 or equivalent.

MA 154†   Elements of Abstract Algebra   3:0:3
Basic properties of groups, rings, fields, ideals, Euclidean rings, modules, field extension, Galois theory, finite fields, finite division rings. Prerequisite: MA 153.

MA 161   Introduction of Point Set Topology   3:0:3
Definitions of topology and topological space, mappings, compact sets, seperation axioms, metric space and completion of a metric space. Prerequisite: MA 211 or MA 202.

MA 194†   History of Mathematics   3:0:3
Historical study of fundamental ideas of mathematics from antiquity to present day. Designed to develop deeper understanding of and cultural appreciation for signifcance of mathematics in civilization. Prerequisite: MA 102 or equivalent.

MA 201-202   Applied Analysis   each 3:0:3
Study of basic topics in analysis with emphasis on methods. Sequences, series, functions, uniform convergence, continuity, partial differentation, extreme value problems with constraints, Reimann integrals, line integrals, imporper integrals, integrals with parameters, transformations, Riemann-Stieltjes integral, uniform and absolute convergence of integrals. Beta, Gamma functions. Prerequisites: MA 103 and MA 104 or MA 113 and MA 114.

MA 211-212   Analysis I, II   each 3:0:3
Careful and rigorous discussion of real numbers. Limits, sequences, series. Functions of one real variable: continuity, derivatives, integral. Continuation of MA 211. Series and sequences of functions of one variable. Functions of several variables, transformation. Theorems of Gauss, Green, Stokes. MA 211 prerequisite: MA 114. MA 212 prerequisite: MA 211.

MA 217   Complex Variables   3:0:3
Functions of complex variables, derivatives, Cauchy-Reimann equations, integrals. Cauchy integral theory, power series, residue theory, conformal mapping. Schwarz-Christoffel transformation. Prerequisites: MA 103 and MA 104 or MA 113 and MA 114.

MATHEMATICS AND STATISTICS

MA 223† Introduction to Probability   3:0:3
Standard first course in probability; recommended for those planning further work in probability or statistics. Probability of events, random variables and expectations, discrete and continuous distributions, joint and conditional distribution, moment generating functions, central limit theorem. Prerequisite: MA 103.

MA 224† Introduction to Mathematical Statistics   3:0:3
Standard first course in mathematical statistics, recommended for those planning to take advanced work in statistics. Sampling distributions, tests of hypotheses, significance tests, point and interval estimation, regression and correlation. Prerequisite: MA 223 or MA 561.

MA 231† Statistical Methods I   3:0:3
Descriptive statistics computed from data; means, variances, histograms. Applications of bionomial, normal, t and chi square distributions; Point estimation. Statistical tests. Confidence intervals. Prerequisite: MA 102 or equivalent.

MA 232† Statistical Methods II   3:0:3
Analysis of vaiance with simple experimental designs. Sampling procedures, including sequential analysis. Nonparametric statistical methods. Statistical decisions. Prerequisite: MA 231 or MA 562 or MA 224.

MA 238† Applied Probability   3:0:3
Second course in probability with emphasis on applications. Topics chosen from reliability theory, sampling theory. Monte Carlo methods, combinatorial analysis. Prerequiste: MA 223.

MA 239† Mathematical Modeling   3:0:3
The construction of a Mathematical Model. Simple examples. Discrete and Continuous Models. Deterministic and Probabilistic Models. Linear and Nonlinear Models. Detailed examples from mechanical vibrations, population dynamics, theory of epidemics, graph theory, traffic flow, optimization theory, etc. Testing the validity of a model. Prerequisites: MA 103, MA 104.

MA 250† Vector Analysis and Partial Differential Equations   4:0:4
Vector algebra and vector calculus. Surface, line, volume, integrals. Theorems of Gauss, Green, Stokes. Curvilinear coordinates. Fourier series. Legendre polynomials and Bessel functions. Dirichlet and Neumann problems. Heat flow, wave motion, vibration problems. Prerequisites: MA 103 and MA 104.

MA 333 Partial Differential Equations   3:0:3
Fourier series and integral. Heat, wave and La Place differential equations. Dirichlet and Neumann problems. Legendre polynomials and Bessel functions, some numerical techniques. Prerequisites: MA 103 and MA 104.

MA 341 Discrete Computational Structures I   3:0:3
Basic concepts of discrete mathematics. Logic and Proof Techniques. Sets, Relations and Functions. Introductory combinatorics. Directed and undirected graphs. Boolean Algebra.

MA 342 Discrete Computational Structures II 3:0:3
Extends Graph Theory to Network Algorithms and covers material from Finite State Machines, Computability, and Formal Languages. Introduces basic concepts of Queueing Theory.

MA 358 Introductory Numerical Analysis
Polynomial interpolation and approximation of functions. Divided differences. Least-squares data fitting, orthogonal polynomials. Numerical differentiation and integration. Solution of nonlinear equations. Gaussian elimination, pivoting, iterative refinement, conditioning of matrices. Numerical solution of ordinary differential equations. Prerequisites: MA 104 and some experience in computer programming.

MA 385-386 Reading Seminar in Mathematics I, II   3:0:3
Reading, study and investigation of selected topics in mathematics. Problem discussions and presentations by participating students. Prerequisite: department adviser's permission.

Additional offerings in the area of statistics may be found under 500-number courses.

ACTUARIAL SCIENCE

AC 301 Actuarial Science Workshop I   1½:1½:2
Applications of analysis, linear algebra and probability to actuarial science. Review and extension of concepts skimmed in prerequisite courses. Prerequisites: MA 104 or MA 114, MA 153, MA 223.

AC 302 Actuarial Science Workshop II   1½:1½:2
Application of statistics, operations research and numberical methods to actuarial science. Prerequisites: AC 301, MA 224, IE 327. Corequisites: IE 328, MA 358.

AC 401 Actuarial Science Workshop III   1½:1½:2
Further applications of operations research and numerical methods to actuarial science. Compound interest workshop. Prerequisites: AC 302, AC 501, IE 328. Corequisite: AC 502.

AC 402 Actuarial Science Workshop IV   1½:1½:2
Workshops on life contingencies. Prerequisites: AC 401, AC 502. Corequisite: AC 503.

AC 501 Actuarial Science I — Mathematics of Compound Interest and Introduction to Life Contingencies   2½:0:3
Measurement of interest; elementary and general annuities; amortization schedules; sinking funds; bonds and other securities; introduction to life contingencies. Prerequisites: MA 103, MA 104, MA 223.

AC 502 Actuarial Science II — Single Life Functions 2½:0:3
Life annuities; insurance premiums; reserves; expenses; combined benefits; and population theory. Prerequisite: AC 501.

AC 503 Actuarial Science III — Multi-Life and Multi-Decrement Functions   2½:0:3
Joint life status; general multi-life statuses, contingent functions; reversionary annuities; multiple decrement tables; secondary decrements; a generalized model. Prerequisite: AC 502.

GRADUATE COURSES

MA 503 Mathematical Logic   2½:0:3
Propositional logic, quantification theory, independence, completeness, computability, decidability. Topics to be chosen from: Godel's theorems on completeness, incompleteness, and consistency; Turing machines; recursive functions; switching circuits; Hilbert's 10th problem; lattices and boolean algebra.
(Acceptable for graduate credit in the Mathematics Dept.)

MA 505-506 Foundations of Mathematics   2½:0:3
Propositional logic, quantification theory, relations, functions, cardinals, ordinals, cardinal arithmetic, axiom of choice, filters and ultrafilters. Topics to be chosen from: Lattices and boolean algebra; nonstandard analysis, quantum logic; multivalued logic; model theory; ordinal arithmetic; measurable cardinals.
(Acceptable for graduate credit in the Mathematics Dept.)

MA 531-532† Applied Mathematics in Engineering and Science I, II   each 2½:0:3
Vector algebra and vector analysis. Determinants and matrices. Jordan normal forms. Eigenvalues of symmetric matrices by iteration. Applications to systems of differential equations, matrix exponential Sturm-Liouville problems. Legendre polynomials and Bessel functions. Applications. Not accepted to graduate credit in Department of Mathematics. MA 531 prerequisites: MA 103 and MA 104. MA 532 prerequisites: MA 531.

MA 535   Vector and Tensor Analysis   2½:0:3
Vector analysis in three dimensional space, integral theorems, applications to potential theory. Tensor algebra, tensor calculus, fundamentals of Reimannian geometry, divergence theorem. Applications of tensor calculus to the calculus of variations and field theories of relativity. Prerequisite: MA 103 and 153 or equivalent.

**MA 541-542†   Fundamentals of Discrete Mathematics I, II
each2½:0:3**
Mathematical models, mathematical reasoning, primitives of naive set theory, inductive and recursive procedures, functions, relations, orderings, introduction to graph theory, counting and algorithm analysis, introduction to algebraic structures. MA 541 prerequisite: permission of adviser. MA 542 prerequisite: permission of adviser.

MA 551†   Applied Statistics I (Data Analysis)   2½:0:3
Treatment of statistical methods and application to analysis of data, to fitting of functions to data. Estimation of population parameters, t-tests, chi-square tests, rank tests. Prerequisite: MA 102 not accepted for graduate credit in Department of Mathematics.

MA 552   Correlation-Regression-Variance Analysis   2½:0:3
Discussion of models and computational schemes associated with correlation, regression coefficients, and variances. Prerequisite: MA 224 or MA 231 or MA 551 or MA 562.

MA 554†   Applied Decision Theory   2½:0:3
Principles of statistical decision procedures; introduction to utility theory, minimax, Bayes strategies. Applications to problems in engineering, science, management. Prerequisite: MA 224 or MA 562.

MA 555†   Design of Experiments   2½:0:3
Principles of modern statistical experimentation and practice in use of basic designs for scientific and industrial experiments. Single-factor experiments, randomized blocks, Latin squares, factorial and factional experiments, surface fitting designs. Prerequisite: MA 224 or MA 232.

MA 556†   Correlation and Multivariate Models   2½:0:3
Treatment of experimental data involving several types of measurements per individual. Regression and correlation. Simple multiple and partial correlations. Problems of discrimination and classification, elements of factor analysis. Applications to analysis and interpretations of data. Prerquisite: MA 224 or MA 232.

MA 557†   Sampling   2½:0:3
Statistical theory and methods applicable to survey sampling. Simple random sampling, stratified, cluster double and systematic sampling, ration and regression estimates, purposive sampling. Control of errors, costs and nonsampling aspects of survey investigations. Prerequisite: MA 224 or MA 232.

**M. 558-° ✓†   Topics in Geometric
Optimization I, II   each 2½:0:3**
Topics to be chosen from: search techniques, geometric distributions, packings and coverings, arrangements and spreads, curve fittings and pattern recognitions, mathematical stereology and extremum problems. MA 558 prerequisites: MA 103 and MA 104. MA 559 prerequisites: MA 103 and MA 104.

MA 561†   Elements of Probability   2½:0:3
Probability of events. Random variables and expectations, discrete and continuous distributions, important standard distributions and applications, moment generating functions, central limit theorem. Not acceptable for graduate credit in Department of Mathematics. (Not open to students who have taken MA 223 or equivalent.) Prerequisite: MA 103.

MA 562†   Statistics   2½:0:3
Estimation, confidence limits, tests of hypothesis, regression analysis. Applications to engineering problems. (Not open to students who have taken MA 224.) Not acceptable for graduate credit in Department of Mathematics. Prerequisite: MA 561.
Also listed under IE 608

MA 565†   Intermediate Differential Equations   2½:0:3
Solutions of ordinary differential equations. Applications to geometry and physics. Oscillation theory. Introduction to geometric theory, elementary critical points. Prerequisite: MA 103 and MA 104.

MA 570†   Introductory Geometry   2½:0:3
First course in modern geometry. Surface areas, volumes, transformation groups, convexity, Minkowski spaces, elementry metric spaces. Prerequisite: MA 113 or MA 103, and MA 153.

MA 575   Introduction to Differential Geometry   2½:0:3
Differential geometry in the plane, theory of dented gears. Introduction to transformation groups. Space curves and rules surfaces. Tensors and exterior forms, manifolds and tensor fields. Theory of surfaces. Introduction to Riemannian geometry. Prerequisites: MA 103 and MA 153 or equivalent.

LOGIC AND FOUNDATIONS

MA 603   Symbolic Logic   2½:0:3
Formal, manipulative, symbolic logic. Russell's theory of types, existance and universal quantification, material implication and equivalence, consistency. Prerequisites: MA 103 and MA 104.

**MA 605-606   Topics in Analysis for
Teachers I, II   each 3¾:0:4½**
Elements of abstract spaces and structures with applications to specific modern problems in ordinary and partial differential equations, probability and statistics, linear programming. Credit for these courses granted only to those students in high school teachers' program. MA 605 prerequisite: calculus. MA 606 prerequisite: MA 605.

**MA 607-608   Fundamentals of
Mathematics I, II   each 2½:0:3**
Introduction to informal axiomatic set theory: relations, functions, the axiom of choice, well ordering, Zorn's lemma, transfinite recursion, cardinal numbers, ordinal numbers, cardinal arithmetic, ordinal arithmetic. Introduction to mathematical logic: propositional calculus, first-order logic, first-order recursive arithmetic. Topics to be chosen from the following: Boolean algebra and lattices, Turing machines, computability, non-standard analysis, model theory. Prerequisite: calculus.

ANALYSIS

MA 619-620   Advanced Calculus I, II   each 2½:0:3
Functions, sequences, bounds, limits. Properties of continuous functions. Mean value theorems, Taylor's series. Partial differentiation. Extreme value problems with constraints. Implicit functions. Transformations. Line integrals, Green's theorem. Transformation of double integrals. Uniform continuity. Theory of Riemann integral. Infinite series and power series. Uniform convergence. Imporper integrals. MA 619 prerequisites: MA 103 and MA 104. MA 620 prerequisite: MA 619.

MA 621   Real and Complex Analysis I   2½:0:3
Cardinal numbers, topology of n-dimensional Euclidean space, introduction to measure theory, Lebesgue integration theory, measurable functions, functions of bounded variation, absolutely continuous functions, differentiation and convergency theorems, Radon-Nikodym theorems, Lusin's theorem, product measure, Fubini theorems. Prerequisite: MA 620 or equivalent.

MA 622   Real and Complex Analysis II   2½:0:3
Rigorous development of theory of functions of complex variables. Complex number systems, differentiation and integration, analytic and meromorphic functions, residue theory, introduction to Rieman surfaces, conformal mappings, Blaschke products, Picard theorems. Prerequisite: MA 621.

MA 625-626 Measure and Integration Theory I, II — each 2½:0:3

General measure spaces, abstract integral and its properties, signed and complex measures, product measures, measureable transformations, measures in locally compact topological spaces, measure and topology in groups. Haar measure, measures in functional spaces. MA 625 prerequisite: MA 622 or instructor's permission. MA 626 prerequisite: MA 625.

MA 630 Elements of Complex Variables — 2½:0:3

Analytic functions of complex variables. Complex numbers, differentiation and integration. Cauchy theorems, power series. Evaluation of integrals by residues. Conformal mapping, Schwarz-Christoffel transformations. Prerequisites: MA 103 and MA 104. (Not open to students who have taken MA 217.)

MA 637-638 Topics in Complex Variables — each 2½:0:3

Content of course varies. In spring of year prior to one in which course is offered, detailed description posted and mailed to all graduate mathematics students. Prerequisite: MA 622.

MA 645 Theory of Ordinary Differential Equations — 2½:0:3

Ordinary differential equations. Existance and uniqueness theorems, linear systems, isolated singularities, self-adjoint eigenvalue problems, geometric theory of differential equations in the plane. Prerequisite: MA 620 or equivalent.

MA 646 Theory of Partial Differential Equations — 2½:0:3

Partial differential equations. Cauchy-Kowalewski theorem, first-order differential equations, system of differential equationss in two variables, characteristicss and classificaiton, hyperbolic, parabolic and elliptic systems, wellposedness. Prerequisite: MA 645.

MA 649-650 Topics in Ordinary and Partial Differential Equations — 2½:0:3

Content of course varies. In spring of year prior to one in which course is offered, detailed description posted and mailed to all graduate mathematics students. Prerequisite: MA 620 or equivalent.

MA 658 Calculus of Variations — 2½:0:3

Extension of elementary theory of maxima and minima. Euler equations, conditions of Weierstrass, Legendre, and Jacobi, Mayer fields, Hamilton-Jacobi equations, transversality, conjugate and focal points. Applications to geodesics, minimal surfaces, isoperimetric problems, Hamilton's principle, Fermat's principle, brachistochrones. Prereqisite: MA 202 or MA 212 or MA 620.

MA 661-662 Special Functions of Mathematical Physics I, II — each 2½:0:3

Gamma functions, orthogonal polynomials, hypergeometric functions, special cases such as Legendre functions, confluent hypergeometric functions — in particular, Whittaker and Bessel functions. Hill's equations with emphasis on Mathieu equation. Stress on development as functions of complex variable and as asympototic series. MA 661 prerequisite: MA 630 or MA 622. MA 662 prerequisite: MA 661.

MA 681-682 Functional Analysis I, II — each 2½:0:3

Hilbert spaces, Banach spaces, Banach algebras, linear operations, spectral theory, perturbation theory, completely continuous operators. Gelfand theory. Application of these in classical analysis. Prerequisite: MA 703 or equivalent.

MA 683-684 Special Topics in Functional Analysis — each 2½:0:3

Content of course varies. In spring of year prior to one in which course is offered, detailed description posted and mailed to all graduate mathematics students. MA 683 prerequisite: MA 682. MA 684 prerequisite: MA 683.

ALGEBRA AND NUMBER THEORY

MA 703 Linear Algebra — 2½:0:3

Systems of linear equations and matrices, determinants, vector spaces, linear transformations, eigenvalues, eigenvectors, diagonalization, symmetric matrices, introduction to numerical methods of linear algebra. Prerequisites: MA 103 and MA 104 or equivalent.

MA 705 Linear and Modern Algebra I — 2½:0:3

Basic algebraic structures, groups, rings, fields, integral domains, ideals, modules. Extentions of fields, Galois theory. Prerequisite: MA 620 or equivalent.

MA 706 Linear and Modern Algebra II — 2½:0:3

Algebra of linear transformations, matrix theory, Jordan canonical form, Hermitian operators, unitary operators, normal operators, spectral theorem. Dual spaces, inner product spaces. Prerequisite: MA 705.

MA 715-716 Advanced Topics in Algebra — each 2½:0:3

Content of course varies. In spring of year prior to one in which course is offered, detailed description posted and mailed to all graduate mathematics students. MA 715 prerequisite: MA 705 and MA 706. MA 716 prerequisite: MA 715.

GEOMETRY AND TOPOLOGY

MA 754 Topological Methods in Analysis — 2½:0:3

Aspects of topological methods and applications to existence theorems in analysis. Use of fixed-point theorem and topological degree in study of properties of solutions of ordinary and partial differential equations. No previous courses in topology required. Prerequisite: MA 212 or 202 or MA 620.

MA 755-756 Topology I, II — each 2½:0:?

Topological spaces, compactness, connectedness, continua, extension theorems, metrization theorems, Simplexes, simplicial topology and applications, fixed-point theorems, graphs and networks homology and co-homology theory, introduction to Morse theory MA 755 prerequisite: MA 620 or equivalent. MA 756 prerequisite: MA 705.

MA 775-776 Manifolds — Geometry and Differential Topology I, II — each 2½:0:?

Elementary theory of manifolds. Tangent space, mappings, sub manifolds, fields, fiber bundles, lie groups, homogeneous spaces Elements of theory of connections, Riemannian geometry. Imbedded manifolds. Calculus of variations. Harmonic forms, complex manifolds, Morse's theory. MA 775 prerequisite: instructor's approval. MA 776 prerequisite: MA 775.

MA 785 Selected Topics in Geometry — 2½:0:3

Integral geometry, combinatorial geometry, transformation groups. Lie groups and algebras, algebraic geometry, convex polytopes and geometry of numbers. Prerequisite: MA 751 and instructor's approval.

MA 786 Selected Topics in Topology — 2½:0:3

Complex spaces (several complex variables), calculus of variations in the large (Morse theory), global differential geometry. Differential topology, homotopy theory. Prerequisite: instructor's approval.

APPLIED MATHEMATICS

MA 801-802 Special Topics in Applied Mathematics I, II — each 2½:0:3

Asymptotic expansions of definite integrals and of solutions to differential equations, perturbation theory, variational methods, non-linear vibrations, distributions, spectral representation of linear operators, relaxation methods, boundary-value problems. MA 801 prerequisites: linear algebra and complex variables. MA 802 prerequisite: MA 801.

MA 804   Calculus of Finite Differences   2½:0:3
Discussion of various difference equations, generating functions, analogies with differential equations. Introduction to stability theory, mixed differential difference equations, applications to mathematical physics, adaptability of computers to solution of difference equations. Prerequisites: MA 103 and MA 104.

MA 812-817   Listed below under Probability, Statistics, Operations Research

MA 819-820   Theory of Approximation   each 2½:0:3
Theory and application of methods of fitting matthematical curves or surfaces to experimental data in two or three variables, including method of least squares, methods of averages, rectification of data, determination of periodicities. Orthogonal polynomials in least squares fitting. Chebyshev approximation. Statistical aspects of principle of least squares. MA 819 prerequisites: MA 103 and MA 104. MA 820 prerequisite: MA 819.

MA 821   Numerical Analysis   2½:0:3
Interpolation. Approximation of functions by polynomials. Fast Fourier transform. Numerical integration. Solution of non-linear equations. Iterative improvement of solutions of linear equations. Eigenvalues of matrices. Numerical solution of ordinary differential equations. Prerequisite: MA 153 and some experience in computer programming.

MA 822   Numerical Solution of Partial Differential Equations   2½:0:3
Stability, consistency, and convergence of finite-difference methods for initial-value problems. Implicit and explicit schemes. Method of lines. Alternating direction methods. Direct and iterative solutions of elliptic equations. Finite element methods. Prerequisite: MA 821 or 358 and 153 and some experience in computer programming.

MA 823   Special Topics in Numerical Analysis   2½:0:3
Numerical solution of ordinary and linear partial differential equations. Stability, consistency, error estimates, convergence of difference schemes. Prerequisite: MA 821 and MA 153.

MA 825   Numerical Linear Algebra   2½:0:3
Direct and iterative solutions of linnear equations. Relaxation. Matrix norms, operation counts. Algebraic eigenvalue problem, QR algorithms. Prerequisite: MA 153.

MA 833   Partial Differential Equations of Mathematical Physics   2½:0:3
First- and second-order partial differential equations and systems of equations. Initial and boundary value problems. Fundamental solutions and Green's functions. Theory of characteristics. Eigenvalue problems. Rayleigh-Ritz and Ritz-Galerkin methods. Approximate and asymptotic methods. Nonlinear equations and applications. Prerequisite: MA 202 or MA 212 or MA 620 or equivalent.

MA 83_   Potential Theory   2½:0:3
Theory of potential and application to problems. Newtonian potential, expansion of potential in series of spherical harmonics, properties of harmonic functions, relation of potential to theory of functions, inversions, Green's function, Poisson's integral. Prerequisite: MA 212 or 202 or MA 620.

MA 836   Applied Complex Variables   2½:0:3
Brief review of important characteristics of analytic functions. Use of conjugate functions in solution of two-dimensional potential problems. Study of conformal mapping with emphasis on Schwarz-Christoffel transformation and its applications. Prerequisite: MA 630 or MA 622.

MA 837   Applied Matrix Theory   2½:0:3
In-depth introduction to theory and application of linear operators and matrices in finite-dimensional vector space. Invariant subspaces, elementary divisors, canonical forms, and minimax theorems for eigenvalues of hermitian pencils. Prerequisites: MA 103 and MA 104.
Also listed under EL 613

MA 838   Linear Algebra and Differential Equations   2½:0:3
Basic theory of linear algebra and its application to systems of ordinary differential equations, method of adjoints, series solutions, equations with periodic coefficients, stability theory, applications to nonlinear systems. Prerequisites: MA 103 and MA 104.

MA 839   Introduction to Functional Analysis   2½:0:3
Study of operations on metric, Banach and Hilbert spaces. Applications of functional analysis concepts to integral and differential operators of mathemattical physics, spectral theory, special topics in nonlinear functional analysis. Prerequisite: MA 838 or equivalent.

MA 841-842   Integral Equations I, II   each 2½:0:3
Fredholm theory, Hilbert-Schmidt theorem, singular integral equations, Wiener-Hopf equation. Applications of integral equations to potential theory, elasticity, other physical problems. MA 841 prerequisites: advanced calculus and complex variables. MA 842 prerequisite: MA 841.

MA 844   Optimal Control Theory*   2½:0:3
Optimal control problems for deterministic systems with various constraints. Solutions for both continuous and discrete-time systems using maximum principle and dynamic programming. Hamilton-Jacobi theory as applied to synthesis problem. Prerequisite: EL 723.
Also listed under EL 823

MA 846   Fourier and La Place Transforms   2½:0:3
Application of transform methods to partial differential equations of mathematical physics. Includes introduction to Wiener-Hopf technique. Prerequisite: MA 630.

MA 853-855, 860-874   Listed below under Probability, Statistics, Operations Research

PROBABILITY, STATISTICS, OPERATIONS RESEARCH

MA 812   Theory of Games   2½:0:3
Introduction to mathematical analysis of conflict situations. Network and extensive form games, matrix games, solution algorithms, consideration of n-person and non-zero sum games. Prerequisite: MA 153 and MA 223.

MA 813   Linear Programming   2½:0:3
Theory and application of linear programming techniques. Simplex and revised simplex algorithms. Duality theory, dual simplex method, postoptimality analysis. Degeneracy. Transportation and assignment problems. Applications, problem formulation, computer solutions. Prerequisite: MA 153.
Also listed under IE 631

MA 814   Integer Programming   2½:0:3
Solution techniques for integer and mixed-integer linear programming problems. Cutting plane methods, zero-one programming, branch and bound methods. Surrogate constraints. Quadratic programming. Applications to combinatorial analysis. Prerequisite: MA 813.
Also listed under IE 633

MA 815   Theory of Queues   2½:0:3
Steady-state solutions for single and multiple channels, various arrival and service distributions, queue disciplines. Transient solutions. Emphasis on theory, with solution techniques given for specific classes of queues. Prerequisite: MA 223.

MA 816-817   Graph Theory I, II   each 2½:0:3
Graphs and subgraphs, convectivity, trees and girth, planarity, embeddings, n-connectivity and edge-connectivity, Hamilton graphs, matchings, factorization and covering, graphs and groups, graph isomophism and reconstruction, colorings, map colorings, Ramsey and exteremal graph theory, enumeration, connectedness in digraphs. Euler and Hamilton graphs, tournaments, networks. MA 816 prerequisites: MA 103 and MA 104. MA 817 prerequisite: MA 816.

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MATHEMATICS AND STATISTICS

MA 818   Nonlinear Programming   2½:0:3
Optimization of nonlinear functions. Classical methods. Constraints and Lagrangian methods. Kuhn-Tucker theory, duality and economoc interpretation. Separable programming, feasible directions, gradient projection. Quadratic and convex programming. Industrial and engineering applications. Prerequisite: MA 813.
Also listed under IE 632

MA 821-823, 825-833, 835-839, 841-842, 844, 846, listed above under Applied Mathematics.

MA 853   Probability I   2½:0:3
Probability for events, distribution of random variables, joint distribution, transformations. Prerequistes: MA 103 and MA 104, MA 223 or equivalent.

MA 854   Probability II   2½:0:3
Charcteristic functions. Proofs of central limit theorem and laws of large numbers. Study of conditioning. Markov chains. Introduction to stochastic processes. Prerequisite: MA 853 or equivalent.

MA 855   Stochastic Processes   2½:0:3
Normal and stationary processes, Wiener processes, Poisson and renewal processes, Markov Processes. Prerequisites: MA 854 or equivalent.

**MA 861-862   Principles of Statistical
                Inference I, II   each 2½:0:3**
Two semester sequence in statistical inference. Point and interval estimation of statistical parameters. Theory of statistical estimators. Fundamentals of statistical tests of hypotheses. Second semester extends theory of tests of hypotheses, including sequential tests. Non-parametric methods in stastics. MA 861 prerequisite: MA 224 or equivalent. MA 862 prerequisite: MA 861.

MA 863-864   Multivariate Analysis I, II   each 2½:0:3
Multivariate normal distribution, simple, partial, multiple correlation. Generalization of student's ratio, tests of significance of sets of means. Tests of general linear hypothesis. Some generalizations in analysis of variance. Prerequisite: MA 862 and MA 153.

**MA 865-866   Regression and Analysis of
                Variance I, II   each 2½:0:3**
Linear regression of one or more independent variables. Least square estimates of regression coefficients. Gauss-Markov theorem. Confidence regions for and tests of hypothesis about regression coefficients. Test of general linear hypothesis. Multiple classification in analysis of variance. Power of F-test. Alternative models: I and II, mixed models, analysis covariance and compoents of vaiance. Prerequisites: MA 862 and MA 153.

MA 867   Nonparametric Methods in Statistics   2½:0:3
Statistical methods not bound by assumption of known parametric form distribution of observations. Applications to engineering and scientific research in which observations are not ordered on numerical scale. Order statistics, tolerance regions, permutation tests, goodness of fit tests, limiting distributions, large-sample properties of tests. Prerequisite: MA 224 or MA 562/IE 608.

MA 868   Sequential Statistical Methods   2½:0:3
Fixed sample size vs. sequential statistical procedures Wald's sequential probability ratio test. OC and ASN functions, optimal properties, approximation, generalizations. Sequential estimation, optimal stopping. Sequential design of experiments. Application to sampling inspection, inventory and control problems. Prerequisite: MA 224 or MA 562/IE 608.

**MA 869-870   Advanced Statistical Inference I, II
                                                   each 2½:0:3**
First semester: general decision problem, optimal decision rules, estimation based on Bayes, minimax, admissible, maximum, likelihood, sequential rules, density and distribution estimation. Second semester: hypothese testing, including uniformly most powerful tests, least favorable distributions, unbiasedness, rank tests, invariance, sequential tests. MA 869 prerequisite: MA 862. MA 870 prerequisite: MA 869.

MA 871-872   Advanced Probability I, II   each 2½:0:3
Measure-theoretic foundations of probability. Expectations, distribution functions, characteristic functions. Modes of convergence of random variables and distribution functions. Laws of large numbers. The multidimensional, central-limit problem and related asympototic expansions. Infinitely divisible laws. Prerequisite: MA 622 or equivalent.

**MA 873-874   Theory of Stochastic Processes I, II
                                                   each 2½:0:3**
Foundations of stochastic processes. Kolmogorov's theorem. Properties of sample paths. Conditional expectation. Martingales. Classes of stochastic processes, Gaussian processes, Markov processes, others. Second-order properties. Stationary processes. Applications. Prerequisite: MA 872 or equivalent.

**MA 881-882   Statistical Analysis of
                Time Series I, II   each 2½:0:3**
Careful study of tractable models for statistical analysis of scalar time series. Models treated: (1) "error plus trend" models and (2) stationary stochastic process models with special emphasis on autoregressive models. Estimation, tests of hypotheses and multiple-decision procedures for these models, spectral representation and filtering, estimation of spectral density. Prerequisites: MA 153, MA 854 and MA 862

READING, PROJECT, THESIS, DISSERTATION

MA 941-944   Reading in Mathematics I-IV   each 2½:0:3
Courses intended primarily for students who have completed two years of full-time graduate study and who wish to do research in a specialized area. Reading done under guidance of faculty member and devoted mainly to scholarly papers. Prerequisite: permission of department.

**MA 955-956   Selected Topics in Advanced
                Mathematics I, II   each 3¾:0:4½**
Review of current mathematical research, designed for mature students. May be given by visiting professor. Specific topics vary, depending on instructor. Prerequisite: permission of department.

**MA 958-959   Selected Topics in Advanced
                Mathematics I, II   each 2½:0:3**
Same course description as MA 955-956 except for credit structure. Prerequisite: permission of department.

**MA 997   Thesis for Degrees of
            Master of Science   each 3 units**
Thesis to present results of independent investigation of suitable problem in abstract or applied mathematics. Study must include adequate investigation of existing literature relating to subject. Regular reports on progress of work and regular conferences with assigned faculty adviser required. Reregistration fee, any part: 3-unit charge. Prerequisite: degree status.

**MA 999   Dissertation for Degrees of
            Doctor of Philosophy   each 3 units**
Results of independent investigation of some problem in mathematics. Must demonstrate ability to do creative work and include original research of caliber deemed worthy of publication in recognized scientific journals. Oral examination on subject of dissertation and related topics required. Minimum of 24 dissertation units required for degree. Reregistration fee, any part: 3-units charge. Prerequisite: degree status and qualifying examination.

ST 941-942   Readings in Statistics I, II   each 2½:0:3
Courses intended primarily for students who have completed two years of full-time graduate study and who wish to do research in a specialized area. Reading done under guidance of faculty members and devoted mainly to scholarly papers. Prerequisite: permission of department.

ST 958-959   Selected Topics in Statistics I, II   each 2½:0:3
Review of current statistical research, designed for mature students. May be given by visiting professor. Specific topics vary, depending on instructor. Prerequisite: permission of department.

ST 995   Project for Degrees Master of
Science (Statistics)   each 3 units
Results of detailed study from the field of statistics carried out under the supervision of faculty adviser. Prerequisite: degree status. Reregistration fee, any part: 3-unit charge.

ST 997   Thesis for the Degree of Master of
Science (Statistics)   each 3 units
Thesis presents results of independent investigation of suitable aspects of statistics. Investigation of existing literature and related work must be included. Topic is selected with the help of a faculty adviser who also supervises the thesis work. Prerequisite: degree status. Reregistration fee, any part: 3-unit charge.

ST 999   Dissertation for the Degree of Doctor of
Philosophy (Statistics)   each 3 units
Results of independent investigation of some area of statistics. Must demonstrate ability to do creative work and include original research of caliber deemed worthy of publication in recognized scientific journals. Oral examination on subject of dissertation and related topics is required. Prerequisite: degree status and qualifying examination. Reregistration fee, any part: 3-unit charge.

Students in other departments should note that there are certain undergraduate courses in mathematics that may be accepted for graduate credit in their departments. Such courses are identified by a dagger following the course number (e.g., MA 223†).

FACULTY

Harry Hochstadt, Professor and Head of Mathematics
B.Ch.E., Cooper Union; M.S., Ph.D., New York University
Differential equations; spectral theory; functional analysis

Ronald Hirshon, Professor of Mathematics and Administrative Officer
B.S., M.S., Brooklyn College; Ph.D., Adelphi University
Group Theory

George Bachman, Professor of Mathematics
B.E.E., M.S., Ph.D., New York University
Fields and Valuations, Banach algebras, topological measure theory

Emeric Deutsch, Professor of Mathematics
B.S., Pedagogical Institute of Timisoara (Romania); M.S., Ph.D., Polytechnic Institute of Brooklyn
Matrix theory, functional analysis

Heinrich Guggenheimer, Professor of Mathematics
Dipl., Dr.Sc., Swiss Federal Institute of Technology-Zurich (Switzerland)
Differential equations; geometry-convexity

Leon H. Herbach, Professor of Mathematics and Statistics
A.B., Brooklyn College; M.A., Ph.D., Columbia University
Reliability, stochastic models of physical systems; Monte Carlo methods

Erwin Lutwak, Professor of Mathematics
B.S., M.S., Ph.D., Polytechnic Institute of Brooklyn
Convexity

Clifford W. Marshall, Professor of Mathematics
B.A., Hofstra University; M.A., Syracuse University; M.S., Polytechnic Institute of Brooklyn; Ph.D., Columbia University
Graph theory; conflict analysis; applied probability

Edward Y. Miller, Professor of Mathematics
B.A., University of Pennsylvania; M.A., Ph.D., Harvard University
Topology

Paul F. Pickel, Professor of Mathematics
B.S., Ph.D., Rice University
Mathematical programming, computer graphics, artificial intelligence

Stanley Preiser, Professor of Mathematics and Computer Science
B.S., CCNY; M.S., Ph.D., New York University
Numerical analysis; applied mathematics; algorithms; system performance evaluation

George Weill, Professor of Mathematics
Lic. Math., Dr.Sc., University of Paris (France); Ph.D., University of Southern California
Complex analysis; global analysis; partial differential equations

Kathryn Kuiken, Associate Professor of Mathematics
B.A., M.A., Montclair State College; M.S., New York University; Ph.D., Polytechnic Institute of New York
Group theory

Burton Lieberman, Associate Professor of Mathematics
B.A., Harvard University; M.S., Ph.D., New York University
Differential equations, stochastic processes

Joel Rogers, Associate Professor of Mathematics
B.S., Ph.D., Massachusetts Institute of Technology
Partial differential equations; fluid mechanics; numerical methods

Lesley Sibner, Professor of Mathematics
B.S., CCNY; M.S., Ph.D., New York University
Partial differential equations; global analysis

Erich Zauderer, Associate Professor of Mathematics
B.A., Yeshiva College; M.S., Ph.D., New York University
Nonlinear wave propagation; partial differential/equations; diffraction problems.

ADJUNCT FACULTY

Wallace Goldberg, Adjunct Professor of Mathematics
B.A., Yeshiva University; M.S., New York University; Ph.D., Polytechnic Institute of New York

Norman Grossman, Adjunct Professor of Mathematics
Bachelor of Aeronautical Engineering, New York University; M.S., Ph.D., New York University

Barbara Cain, Lecturer
B.S., Syracuse University; M.S., New York University

Daniel Drance, Lecturer
M.S., State University of New York, Stony Brook

George Eid, Lecturer
M.S., Ph.D., Polytechnic University

MATHEMATICS AND STATISTICS

Carl Gogolak, Lecturer
M.A., Fordham University; Ph.D., Polytechnic University

John Scolarikas, Lecturer
Diploma University of Athens; Eng. Diploma National
Technical University of Athens; M.S., Illinois Institute of
Technology; M.S., Columbia University

Rose Slomowitz, Lecturer
B.S., M.A., Brooklyn College

Daniel Steinitz, Lecturer
B.Sc., Hebrew University, Jerusalem, Israel; M.Sc., New
York University

Martin Weinless, Lecturer
B.S., City University of New York

Carmen Vlad, Lecturer
B.S., M.S., University of Bucharest;
M.S., Ph.D., Polytechnic University

Francis Voyticky, Lecturer
B.S., Polytechnic Institute of Brooklyn;
J.D., Touro College of Law

EMERITUS FACULTY

Aaron Fialkow, Professor Emeritus
B.S., M.S., CCNY; Ph.D., Columbia University
Differential geometry, network theory

Ronald M. Foster, Professor Emeritus
B.A., Harvard; D.Sc. (Hon.), Farleigh Dickinson University;
D.Sc. (Hon.), Polytechnic Institute of New York
Network theory; graph theory

Andrew J. Terzuoli, Professor Emeritus
B.S., Brooklyn College; M.S., New York University
Probability Statistics

MECHANICAL ENGINEERING

At the undergraduate level, a program in mechanical engineering is offered at both the Brooklyn and Long Island campuses; the program leads to the degree of bachelor of science. At the graduate level, three separate curricula are offered: the first in applied mechanics; the second and third in mechanical engineering. The latter two are distinguished by options in (1) mechanical analysis and design; and (2) the thermal/fluid/energy fields, respectively. In each of these three curricula, graduate degrees are offered at the master of science, engineer, and doctor of philosophy levels.

THE MECHANICAL ENGINEERING PROFESSION

Mechanical engineering is a dynamic and evolving profession. Mechanical engineers develop the physical systems and devices that modern society needs or wants from automobiles to air-conditioning units, robots to power plants, people movers to artificial limbs, and rocket engines to communications satellites. It has a long tradition of leadership in helping to develop the natural environment while breaking new ground in such areas as resource conservation through better maintenance techniques, improved efficiency of energy-consuming devices, development of codes for a safer technological environment and new energy sources such as solar power, co-generation, fuel cells and wind power.

While undergraduate and graduate programs in mechanical engineering are designed primarily to develop talents in these areas, graduating students eventually apply their training to the additional diversified fields of bioengineering, city planning, astronautics, systems engineering, management and patent law. As students mature and realize their abilities, their professional lives may center on engineering research, government, business, or education.

UNDERGRADUATE PROGRAM

For undergraduates in mechanical engineering, a strong program in mathematics, physics, chemistry, and computer usage provides the base for the more professional courses in engineering sciences such as solid and fluid mechanics, thermodynamics, and dynamic system analysis. The curriculum then develops engineering analysis and concludes with engineering design and energy conversion. Project work in the senior year integrates the diverse disciplines of mechanical engineering. The program offers the basic and engineering sciences as the foundation for subsequent graduate studies and outstanding career opportunities.

The undergraduate program leads to the degree of bachelor of science in mechanical engineering and is recognized by the Accreditation Board for Engineering and Technology.

TRANSFER STUDENTS (Undergraduates)

Qualified graduates of two-year pre-engineering programs, such as those at liberal arts and community colleges, may fulfill the requirements for the B.S. degree in mechanical engineering in two additional years. Since pre-engineering programs vary, a prescribed program is not possible; consequently, students should consult with an undergraduate adviser.

Graduates of technology programs may be able to fulfill the requirements for the B.S. degree in mechanical engineering in two to three and a half years depending on the scope and level of their previous education. Consult with an undergraduate adviser for details.

Transfer credits for courses taken at other schools are subject to frequent changes based on evaluation of content and level. Thus students completing the same program, but in different years, may receive different amounts of transfer credits. Consult the mechanical engineering undergraduate adviser for current information.

Transfer students must arrive and present their records for initial evaluation at least one week before the regular registration period of their first semester at Polytechnic and must have all transfer credit requests acted upon within one year of such registration.

STANDARD DEPARTMENTAL REQUIREMENTS

An "Undergraduate Student Manual", available to all students accepted into the mechanical engineering program, contains detailed information on honors, probation, incomplete grades, withdrawals, approved electives, projects, faculty expertise, and many other matters of interest. All students of mechanical engineering are expected to keep abreast of departmental requirements and are responsible for satisfying such requirements.

To earn a B.S. degree in mechanical engineering, a student must have a minimum C average (2.00 grade-point average) in certain key courses of his technical major. This minimum technical average requirement is above and beyond the Polytechnic B.S. degree requirement for a minimum 2.00 grade-point average overall. Students below average, or deficient in a subject will be placed on departmental probation as a warning that they are not acceptably progressing towards the degree. Continued inability to meet the conditions of probation may lead to academic disqualification from the B.S. (ME) degree program.

Probation action may be occasioned by a semester of cumulative technical average of less than 2.00, grades lower than C in key courses (particularly ME111-112 and ME121), or withdrawal from any prerequisite courses. Students on probation may be required to reduce their course load or restrict their extracurricular activities, to postpone an advanced course, to undertake a remedial course program, or to repeat courses with a grade less than C. Almost without exception, students earning a D+, D, or I in ME111-112 will be asked to repeat these courses. Likewise, a student with less than a C semester average or less than a C average in courses of a closely related sequence, may be asked to repeat courses in which the grades of D+, D, or I were obtained.

When a course is repeated, the second grade is required to be no less than C. Failure to acheive this grade may lead to disqualification from the ME program. Permission to rectify this problem with a third attempt is granted only under exceptional conditions. In any event, the first grade of a repeated course will be excluded in the computation of the technical grade-point average.

Students on probation are usually permitted to preregister for the next semester, but are obliged to consult with an ME advisor after their grades are posted — and before the start of classes.

Humanities and Social Science Requirements

Elective courses are chosen in consultation with a mechanical engineering undergraduate adviser according to the following university and departmental guidelines:

In humanities and social sciences, students must take HU 101, HU110 and either HU 200 and SS 104 or IS 140 and IS 141 (total 12 credits). Students placed in HU 103 on the basis of the English Composition Placement Test administered at Polytechnic to all incoming students may substitute HU 103 for HU 101. Students placed in HU 008 or HU 009 must complete this noncredit course before taking HU 101 (or HU 103). All students must elect 12 additional credits in humanities and social sciences to bring to 24, the total of such credits.

At least 18 of the credits selected in the humanities and social sciences must meet the requirements of the Accreditation Board for Engineering and Technology (ABET). These credits may not include skills-oriented courses such as technical writing, public speaking, or English as a second language. Courses in literature, foreign languages, history, economics, and others are acceptable. Students should consult their ME advisers to ensure that these criteria are met. Managements courses and ROTC courses may not be used as substitutes for Hum/Soc. Sci. electives (see additional footnote accompanying Mechanical Engineering curriculum).

For further information, students should refer to the section of this catalog entitled Humanities and Social Sciences Requirements for Engineering and Computer Science Majors.

Typical Course of Study for the Bachelor of Science Degree in Mechanical Engineering

Freshman Year

First Semester			Hours/Week			Second Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.	No.		Subject	Cl.	Lab	Cr.
CM	101	General Chemistry I	2½	0	2½	CM	102	General Chemistry II	2½	0	2½
CM	111	General Chemistry Lab. I	0	1½	½	CM	112	General Chemistry Lab. II	0	1½	½
MA	101	Calculus I	4	0	4	MA	102	Calculus II	4	0	4
CS	100	Intro. to Programming	2	0	2	PH	104	Introductory Physics I	3	0	3
HU	101	Writing and the Humanities I	3	0	3	HU	200	Writing and the Humanities II[1]	3	0	3
SS	104	Contemp. World Hist.[1]	3	0	3			Hum./Soc. Sci.[2]	3	0	3
SL	101	Student Survival	0	1	0	PE	102	Physical Education II[3]	0	2	0
PE	101	Physical Education[3]	0	2	0						16
					15						

Sophomore Year

			Cl.	Lab.	Cr.				Cl.	Lab	Cr.
MA	103	Calculus III	3	0	3	MA	104	Applied Diff. Equations	3	0	3
PH	105	Introductory Physics II	3½	0	3½	PH	106	Introductory Physics III	2½	0	2½
PH	115	Introductory Physics Lab I	0	1½	½	PH	116	Introductory Physics Lab II	0	1½	½
ME	101	Graphics	1	3	2	ME	112	Mechanics II	3	0	3
ME	111	Mechanics I	3	0	3	ME	121	Mechanics of Materials	3	0	3
MT	305	Mech. Properties of Materials	3	0	3			Science elective	3	0	3
HU	110	Report Writing I	3	0	3			Hum./Soc. Sci.[2]	3	0	3
PE	103	Physical Education III[3]	0	2	0	PE	104	Physical Education IV[3]	0	2	0
					18						18

Junior Year

			Cl.	Lab.	Cr.				Cl.	Lab	Cr.
MA	260	Vectors and P.D.E.	3	0	3	ME	202	Thermodynamics II	3	0	3
ME	201	Thermodynamics I	3	0	3	ME	232	Fluids II	3½	1½	4
ME	231	Fluids I	3	0	3	ME	271	Fund. Stress Analysis	3½	1½	4
ME	261	Vibrations	3	0	3	ME	301	Synthesis of Mech. Systems	3	0	3
ME	321	Instrumentation	1½	1½	2	ME	322	Automated Controls	2½	1½	3
ME	331	Computer Methods in ME	2½	1½	3						17
					17						

Senior Year

			Cl.	Lab.	Cr.				Cl.	Lab	Cr.
ME	203	Heat Transfer	3	0	3	ME	204	Design of Energy Transfer	3	0	3
ME	272	Stress Analysis of ME Comp.	3½	1½	4	ME	341	Finite Elements	3½	1½	4
ME	302	Analysis/Design Machine Elem.	3	0	3	ME	352	Thermo/Heat-Transfer Lab. II	½	1½	1
ME	351	Thermo/Heat-Transfer Lab. I	½	1½	1	ME	362	Design Project II	0	6	2
ME	361	Design Project I	0	6	2			Technical Elective[4]	3	0	3
		Technical Elective[4]	3	0	3			Hum./Soc. Sci.[2]	3	0	3
		Hum./Soc. Sci.[2]	3	0	3						16
					19						

Total credits required for graduation: 136

[1]Students may substitute IS140-141 for SS104 and HU200.

[2]The four Hum./Soc. Sci. electives, in the Freshman, Sophomore, and Senior years, may be selected such that (a) two sequences each of two courses, or (b) one three-course sequence (plus a free Hum/SS elective) are taken. In either case, introductory course(s) must be followed by advanced course(s). All students must consult with an ME adviser on this matter.

[3]ROTC students should note that freshmen and sophomores may substitute zero-credit military science courses for PE101-104 (Physical Education I-IV).

[4]Technical Electives must be of Senior-Year quality, taken during the Senior Year after approval by an ME adviser has been secured.

GRADUATE PROGRAM

Programs of study are offered leading to the degrees of master of science, engineer, and doctor of philosophy in both mechanical engineering, and in applied mechanics. In mechanical engineering students may specialize in either (1) the mechanical analysis and design option or in (2) the thermal/fluids/energy option. Bachelor's degrees in mechanical, aerospace, civil or chemical engineering are generally required. Applicants with degrees in other fields may be admitted with deficiencies. Mathematics or physics majors who have completed an undergraduate course in strength of materials may be admitted to the applied mechanics program without deficiencies.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE

Core Courses:

A. For mechanical engineering (mechanical analysis and design option) and for applied mechanics

ME 601-02	Stress Analysis I & II	
	or	6
ME 603-04	Elasticity I & II	
ME 651-52	Advanced Dynamics I & II	
	or	6
ME 653-54	Dynamics of Machines and Mechanical Vibrations	
ME 971-72	Seminar in Mechanical Engineering	0
		12

Students who have not achieved the level of mathematical proficiency required by MA 260 are required to complete MA 531-32.

B. For mechanical engineering (thermal/fluids/energy option)

ME 701	Thermodynamics I	3
ME 710	Convection	3
ME 740	Principles of Fluid Dynamics	3
ME 971-72	Seminar in Mechanical Engineering	0

Students who have not achieved the level of mathematical proficiency required by MA 260 are required to complete MA 531-32.

Programs

A1 — Mechanical Engineering (mechanical analysis and design option)

Core Courses (A)		12
Select 6 additional units from		
ME 601-602	Stress Analysis I, II	
ME 603-04	Elasticity I & II	
ME 613-14	Theory of Plates and Shells	6
ME 651-52	Advanced Dynamics I & II	
	Electives	18
		36

A2 — Applied Mechanics

Core Courses (A)†		12
ME 603-04	Elasticity I & II	6
ME 613-14	Theory of Plates and Shells	6
	Electives	12
		36

B1 — Mechanical Engineering (thermal/fluids/energy option)

Core Courses (B)		9
Select 12 additional units from		
ME 702	Thermodynamics II	
ME 711	Convective Heat Transfer	
ME 712	Conductive Heat Transfer	
ME 713	Radiative Heat Transfer	
ME 731	Analytical Methods in Thermal & Fluid Mechanics	12
ME 732	Computational Methods in Thermal & Fluid Mechanics	
ME 741	Compressible Flow	
ME 742	Viscous Flow	
	Electives	15
		36

In each of the above master's degree programs students may pursue a project (up to six units counted toward the degree) or a thesis (up to twelve units counted toward the degree) under the guidance of a faculty sponsor or may elect to complete the program solely with courses. All elective courses must be approved by a graduate ME adviser and should be consistent with a definable objective associated with the master's program.

In all cases, at least 24 units of work must be completed by students in ME courses (including thesis or project) at the Polytechnic.

The department limits to nine the total of transfer, reading (guided studies), and validation credits which can be offered toward master's degrees. The certification of validation credits is administered by the ME departmental graduate advisers.

To obtain any graduate degree or certificate, a student must have 3.0 grade point averages or better in all graduate courses and B or better averages in all guided studies (readings, project, thesis, dissertation). Additionally, students must establish overall B averages in those departmental courses submitted in partial fullfilment of degree requirements. All courses submitted for degrees must have been completed within the four-year period prior to the awarding of degrees.

REQUIREMENTS FOR THE ENGINEER DEGREE

Master's degrees in mechanical, aerospace, civil or chemical engineering which meet one of the department specialization area requirements are generally required. Applicants with master's degrees not meeting these requirements may be conditionally admitted with deficiencies as evaluated by a departmental graduate adviser. All candidates must complete programs of study of at least 36 units beyond the master's degrees as approved by an appropriate ME departmental graduate adviser. These programs of study normally include at least 24 units of work within the department; part of this work includes a project of 6 but not more then 12 units. Course work may be substituted for the project if applicants' backgrounds include satisfactory evidence of equivalent experience as evaluated by the guidance committee. In addition, satisfactory attendance in ME 971-72 (Seminar in Mechanical Engineering) is required for two semesters.

To obtain any graduate degrees or certificates, students must have 3.0 grade point averages or better in all graduate

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†Either the core courses or the electives must include ME 651-52, Advanced Dynamics I & II.

courses and B or better averages in all guided studies (readings, project, thesis, dissertation).

REQUIREMENTS FOR THE DOCTOR OF PHILOSOPHY DEGREE

Students interested in the Ph.D. program are required to consult as soon as possible with ME department graduate advisers regarding eligibility to the qualifying examinations and other regulations.

Master's degrees in mechanical, aerospace, civil or chemical engineering which meet one of the department's area requirements are generally required. Applicants with degrees not meeting these requirements may be admitted with credit for previous work as evaluated by an ME departmental graduate adviser.

In order to enroll in a doctoral program of study, each candidate must pass a set of qualifying examinations in certain basic fields. Upon passing these examinations, a guidance committee is formed, and the candidate may then register for dissertation research.

All candidates for the Ph.D. must complete a minimum of 36 units of approved courses beyond the master's degree. In addition, registration for a minimum of 24 units of dissertation research is required at the rate of a minimum of three units per term, continuously, until the dissertation is completed and accepted. Satisfactory attendance in ME 971-72 (Seminar in Mechanical Engineering) is required each semester (normally, two semesters for the M.S. and four additional semesters for the Ph.D.). All of the above requirements must be met within a seven-year period prior to awarding degrees.

UNDERGRADUATE COURSES

ME 101   Graphics 1:3:2
Sketching and instrument drawings. Projection theory, multiview isometric, oblique, A.N.S.I. standards: dimensioning, sections, auxiliaries, fasteners, working and assembly drawings. Descriptive geometry: points, lines planes. Graphical mathematics: vectors, calculus. Project: simple concepts relating to students' majors.

ME 102   Computer-Aided Drafting 1:3:2
Current equipment in the Computer-Graphics Laboratory. State-of-the-art developments in computer-aided drafting techniques. The user-computer interface in operating computer-aided drafting packages. Visual representation of projection schemes, dimensioning techniques, sections, and assembly drawings on various display devices.

ME 111   Mechanics I 3:0:3
Three-dimensional vector treatment of the static equilibrium of particles and rigid bodies. Equivalent force and couple systems. Distributed force systems. Static analyses of trusses, frames and machines. Friction, impending motion. Methods of virtual work. Potential energy and stability of equilibrium. Prerequisites: MA 102 and PH 104.

ME 112   Mechanics II 3:0:3
Three-dimensional vector treatment of the kinematics and kinetics of particles and rigid bodies using various coordinate systems. Newton's laws, work, energy, impulse, momentum, conservative force fields, impact. Rotation and plane motion of rigid bodies. Prerequisite: ME 111.

ME 115   Engineering Mechanics 4:0:4
Equivalent to ME 116 and ME 117. Prerequisites: MA 102 and PH 104.

ME 116   Engineering Mechanics I 2:0:2
Three-dimensional vector treatment of the static equilibrium of particles and rigid bodies. Equivalent force and couple systems. Static analyses of trusses, frames, and machines. Friction, impending motion. Prerequisites: MA 102 and PH 104.

ME 117   Engineering Mechanics II 2:0:2
Three-dimensional vector treatment of the kinematics and kinetics of particles using various coordinate systems. Newton's laws, work, energy, impulse, momentum, conservative force fields, impact. Prerequisite: ME 116.

ME 118   Engineering Mechanics III 2:0:2
Methods of virtual work. Potential energy and stability of equilibrium. Distributed force systems. Kinematics and kinetics of rigid bodies. Rotation and plane motion of rigid bodies. ME 116, ME 117 and ME 118 equivalent to ME 111 and ME 112. Prerequisite: ME 117.

ME 119   Elements of Dynamics 3:0:3
Three-dimensional vector treatment of the kinematics and kinetics of particles and rigid bodies using various coordinate systems. Newton's laws, work, energy, impulse, momentum, conservative force fields. Rotation of a rigid body about a fixed axis; systems in translation and rotation. Prerequisites: MA 102 and PH 104.

ME 121   Mechanics of Materials 3:0:3
Basic principles of stresses and strains of members subjected to direct force, torsion and bending. Deflections of beams. Statically determinate and indeterminate problems. Column stability. Prerequisite: ME 111 or ME 116.
Also listed under CE 202

ME 201   Thermodynamics I 3:0:3
Properties of pure substances; concepts of work and heat; closed and open systems. The fundamental laws of thermodynamics; entropy and entropy production; Carnot and Clasius statements; heat engines, refrigerators, heat pumps; efficiencies, coefficients of performance. Prerequisites: MA 104 and PH 105.

ME 202   Thermodynamics II 3:0:3
Continuation of ME 201. Irreversibility and availability. Power and refrigeration cycles. Maxwell's equations and other thermodynamic relations. Properties of mixtures; air-conditioning. Energy and equilibrium aspects of chemical reactions; flame temperatures. Introduction to phase and chemical equilibrium. Prerequisite: ME 201.

ME 203   Heat Transfer 3:0:3
Conduction, convection and radiation heat transfer. Steady-state and transient analyses of multidimensional conduction systems. Numerical solutions augmented with computer programs for various modes of heat transfer. Prerequisites: ME 201 and ME 231.

ME 204   Design of Energy Transfer and Conversion Systems 3:0:3
Principles of thermodynamics, fluid dynamics and heat transfer applied to design of heat exchangers. Applications of first and second laws of thermodynamics to design and evaluation of energy conversion cycles. Detailed heat exchangers or energy system design required of students. Prerequisites: ME 202 and ME 203.

ME 211   Statistical Thermodynamics* 3:0:3
Elementary probability theroems, statistical mechanics of noninteracting particles. Development of engineering thermodynamic expressions. Applications to engineering problems including deduction of thermodynamic properties for elementary gases and solids; thermal radiation from solids. Calculations of transport properties. Senior elective. Prerequisite: ME 201.

ME 212   Air Conditioning and Refrigeration* 3:0:3
Application of thermodynamics and other sciences needed for rational approaches to solutions of engineering problems in air conditioning and refrigeration. Senior elective. Prerequisite: ME 202.

MECHANICAL ENGINEERING

ME 213   Transport Processes*   3:0:3
Extensions of principles developed in ME 201, ME 203, and ME 231. Energy release and momentum, heat and mass transfer processes. Unified treatment using transport phenomena methods. Prerequisite: ME 203.

ME 231   Fluids I   3:0:3
Fluids, kinematics, hydrostatics, thermodynamics. Derivations of continuity, momentum and energy equations. Flux concepts and relation with divergence theorem. Control volume equations and applications. Bernoulli equation. Discussion of vorticity and stream function. Potential flows over simple geometric configurations. Co/ Prerequisites: ME 201 and MA 260.
Also listed under AE 231.

ME 232   Fluids II   3½:1½:4
Flow in pipes and ducts. Students required to design flow measuring and piping systems. One-dimensional gas dynamics. Convergent-divergent nozzles. Normal and oblique shocks. Expansion fans. Effects of friction and heat addition. Laboratory experiments related to: fluid properties, streaklines and streamlines, laminar-turbulent transition pipe flow, sonic pipe flow, converging and diverging nozzle flow. Prerequisite: ME231.

ME 243   Turbomachinery*   3:0:3
Thermodynamics, fluid mechanic principles and elements of turbomachinery (fans, pumps, compressors, turbines) including design principles and operation of turbomachines. Prerequisite: senior status.

ME 261   Vibrations   3:0:3
Mechanics of vibrating systems. Equations of motion, Lagrange's equations and Rayleigh's method. Free vibrations of undamped and damped single degree of freedom systems. Forced vibrations. Two degrees of freedom vibration. Methods in multi-degree of freedom systems. Prerequisite: ME 112.

ME 262   Advanced Vibrations*   3:0:3
Lagrangian mechanics. Normal mode analysis of free and forced vibration. Energy and numerical methods in vibration analysis. Non-linear oscillatory systems. Prerequisite: ME 261.

ME 271   Fundamentals of Stress Analysis I   3½:1½:4
Stress, equilibrium equations, strains, compatibility conditions, stress strain relations, superposition, strain energy. Bending of beams: unsymmetric bending of arbitrary section beams, bending stresses, deflections, shear stresses on thin-walled section beams, shear center. Laboratory experiments related to determining material properites; tension and torsion tests; unsymmetric bending of beams of Z and L cross sections; principle axes, stress-strain measurements. Prerequisite: ME 121.

**ME 272   Stress Analysis of Mechanical
           Components**   3½:1½:4
Beams on elastic foundation. Thin circular cylindrical shells. Discontinuity methods. Optimization of design by geometry and material selection. Thick-walled cylinders. Shrink fits. Rotating machinery. Thermal stresses in rotors. Torsion of mechanical elements. Laboratory experiments related to determining shear centers, stress concentrations by photoelasticity. Viscoelastic effects: creep tests. Prerequisite: ME 271.

ME 301   Synthesis of Mechanical Systems   3:0:3
Kinematic analysis of linkages, velocity and acceleration images, instantaneous centers. Design of cams, gears, gear trains. Geometric and algebraic methods of synthesis for path and function generation. Prerequisite: ME 112 or ME 117.

ME 302   Analysis and Design of Machine Elements   3:0:3
Application of basic principles to in-depth analysis and design of selected machine elements, typically: brakes, clutches, springs, screws, shafting, belt and gear systems. Fundamentals of friction, wear, boundary, hydrodynamic lubrication. Engineering principles from several disciplines applied to individual problems. Prerequisites: ME 121 and MA 260.

ME 321   Instrumentation   1½:1½:2
Measurement statistics: Standard deviation, curves of regression, accumulation of errors. Instrument systems and components: transduction of mechanical information into analog and digital signals; signal processing and filtering devices; readout devices. Static and dynamic measurements of mechanical components and systems; computer simulation studies. Laboratory: Active transduction, measurements of mechanical characteristics, computer simulation: air compressibility. Prerequisite: EE 370.

ME 322   Automated Controls   2½:1½:3
Feedback and development of control systems. Transfer functions. Block and signal flow diagrams. Response to aperiodic and periodic excitations. Error considerations. Stability: Routh-Hurwitz criterion, root locus, Bode-plot techniques. Laboratory: component studies, servo systems, compensation and stabilization, robot link systems. Prerequisite: ME 321.

**ME 331   Computational Methods in   Mechanical
           Engineering**   2½:1½:3
Introduction to computing hardware peripherals used for computer aided design, and to computational methods used in design processes. Laboratory sessions reinforce classroom instruction through use of remote terminals and mainframe computer, microcomputers and graphics peripherals. Students are required to develop elementary graphics software for CAD applications. Prerequisites: CS 100, MA 104, and ME 101.

**ME 332   Computer Graphics in Computer
           Aided Design**   2:3:3
Computational methods for geometric representation, of complex geometrics including curved surfaces. Rotation and perspective considerations. Review and application of representative CAD packages. Interfacing graphics and analysis software for design interation. Laboratory work includes use of packaged programs and a student project involving geometric data development and use in conjuntion with analysis tools for design. Prerequisite: ME 331.

ME 337   Introduction to Robotics   3:0:3
Robotics and the relevant fields related to robot design and operation. Kinematic problems peculiar to robotic construction, control consideration, power sources, and the need for sensory equipment and intelligence. Specifications used to evaluate robot performance and some considerations of the economics of robotized operations. Prerequisites: ME 302 and ME 322.

ME 341   Finite Elements   3½:1½:4
Review theorems of potential energy, Castigliano and matrix algebra. The stiffness (displacement) method; local and global two-dimensional orientations. Finite element solutions to trusses, beams, frames, and grids. General vs. special-purpose programs. Standard structural and scientific subroutines as well as appropriate selected programs. Prerequisite: ME 272 or equivalent.

ME 351   Laboratory I   ½:1½:1
Experiments related to thermodynamics: heat capacity, thermal conductivity. The refrigeration cycle; the centrifugal pump. Two dimensional and numerical conduction; radiation heat transfer. Prerequisite: Senior-year status.

ME 352   Laboratory II   ½:1½:1
Experiments related to thermodynamics; the gasoline engine. Conduction in composite bars; forced and natural convection; shell and tube heat exchangers; heat and mass transfer analogies. Prerequisite: ME 351.

ME 361   Design Project I   0:6:2
Basic design and analysis of engineering project. Formulation of formal plan of execution of design project. Prerequisite: senior status.

ME 362   Design Project II   0:6:2
Execution of design project as proposed in ME 361. Prerequisite: ME 361.

ME 363-366   ME Project or Study   credit to be arranged
Continuation of ME 362 on approval of project adviser. Directed studies or special topics in mechanical engineering. Prerequisite: ME 362.

ME 381-382   Senior Honors Work in Mechanical
                    Engineering I, II   credit to be arranged
Independent work undertaken by qualified honors students in mechanical engineering Course material arranged by faculty steering committee. Prerequisite: senior status.

ME 391-392   Guided Studies in Mechanical
                    Engineering I, II   credit to be arranged
Senior-year sequence for qualified students in mechanical engineering. Course material arranged by committee of faculty members.

GRADUATE COURSES

ME 601   Stress Analysis I   2½:0:3
Review of theory of beam bending. Use of Castigliano's theorems for determining deformations and statically indeterminate loads. Columns, beam columns, beams on elastic foundations. Circular cylindrical shells. Discontinuity analysis in composite structures. Prerequisite: mechanical engineering adviser's approval.

ME 602   Stress Analysis II   2½:0:3
Stress-strain relationships. Two dimensional stress and strain analysis. Equations of compatibility and equilibrium. The Airy stress function. Solutions of various classical, two dimensional problems, including those of stress concentration and thermal stress. Torsion of prismatic bars, open and closed thin-walled structures, and multicellular structures. Prerequisite: ME 601.

ME 603-604   Elasticity I, II*   each 2½:0:3
Stress and strain tensors. Generalized Hooke's Law. Formulation of elasticity problems. Plane stress and strain problems. Solution by complex variables. Stress concentrations. Rotating discs and cylinders. Thermal stresses. Three-dimensional problems. St. Venant problems, extension, flexure, torsion Energy principles and variational methods. Approximation techniques. Prerequisite: mechanical engineering adviser's approval.

ME 605   Limit Analysis of Structures*   2½:0:3
Plastic analysis of beams, frames, arches. Deformation under combined stress. Upper-and lower-bound theorems. Beams under combined stress; collapse of circular plates limiting loadcarrying capacity of shells. Prerequisite ME 601 or ME 603.

ME 606   Applied Plasticity   2½:0:3
Analysis of stress and strain, plastic constitutive relationships. Yielding criteria, extremum principles. Problems of plates and shells for various types of plasticity. Slip-line, analytical and numerical procedures. Steady and non-steady motion in two dimensions. Plastic instability. Prerequisite: ME 602.

ME 607   Continuum Mechanics*   2½:0:3
Cartesian tensors introduced and employed in analysis of stress and strain. Laws of mechanics and thermodynamics for general material. Introduction of various constitutive relations. Specialization of governing equations to elasticity, thermoelasticity, plasticity, viscoelasticity and creep, and fluid mechanics. Prerequisite: mechanical engineering adviser's approval.

ME 611   Advanced Mechanics of Materials*   2½:0:3
Unsymmetrical bending of elastic bars, shear center for members of thin-walled, open cross section, curved beams, beams on elastic foundations, membrane and bending stresses in shells. Prerequisite: ME 121 or CE 202.
Also listed under CE 621

ME 613   Theory of Plates   2½:0:3
Bending theories of elastic plates of various shapes from equilibirum considerations. Equilibirum equations and boundary conditions derived from energy principles. Exact and approximate solutions (series, Rayleig-Ritz, Galerkin). Introduction to large deflection and buckling theories. Application to structures and vehicles. Prerequisite: mechanical engineering adviser's approval.

ME 614   Theory of Shells   2½:0:3
Membrane theory of arbitrary thin shells and linear bending theory of shells with emphasis on circular cylinders. Derivation of buckling theory of circular cylindrical shells. Applications include shell-type roof structures, pressure vessels, underwater structures, vehicles and aerospace structures. Prerequisite: ME 613.

ME 615   Energy Methods in Structural Analysis*   2½:0:3
Unified treatment of structural analysis using the principles of virtual work, total potential energy, total complementary potential, and mixed-energy. Applications to trusses, beams, frames, rings, sandwich structures, and to plane stress and plane strain problems. Rayleigh-Ritz procedure, Galerkin, method. Prerequisite: mechanical engineering adviser's approval.

ME 616   Theory of Elastic Stability*   2½:0:3
Energy methods employed to investigate buckling loads of structural configurations composed of beams, rings, plates, shells. Applications to problems of technical interest associated with structures and vehicles. Prerequisite: mechanical engineering adviser's approval.

ME 621   Finite Element Analysis of Structural
                    Systems*   2½:0:3
Derivation of element stiffness matrices. Construction of general stiffness matrices in global coordinates. Application to problems in plane stress, plates, and shells under static and dynamic loads. Emphasis on problems involving analysis of systems with many unknowns. Prerequisite: mechanical engineering adviser's approval.

ME 623   Computational Methods in Mech. Eng. I*   2½:0:3
Integrated survey of principal methods in obtaining approximate solutions to boundary value problems that occur in structural analysis. Particular attention to continuum techniques such as Fourier, Ritz, Galerkin, least square and collocation methods. Prerequisite: mechanical engineering adviser's approval.
Also listed under AE 623.

ME 624   Computational Methods in Mech. Eng. II*   2½:0:3
Continuation of ME 623 with particular emphasis on numerical techniques of analysis, such as finite differences, iteration procedures and Runge-Kutta method. Consideration of recently developed hybrid methods. Consideration of recently developed hybrid meethods. Illustrative examples from contemporary literature in structural analysis. Prerequisite: ME 623.
Also listed under AE 624.

ME 625   Experimental Stress Analysis*   1:2½:3
Application of experimental stress analysis techniques to aerospace, civil and mechanical engineering systems. Mechanical strain gages, electrical strain gages and associated instrumentation, brittle coating, photoelasticity and photostress, Moire fringes. Static and dynamic loading; creep and fatigue of structural elements. Prerequisite: mechanical engineering adviser's approval.

ME 626   Advanced Topics in Experimental
                    Stress Analysis*   1:2½:3
Course orientation is toward advanced research. Introduction to modern optics followed by analysis of optical image formulation. Theory of holography and wave propagation in anisotropic media; advanced topics in three-dimensional photoelasticity, Moire analysis of three dimensional surfaces by means of holography and other optical techniques. Prerequisite: ME 625.

ME 630   Design Methods for Power Plant
Structures   2½:0:3
Fracture analysis. Theories of failure. Classification of stresses in power plant structural components. Introduction to limit analysis. Establishment of allowable stress intensities. Fatigue analysis. Thermal ratcheting. Understanding of the criteria in Sections III and VIII, Division 2 of ASME Code. Prerequisite: mechanical engineering adviser's approval.

ME 632   Introduction to Piping Analysis   2½:0:3
Use of displacement energy, complementary energy and thermoelastic reciprocal theorem in solution of problems of plane bending of rings, frames and piping; three-dimensional analysis of piping systems; computational methods of analysis using concepts of elastic center; bending of bimetals and layered elements. Prerequisite: ME 601.
Also listed under CE 632.

ME 634   Pressure Vessel Analysis   2½:0:3
Stress and deformation analysis of pressure vessel components. Discontinuity analysis. Stress intensities in the primary, secondary, and peak categories. Thermal stresses. Review of ASME pressure vessel analyses. Prerequisite: ME 601.

ME 637   Thermal Stress Analysis I*   2½:0:3
Thermal stress-strain relationships. Equivalent thermal loads. Extensional deformations. Stress-free temperature distributions. Plane stress, plane strain, thermal shock. Thermal beam stresses and deformations. Thermal stresses in plates and shells. Prerequisite: ME 602 or ME 603.

ME 638   Thermal Stress Analysis II*   2½:0:3
Energy methods of thermal stress analysis, including modified Castigliano's theorem, complementary energy, reciprocal theorems, and Rayleigh-Ritz technique. Bending of rings and circular plates. Deformation of cylindrical shells under combined axial and radial temperature distributions. Thermal instability: rings, plates. Prerequisite: ME 637.

ME 651   Advanced Dynamics I   2½:0:3
Kinematics and dynamics of a particle in space; translating and rotating frames of reference. Systems of particles; plane motion of rigid bodies. Two-body central force problem. Lagrange equations with holonomic and nonholonomic constraints; applications.
Also listed under AE 651.

ME 652   Advanced Dynamics II   2½:0:3
General motions of rigid bodies, Euler's equations, gyroscopic motions and stability, impulsive motions. Linear oscillations of two-degree and n-degree of freedom systems, matrix formultaions, applications, variational principles. Prerequisite: ME 651.
Also listed under AE 652.

ME 653   Dynamics of Machines   2½:0:3
Dynamics of systems with one and two degrees of freedom. Energy methods, Rayleigh's quotient. Generalized coordinates, Lagrange's equations. Prerequisite: mechanical engineering adviser's approval.

ME 654   Mechanical Vibrations   2½:0:3
Free and forced longitudinal, torsional and transverse vibrations. Continuous systems on many supports. Rayleigh-Ritz method. Damped structures. Prerequisite: ME 653.

ME 661   Structural Dynamics*   2½:0:3
Dynamic response of single degree of freedom systems. Theory of vibration of multidegree of freedom systems. Influence coefficient method. Analytical and numerical solution of dynamic response problems. Nonlinear analysis of single degree of freedom system. Emphasis on computer analysis of large complex systems.
Also listed under CE 625

ME 662   Vibrations of Plates and Shells*   2½:0:3
Linear theories of plates and shells with solutions of vibration problems. Free and forced vibrations. Vibrations of layered plates and shells. Nonlinear vibrations of plates and shells. Damping of vibrations of plates and shells; concept of damping parameters. Prerequisite: ME 601 and ME 654 or ME 661.

ME 663   Matrix Methods in Vibrations*   2½:0:3
Matrix methods in dynamics of conservative and nonconservative systems. Matrix iteration, transfer matrix, force and displacement methods for frames and curved structures. Prerequisite: ME 654.

ME 664   Dynamic Stability of Structures*   2½:0:3
Foundations of theory of dynamic stability. Dynamic stability of straight and curved beams, plates, and shells. Linear and nonlinear theories. Prerequisite: ME 615

ME 671   Analysis of Machines*   2½:0:3
Classification of mechanisms. Review of planar kinematic analysis. Algebraic and geometric methods for kinematic synthesis. Introduction to spatial linkages. Applications to mechanism design. Prerequisite: mechanical engineering adviser's approval.

ME 672   Kinematic Synthesis of Mechanisms*   2½:(
Kinematic analysis of planar motion. Geometric and algebraic methods in linkage synthesis for path function generation. Errors i. dimensional systhesis.Eular-Savary equation and the cubic of stationary curvature. Cognate linkages, Roberts-Chebyshev theorem. Synthesis of spatial linkages. Prerequisite: ME 671

ME 675   Mechanical Servomechanisms I*   2½:0:3
Analysis of linear control and feedback systems. Feedback loops, transfer functions and block diagrams. Proportional, rate, integral control. Root-locus methods, Bode and Nyquist plots, stability criteria. Prerequisite: mechanical engineering adviser's approval.

ME 676   Mechanical Servomechanisms II*   2½:0:3
Compensation techniques. Analog computer simulation of control systems. Analysis of nonlinear systems by use of phase plane and describing functions. Typical components and systems. Prerequisite: ME 675.

ME 681   Dynamics of Elastic Solids*   2½:0:3
Propagation of stress waves in infinite and semi-infinite elastic solids. Rayleigh waves. Pochhammer solution of longitudinal stress waves in cylinders. Torsional stress waves. Effects of rotational inertia and shear in flexural vibrations. Spherical stress waves. Prerequisite: ME 604.

ME 683   Nonharmonic and Random Vibrations   2½:0:3
Determination of factors controlling dynamic errors in shock and vibration; analysis of linear and nonlinear systems. Ritz averaging phase-plane and perturbation methods. Response to periodic and random excitation. Prerequisite: ME 654 or equivalent.

ME 684   Analysis of Nonlinear Systems*   2½:0:3
Introduction to methods of nonlinear analysis, especially to free and forced nonlinear vibrations. Phase-plane techniques, perturbation methods, method of harmonic balance and Krylow-Bogoliubov method. Self-excited oscillations and limit cycles. Liapunov's second method for stability analysis. Prerequisite: mechanical engineering adviser's approval.

ME 685   Noise and Acoustics I*   2½:0:3
Survey of mathematical methods, random signals, acoustic fields room acoustics, subjective criteria, environmental criteria. Prerequisite: mechanical engineering adviser's approval.

ME 686   Noise and Acoustics II*   2½:0:3
Mechanism of noise generation by helicopters, fan engines, jets. Noise characteristics of automobiles, trucks, construction equipment. Estimations of road noise. Problems of subway noise. Techniques of measurement. Environmental impact. Prerequisite: ME 685.

ME 687   Acoustic Radiation from Submerged
Structures*   2½:0:3
Wave equation and elementary solution. Helmholtz integral formulation. Radiation from submerged plates and shells and associated sound radiators; scattering of sound by rigid and elastic scatters; creeping waves. Prerequisite: ME 686.

**ME 691-694   Special Topics: ME and Applied
Mechanics*   each 2½:0:3**
Topics of particular current interest in mechanical engineering and applied mechanics. Prerequisite: mechanical engineering adviser's approval.

ME 701   Thermodynamics I   2½:0:3
Availability functions, general thermodynamic relations, equations of state, general thermodynamics equilibrium criteria. Prerequisite: mechanical engineering adviser's approval.

ME 702   Thermodynamics II*   2½:0:3
Continuation of ME 701. Applications of thermodynamics equilibrium criteria to various problems, including chemical reactions. Prerequisite: ME 701.

ME 705   Combustion I   2½:0:3
Chemical characteristics of flames. Heat of formation and of reaction; phase and reaction equilibrium and adiabatic flame temperature; and specie concentration in stationary and flowing reacting systems. Chemical kinetics of homogeneous and heterogeneous reacting systems. Branching chain reactions and explosion limits are then developed. Prerequisite: ME 701.

ME 706   Combustion II   2½:0:3
Physical characteristics of flames. Basic equations of aerothermochemistry, flame propagation in initially mixed and premixed gases, laminar and turbulent flame speeds, combustion of liquid droplets and sprays, combustion of solid particles and flame spreading in solids, and chemical reactions in boundary layers. Prerequisite: ME 705.

**ME 709   Special Topics:
Thermodynamics and Combustion*   2½:0:3**
Topics of particular current interest in thermodynamics and combustion. Prerequisite: mechanical engineering adviser's approval.

ME 710   Convection   2½:0:3
Developments and applications of laminar hydrodynamic and thermal boundary layer equations for fluid media. Mechanics of turbulence; formulation and analysis of turbulent hydrodynamics and thermal applications; natural convection and film evaporation and condensation. Prerequisite: ME 740 or equivalent.

ME 711   Convective Heat Transfer*   2½:0:3
Theories of free and forced convective systems. Equations for heat transfer coefficients in compressible and incompressible fluids developed from boundary layer concepts. Applications to internal and external laminar and turbulent flows. Prerequisite: ME 710.

ME 712   Conductive Heat Transfer*   2½:0:3
Theoretical development of transient and steady-state temperture distributions in finite and infinite solids. Appropriate mathematical techniques introduced as required. Solids undergoing phase change and two-dimensional fields. Prerequisite: ME 203.

ME 713   Radiative Heat Transfer*   2½:0:3
Fundamentals of radiative mechanisms of energy transfer. Definitions of basic qualities. Equations of transfer, radiative heatflux vector and conservation equations. Properties of surfaces and participating media. Applications to engineering systems. Prerequisite: ME 203.

ME 715   Heat Transfer   2½:0:3
Basic heat transfer mechanisms. Steady and unsteady conduction, including systems with internal heat sources. Internal and external forced and free convection. Radiation between surfaces and in gases. Dimensional and boundary layer considerations. Applications involving fins and heat exchangers. Credit for ME 715 will not be granted if ME 203 was taken. Prerequisite: mechanical engineering adviser's approval.

ME 716   Reactor Heat Transfer*   2½:0:3
Heat transfer problems and solution techniques associated with nuclear reactors including BWR, PWR, LMFBR and HIGR's. Representative core geometries and primary loop components. Flow boiling phenomena, liquid metal heat transfer, combined convection and radiation gas flow. LOCA and ECCS considerations. Prerequisite: ME 203 or ME 715.

ME 717   High-Performance Heat Exchangers*   2½:0:3
Heat exchanger requirements including need for augmentation. Extended surface concepts. Effectiveness-NTU approach. Overall thermodynamic considerations. Basic heat transfer relations for laminar and turbulent internal flows. Selection of exchanger configurations. Regenerators and recuperators. Heat pipes. Prerequisite: ME 203 or ME 715.

ME 718   Multiphase Flows with Heat Transfer*   2½:0:3
Conservation equations for two-phase flow systems with emphasis on gas-liquid mixtures. Bubbly, slug, annular and fog flow regimes. Pressure drops and heat transfer. Nucleate and film boiling; dropwise and film condensation. Critical heat flux. Prerequisites: ME 701, ME 710, ME 740.

ME 729   Special Topics: Heat Transfer*   2½:0:3
Topics of particular current interest in heat transfer. Prerequisite: mechanical engineering adviser's approval.

**ME 732   Computational Methods in Thermal
and Fluid Mechanics   2½:0:3**
Numerical analyses. Finite difference approximations, error and stability analyses, numerical dispersion and damping, matrix inversion methods. Implicit and explicit procedures, SOR, ADI, hopscotch and direct solvers for evaluating linear and nonlinear diffusion and convection problems. Prerequisite: mechanical engineering adviser's approval.
Also listed under AE 732.

ME 740   Principles of Fluid Dynamics   2½:0:3
Conservation laws of mass momentum and energy. Elements of potential theory and gas dynamics. Applications of inviscid flow to simple internal and external geometries; control volume and differential approach to fluid dynamic problems. Prerequisite: mechanical engineering adviser's approval.

ME 761   Energy Conversion*   2½:0:3
Energy resources, modes of energy conservation and principles of energy conversion technology applied to electrical power generation, transportation systems, environmental control and cryogenic systems. Combined cycles and processes and "total energy systems". Environmental considerations. Prerequisite: ME 701.

ME 763   Solar Thermal Engineering I   2½:0:3
Basic course in the use of solar radiation for heating of buildings, swimming pools, domestic hot water and low temperature processes. Direct, diffuse and ground-reflected solar radiation, sun angles, active and passive solar thermal engineering, building heat loss, flat plate collector design, construction and thermal efficiency, fluid friction, heat storage design, heat distribution systems, domestic water heaters, system performance simulations, economics of solar heating. Prerequisite: undergradute engineering degree.

ME 764   Solar Thermal Engineering II   2½:0:3
Extension of ME 763 to more advanced solar heating topics plus cooling and dehumidifcation. Heat transfer and storage in massive walls, double shell houses, Trombe walls, residential and commercial greenhouses, seasonal solar heating performance estimates. Vapor compression refrigeration cycle, solar assisted heat pump systems, absorption refrigeration cycles, heat engines, solar-driven air conditioners, solar dehumidifiers, concentrating solar collectors use of reflectors to improve system performance. Prerequisite: ME 763.

ME 765 Energy Conservation and Environmental Control* 2½:0:3
Atmospheric control in enclosures. Heat load requirements, toxicity control, waste disposal, regeneration. Effect of chemical composition in artifical atmospheres on human performance. Energy requirements and alternatives. Prerequisites: mechanical engineering adviser's approval.

ME 769 Special Topics: Energy Conversion* 2½:0:3
Topics of particular current interest in energy conversion. Prerequisite: mechanical engineering adviser's approval.

ME 771 Computational Geometry for CAD 2½:0:3
Interactive computer graphics, with emphasis on design and manufacturing applications. 2D, 3D geometry and vector algebra. Transformation and viewing of 3D geometry. Parametric representation and design of 3D curve and surface geometry. Theory of splines. Overview of CAD packages. Prerequisite: mechanical engineering adviser's approval.

ME 772 Computer-Aided Design 2½:0:3
Concepts and potentials of computer-aided design. Roles of interactive computer graphics in CAD. Hardware systems and existing software packages. Geometric modeling and object hierarchy. Raster algorithms and display architecture. 3D modeling, hidden surface treatment, of CAD systems. Designs programming, and uses of CAD systems. A project involving the development of CAD system is required. Prerequisite: ME 332 or ME 771.

ME 810 Theory of Propulsion* 2½:0:3
Principles of modern propulsion based on chemical energy sources. Air-breathing engines, combustion thermodynamics, flows with chemical reactions, thermochemisty of solid and liquid rocket engines. Engineering parameters in engine design. Prerequisite: mechanical engineering adviser's approval.
Also listed under AE 810.

ME 901-904 Guided Readings I, II, III, IV each 3 units
Open to qualified graduate students interested in special advanced topics. Directed study including analytical work and/or laboratory investigations. Prerequisite: written permission of departmental head.

ME 935 Engineering Projects Related to Public Administration each 3 units
See Cooperative Program with New York University's Graduate School of Public Administration for details.

SEMINAR, PROJECTS, THESIS AND DISSERTATION

ME 971-972 Seminar in Mechanical Engineering 0
Recent developments through lectures by representatives from industry, research, educational institutions. Discussions from floor. Satisfactory attendance required of master's or engineer students for two semesters; four additional semesters required of Ph.D. students.

ME 996 Project each 3 units
Engineering project pursued with guidance of faculty member. Project titles submitted in writing to department head and adviser appointed. May be extended to thesis with project adviser's recommendation. Credit only upon completion of project. Reregistration fee: 3-unit charge. Prerequisite: degree status.

ME 997 M.S. Thesis each 3 units
Master's thesis to present results of original investigation in field of student's specialty. Thesis an extension of ME 996, on recommendation of project adviser. Continuous registration required. Maximum of twelve units of ME 996-997 counted toward degree. Reregistration fee: 3-unit charge. Prerequisite: ME 996.

ME 998 Engineer Project each 3 units
Analytical, experimental or design project under guidance of faculty member. Oral examination on project and related topics required of candidates. Continuous registration required until satisfactory project completed. Minimum of six, maximum of twelve units of ME 996-997 counted toward degrees. Reregistration fee: 3-unit charge. Prerequisite: post-master status.

ME 999 Ph.D. Dissertation each 3 units
Doctor's dissertation evincing independent study and original contributions in field of specialization. Oral examination on subject of dissertation and related topics required. Minimum of 24 units; also continuous registration at minimum of 3 units per semester required until dissertation completed. Reregistration fee: 3-unit charge. Prerequisite: degree status.

FACULTY

William R. McShane, Professor of Transportation and System Engineering; Head, Department of Mechanical and Industrial Engineering; Director, Transportation Training and Research Center.
B.E.E., Manhattan College, M.S., Ph.D., Polytechnic Institute of Brooklyn; Professional Engineer (N.Y., Cal. (Traffic))
Traffic engineering, highway capacity, expert systems in transportation, PC applications and models, economics and finances.

Anthony E Armenakas, Professor
B.S., Georgia Institute of Technology; M.S., Illinois Institute of Technology; Ph.D., Columbia University
Dynamic analysis of structures, fracture, wave propagation, numerical techniques

William Blesser, Professor
B.M.E., Rensselaer Polytechnic Institute; M.E.E., Polytechnic Institute of Brooklyn
Bioengineering, instrumentation, control systems, wave propagation, numerical techniques.

John R. Curreri, Professor
B.M.E., M.E.E., Polytechnic Institute of Brooklyn, Adelphi University
Nonliner vibrations, stress analysis, earthquake response of structures

Murray Imber, Professor
B.S., University of Illinois; M.S., Eng. Sc. D., Columbia University
Energy conversion, heat transfer, applied mathematics

Joseph Kempner, Professor
B.Ae.E., M.Ae.E., Ph.D., Polytechnic Institute of Brooklyn
Structural analysis, shell theory, structural dynamics

Jerome M. Klosner, Professor
B.C.E., CCNY; M.S., Columbia University; Ph.D., Polytechnic Institute of Brooklyn
Structural dynamics, fluid-structure interaction, thermal stress analysis

Huo-Hsi Pan, Professor
B.S., National Southwest Associated University (China);
M.S., Texas A&M; M.S., Kansas State University; Ph.D.,
University of California (Berkley)
Solid mechanics, rational design, applied mathematics

Sharad A. Patel, Professor
B.Sc., Benares Hindu University (India); M.Ae.E., Ph.D.,
Polytechnic Institute of Brooklyn
Solid mechanics, creep, structural analysis

Frank J. Romano, Professor and Administrative Officer,
Brooklyn
B.M.E., M.S., Ph.D., Polytechnic Institute of Brooklyn
Solid mechanics, structures, thermodynamics

Bernard W. Shaffer, Professor
B.M.E., CCNY, M.S., Case Institute of Technology; Ph.D.,
Brown University
Rational design, elasticity, plastic stress analysis

William P Vafakos, Professor
.M.E., M.M.E., Ph.D., Polytechnic Institute of Brooklyn;
D., Brooklyn Law School
olid mechanics, structures, vibrations

hilip Abrami, Associate Professor
M.E., M.S., Polytechnic Institute of Brooklyn
echanical analysis and design, sport product engineering

sse F. Crump, Associate Professor
S., M.D., University of Nebraska
nysiology, bioengineering, medical instrumentation

Richard S. Thorsen, Associate Professor
Dean of Research and Graduate Studies.
B.M.E., City College of New York; M.M.E., Ph.D., New York
University
Heat transfer, nuclear reactor safety, solar energy, CAD

Tsu-Chin Chu, Assistant Professor
B.S., Nat'l Cheng Kung University (Taiwan); M.S., Auburn
University; Ph.D., University of South Carolina
Computer graphics, CAD/CAM, stress analysis

Karim M. Moallemi, Assistant Professor
B.S. Pahlavi University, Iran
M.S., Ph.D., Purdue University
*Experimental and computational heat transfer, Fluid
mechanics, Energy conversion, combustion*

George C. Vradis, Assistant Professor
Dipl. ME, Nat'l. Tech. University, Greece
M.S., Ph.D., Polytechnic University
Fluid/thermal studies, unsteady flows, energy transfer

Chih-Shing Wei, Assistant Professor
B.S., Nat'l Chung Hsing University (Taiwan); M.S., State
University of New York at Buffalo; Ph.D., Georgia Institute of
Technology
Computer graphics, CAD/CAM, heat transfer

EMERITUS FACULTY

Martin H. Bloom, Institute Professor
B.M.E., M.S., Ph.D., Polytechnic Institute of Brooklyn
*Fluid and thermal studies; aerospace engineering; energy
conservation*

Vito D. Agosta, Professor
B.M.E., Polytechnic Institute of Brooklyn, University of
Michigan; Ph.D., Columbia University
Propulsion, heat power, heat transfer

Simon Slutsky, Professor
B.C.E., CCNY; M.S., Columbia University; Ph.D., Polytechnic Institute of Brooklyn
Urban noise, engine noise, and vibrations

ADJUNCT FACULTY

Edward Pinnes, Adjunct Associate Professor
B.M.E., M.S., New York University; Ph.D., Polytechnic
Institute of Brooklyn
Fluid mechanics, thermodynamics, heat transfer

Robert Atkatsh, Adjunct Lecturer
B.C.E. CCNY; M.S., Harvard University; Ph.D., Columbia
University
Numerical analysis; finite elements; plasticity

Julian Berman, Adjunct Lecturer
B.S., CCNY; M.S., New York University
Vibrations, aeroelasticity, unsteady aerodynamics

Joanne DiMarco, Adjunct Lecturer
B.A., Queens College; M.S., SUNY
Mathematics, computer applications, data processing

Robert DiMarco, Adjunct Lecturer
B.S., AE, Polytechnic Institute of Brooklyn; M.S., Long Island
University
Computer graphics, CAD/CAM

Bernard Roth, Adjunct Lecturer
B.M.E., M.S., City College of New York
Mechanics, mechanics of materials

METALLURGY AND MATERIALS SCIENCE

Metallurgists and material scientists are specialists in the most effective utilization of metals, alloys, ceramics, semiconductors, composites, plastics, and polymers. Their expertise is vital to the solution of problems arising from the intensive quest for superior materials in our rapidly advancing technological age. During the last three decades, we have witnessed increasing demands for ultrahigh-strength corrosion and heat resistant alloys, such as alloy steels, tungsten, titanium, beryllium, and molybdenum as well as nonmetallic epoxy-carbon composites. In electronics, we have witnessed tremendous growth in the use of silicon and other semi-conductor materials for integrated circuits. Yet we have utilized only a fraction of the theoretical potentials of materials. Challenges remain for imaginative individuals to probe, understand, process, fabricate, and use effectively metallic materials, semiconductors, and composites in fields ranging from electronic devices and integrated circuits to new energy production processes and aerospace applications. The broad fields of metallurgy and materials science may be divided into several areas of specialization: physical metallurgy, materials science and engineering metallurgy.

Materials Science

It is estimated that nearly 40% of all engineering RESEARCH is in the area of materials science, which is defined as the study of the interrelation among atomic structure, crystal structure, microstructure and properties of materials. The fundamental principles, which involve basic physics and chemistry, are universally applied to metals, ceramics, polymers, semiconductors and composites. With this understanding it is possible to "tailor make" materials requiring specific properties for particular applications.

The instrumentation used to characterize the materials and the processes used to fabricate them share a common basis. Traditionally, the study of structure-property relationships was the specialty of the physical metallurgist. As a result of this history there exists a strong emphasis in metals in the materials science curriculum and a student may elect to pursue a major in this discipline.

Engineering Metallurgy

In engineering metallurgy, engineering application of metallic materials directly reflect on the electronic, aerospace, energy and chemical production and transportation industries. Metallurgical engineers play vital roles in materials selection and process optimization. They have thorough knowledge of existing metallic materials, their properties and limitations. Borrowing fundamental knowledge from physical metallurgy, they constantly search for new and better materials to improve processes and products. Some areas in which metallurgical engineers work are prevention of corrosion and environmental degradation, welding processes for alloys and composites, failure analysis, product reliability and safety, quality control, materials characterization, and alloy development. Furthermore, metallurgists may work in research and

development, plant operations or do consulting. Metallurgists contribute to progress in oceanography, medical prosthetics, dental materials, environmental protection, and electronic devices.

PROGRAMS OF STUDY

- Bachelor of Science in Metallurgical Engineering (with concentration in Materials Science)
- Master of Science
  Metallurgical Engineering
  Materials Science
  Manufacturing Engineering of Electronic Materials
      (Joint program with Industrial Engineering
      Department)
- Engineer
  Metallurgical Engineering
- Ph.D.
  Materials Science

Undergraduate programs are approved by the Accreditation Board for Engineering and Technology.

UNDERGRADUATE PROGRAM

The program for full-time study is designed to establish a firm base from which the graduate may proceed along any avenue of professional development from graduate study and research to industrial employment. Scientific understanding and utilization of basic concepts — rather than dependence on purely factual knowledge — are the Department's aims, providing the capability to solve present problems and the ability to keep pace with technological advancements and to be able to solve the increasingly complex problems of the future.

Specifically, the curriculum consists of 39 credits in mathematics, physics and chemistry; 24 credits in the humanities and social sciences; 53 credits in engineering science, materials sciences, engineering design and systems; 9 credits of technical electives; 3 credits of free electives; and 8 credits of thesis.

During their junior and senior years metallurgy students may broaden their programs by selecting the technical elective sequence of 12 credits from the following list:

* MA 153	Linear Algebra (3 credits)	
* MA 231	Statistical Methods I (3 credits)	
AM 331	Computational Methods in CAD (3 credits)	
MT 417	Welding Engineering (3 credits)	
IE 300	Engineering Economics (3 credits)	
IE 311	Statistical Quality Control (3 credits)	

Students may (with adviser's approval) elect to substitute for thesis MT 496-497 (6 credits) applied computer courses: AM 331 Devices and Computational Methods in Computer-Aided Design (3 credits) and AM 332 Computer Graphics in Computer-Aided Design (3 credits).

Humanities and social science requirements for all engineering students are given in the section entitled Degree Requirements.

Freshman and sophomore years of metallurgical engineering curricula may be taken on the Long Island Campus. Junior and senior metallurgy courses are offered only on the Brooklyn campus. Any non-metallurgy courses listed in the last two years may also be taken at the Long Island campus, provided they are offered.

GRADUATE STUDIES

The Department of Metallurgy and Materials Science prepares students for the degree of master of science in materials science and metallurgical engineering, the degree of Engineer in metallurgical engineering, and the degree of

doctor of philosophy in materials science. The courses of study and research leading to these degrees are designed for students holding baccalaureate degrees in metallurgy or materials science. Students holding baccalaurate degrees in related disciplines are admitted, and may be required to remove undergraduate deficiencies, if any.

Both fundamental and applied research are carried on within the Department. Excellent facilities are available for work in electron microscopy, x-ray diffraction, deformation and fracture and other fields. Fundamental research is carried out on alloy hardening, deformation and fracture, phase transformations, thermomechanical working, ternary diffusion and rapid solidification. In applied research, the Department is involved in studies of materials for aerospace, electronic applications and energy related applications. The rules governing admittance to graduate studies are applicable to all students.
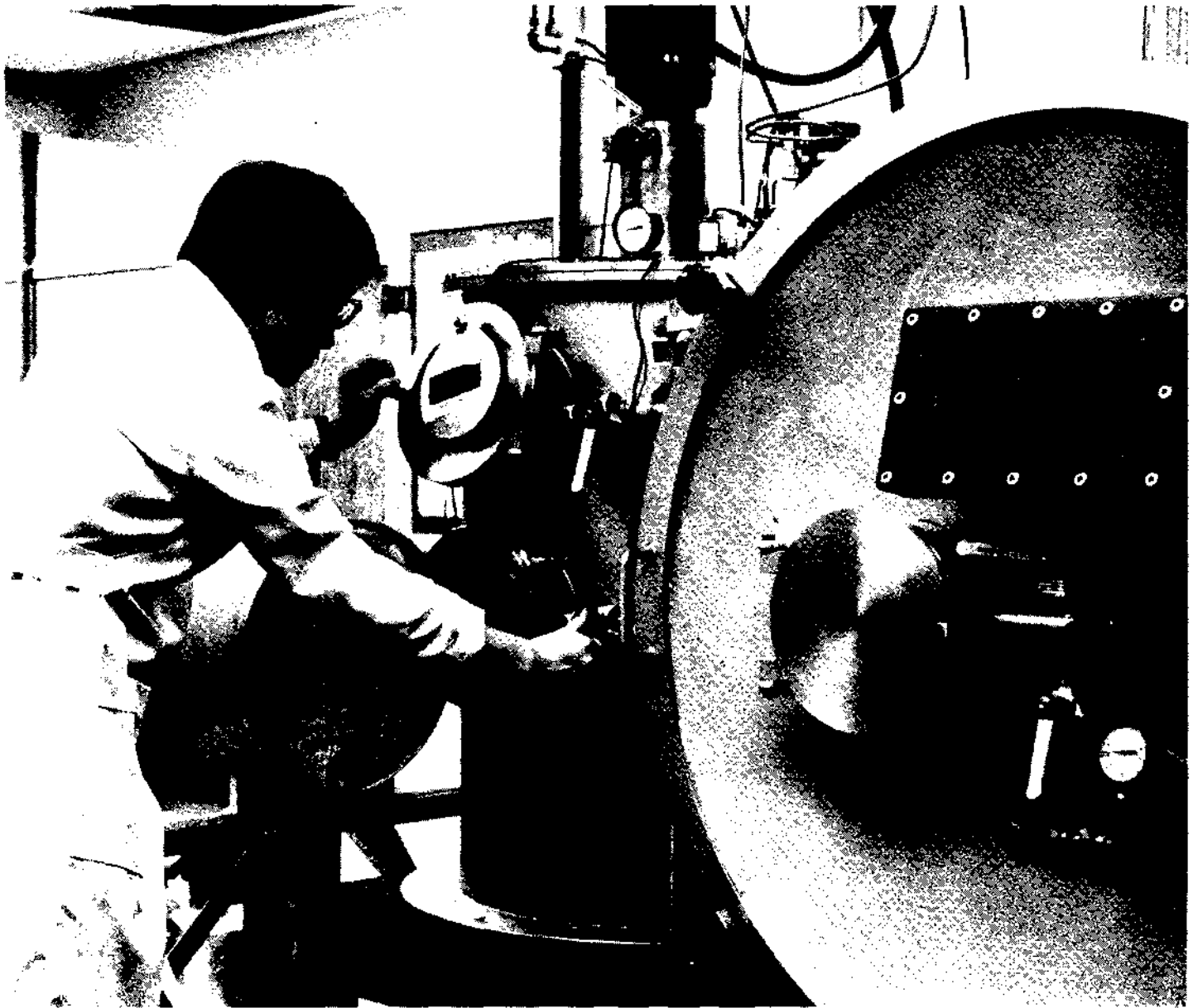
*One of two required.

Typical Course of Study for the
Bachelor of Science Degree in Metallurgical Engineering

Freshman Year

No.		Subject	Cl.	Lab.	Cr.
		First Semester		Hours/Week	
CM	101	General Chemistry I	2½	0	2½
CM	111	General Chemistry Lab I	0	1½	½
CS	100	Intro. to Computer Programming	2	0	2
HU	101	Writing and the Humanities I	3	0	3
MA	101	Calculus I	4	0	4
SS	104	Contemp. World History	3	0	3
SL	101	Student Survival	0	1	0
PE	101	Physical Education	0	2	0
					15

No.		Subject	Cl.	Lab.	Cr.
		Second Semester		Hours/Week	
CM	102	General Chemistry II	2½	0	2½
CM	112	General Chemistry Lab II	0	1½	½
HU	200	Writing and the Humanities II	3	0	3
MA	102	Calculus II	4	0	4
PH	104	Intro. to Physics I	3	0	3
PE	102	Physical Education	0	2	0
		Hum./Soc. Sci. elective	3	0	3
					16

Sophomore Year

			Cl.	Lab.	Cr.
AM	116	Statistics	2	0	2
AM	101	Graphics	1	3	2
PH	105	Intro. to Physics II	3½	0	3½
PH	115	Physics Laboratory I	0	1½	½
MA	103	Calculus III	3	0	3
PE	103	Physical Education	0	2	0
		Hum./Soc. Sci. elective	6	0	6
					17

			Cl.	Lab.	Cr.
EE	370	Princ. Elec. Eng.	3	0	3
EE	374	Inst. Lab.	0	3	1
AM	117	Dynamics	2	0	2
AM	121	Mechs. of Materials	3	0	3
MA	104	Appl. Diff. Eqs.	3	0	3
PH	106	Intro. to Physics III	2½	0	2½
PH	116	Physics Laboratory II	0	1½	½
PE	104	Physical Education	0	2	0
					15

Junior Year

			Cl.	Lab.	Cr.
MT	401	Physical Metallurgy I	3	0	3
MT	402	Mechan. Metallurgy I	3	3	4
MT	404	Metallography Lab.	0	6	2
MT	405	Metallurgical Thermodynamics	3	0	3
		Hum./Soc. Sci. elective	3	0	3
		Elective*	3	0	3
					18

			Cl.	Lab.	Cr.
CM	161	Physical Chemistry I	3	0	3
MT	403	Physical Metallurgy II	3	0	3
MT	406	Mechanical Metallurgy II	3	0	3
MT	407	Metallurgy Transport	3	0	3
MT	408	Phys. Metallurgy Lab.	0	6	2
MT	494	Literature Search	1	3	2
CM	515	Polymer Org. Chem.	3	0	3
					19

Senior Year

			Cl.	Lab.	Cr.
MT	410	Solid-State Metallurgy	3	0	3
MT	416	Electromet. & Corrosion	2	3	3
MT	421	Metal. Failure Analysis	2	3	3
MT	496	Thesis	0	9	3
CM	771	Intro. to Polymer Chemistry.	3	0	3
		Elective*	3	0	3
					18

			Cl.	Lab.	Cr.
MT	413	Process Metallurgy	3	0	3
MT	423	Ceramics & Refract. Mat.	3	0	3
MT	497	Thesis	0	9	3
		Hum./Soc. Sci. elective	3	0	3
		Elective*	6	0	6
					18

Total credits required for graduation: 136

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE

In order to be admitted to the master's program, an applicant must have the equivalent of a bachelor's degree in metallurgy or materials science. An applicant with a bachelor's degree in a field of science or engineering other than metallurgy or materials science may have to remove some undergraduate deficiencies as determined by the Department Advisory Committee.

Full-time graduate students enrolled in the master's program will generally be required to do a master's thesis. Part-time students will be required to complete a master's project. Under special circumstances students may take courses and pass an oral examination in lieu of a thesis or project.

A minimum of 36 units of required and elective courses, and thesis or project is necessary for the M.S. degree.

M.S. Metallurgical Engineering

Required Course Work: **Units**

Take 9 units from:

MT 600	Structure-Property Relationships	3
MT 610	Thermodynamics of Metals & Alloys	3
MT 620	Plastic Deformation & Fracture	3
MT 630	Theory of Metals	3
MT 640	Reactions in Solids	3
MT 650	Advanced Engineering Metallurgy	3
		9

Project or Thesis

MT 966	Project for M.S.	3-6
	or	
MT 997	Thesis for M.S.	9-12

Elective Course Work:
9-24 units chosen from the Department courses listed on subsequent pages of this Catalog.   9-24

Engineering or Science Electives:
With adviser's approval may be chosen from among University courses offered in this catalog.   0-6

Total   36

M.S. Materials Science

Enrollment in the program is open to students with undergraduate degrees in engineering or the physical sciences. Depending on the undergraduate background, two 500 level courses may be required to satisfy principal prerequisite requirements:

CM 515 Polymer Organic Chemistry
MT 540 Survey of Metallurgical Principles

(These courses may not carry credit towards degrees).

Required Course Work (12 units)		Units
MT 600	Structure-Property Relationships	3
MT 640	Reactions in Solids	3
MT 660	Ceramic Technology	3
CM 771	Introductory Polymeric Chemistry	3
		12

Project or Thesis		
MT 996	Report Project for M.S.	3-6
	or	
MT 997	Thesis for M.S.	9-12

Elective Course Work:
With adviser's approval courses from catalog and others in areas related to materials science, e.g., metallurgy, physics, chemistry, and polymers.
                                              12-21
                                    Total   36

REQUIREMENTS FOR THE ENGINEER DEGREE

Applicants for admission to this program must hold a master's degree (or equivalent) comparable in content to that of the Department. This must include at least the equivalent of three of the required courses in the MT 600-650 series listed under the requirements for the master's degree. An applicant holding a master's degree for which the requirements vary substantially from those indicated above may be admitted to the engineer program if the deficiencies, as evaluated by the department graduate adviser, are removed during the time the student is enrolled in the program.

No.	Required Subjects	Units
MT 621-622	Special Topics in Plastic Deformation & Fracture	6
MT 651-652	Special Topics in Advanced Engineering Metallurgy	6
MT 760-761	Seminar in Metallurgical Engineering	3
MT 998	Project for the Engineer Degree	6
	Selected electives in science, mathematics, economics or engineering, in consultation with department advisers.	15
	Total	36

REQUIREMENTS FOR THE DOCTOR OF PHILOSOPHY

Requirements for doctor's degree conform to regulations in Degree Requirements. Specific doctoral requirements are available from the Departmental Administrative Assistant in the publication, *Guide for Doctoral Students in Metallurgy or Materials Science.*

A typical program consists of a minimum of 24 units of research for the doctoral dissertation, and sufficient units of graduate course work for a total of 90 units required by Polytechnic. A minimum of 48 units of graduate course work beyond the bachelor's degree is normally required by the Department. Courses include major concentrations in metallurgy/materials science of 36 units and minor concentrations of 12 units in related areas of physics, chemistry, mathematics, mechanical engineering, etc.

UNDERGRADUATE COURSES

MT 401   Physical Metallurgy I   3:0:3
Introduction to physical metallurgy. Relations of properties to microstructures in pure metals. Recovery, recrystallization and grain growth. Phase diagrams. Solidification. Iron-carbon alloy systems. Ferrous alloys. Prerequisites: PH 103, CM 102 and CM 112.

MT 402   Mechanical Metallurgy I   3:3:4
Behavior of metallic materials under stress. Mechanical properties in tension, compression, direct shear, torsion, flexure. True stress-strain. Cold work, hardness, impact, fracture mechanics, fatigue properties. Effects of temperature on mechanical behavior of metals. Creep. Stress rupture. Prerequisite: MA 103.

MT 403   Physical Metallurgy II   3:0:3
Non-ferrous alloys. Diffusion-controlled phase transformations. Distortion-controlled phase transformations. Elementary alloy theory. Prerequisite: MT 302 or MT 401.

MT 404   Metallography Laboratory   0:6:2
Metallographic preparation of samples, mounting, polishing, etching. Electropolishing and etching of ferrous and non-ferrous alloys. Macroetching and sulphur prints. Temperature measurement: thermocouple and pyrometry. Photomicrography and photographic techniques. Sample preparation techniques for electron microscopy.

MT 405   Metallurgical Thermodynamics   3:0:3
Law of thermodynamics. Free energy of heterogeneous reactions. Phase equilibria. Introduction to statistical thermodynamics. Thermodynamics of solutions and defects. Prerequisite: MT 401.

MT 406   Mechanical Metallurgy II   3:0:3
Mechanism of slip, slip systems, critical resolved shear stress, mechanical twinning. Deformation in polycrystalline materials. Impurity effects and yield point phenomena. Elements of dislocation theory. Dislocation reactions, multiplications, movement under force. Dislocation interaction with impurities and point defects. Prerequisite: MT 402.

MT 407   Phase Transformations   3:0:3
Equilibrium in single component systems and binary solutions. Binary phase diagrams. Interstitial and substitutional diffusion. Solidification of pure solids. Alloy solidification. Diffusional transformations in solids. Diffusionless transformations. Prerequisite: MT 403.

MT 408   Physical Metallurgy Laboratory   0:6:2
Experiments to illustrate principles of physical metallurgy, including phase equilibria, recrystallization, solid-solution and precipitation hardening. Heat treatment of steel. Structure property relationships. Prerequisite: MT 404.

MT 410   Solid-State Metallurgy   3:0:3
Free electron theory of metals. Band and zone theory. Bonding in solids. Thermal, electrical and magnetic properties of metals and alloys. Effects of metallurgical variables. Metallurgical aspects of semi-conductor and superconductor phenomena. Prerequisite: MA 104.

MT 411　Fabrication Technology　　　　　3:0:3
Metallurgical principles of metal fabrication. Forging, rolling, extrusion and wire drawing. Hot and cold forging. Fabrication defects. Elasticity and plasticity theories applied to metal fabrication. Elements of solidification and metal casting. Prerequisites: MT 403 and MT 406.

MT 412　X-ray Diffraction　　　　　　　2:3:3
Production and properties of x-rays. Elements of crystallography. Stereographic projection. Powder and single crystal diffraction techniques. Structures and crystal orientation. Stress analyses and phase diagram determinations by x-ray techniques. Qualitative and quantitative chemical analyses by x-ray techniques. Prerequisites: MA 104 and PH 103.
Also listed under PH 372.

MT 413　Process Metallurgy　　　　　　3:0:3
Casting, metal forming, surface modification by electron beam, laser beam, and ion implantation; powder metallurgy; rapid solidification processing; composite materials processing. Prerequisite: MT 405.

MT 416　Electrometallurgy and Corrosion　2:3:3
Electrode potential and overvoltage. Electrode kinetics. Corrosion types. Corrosion protection. Electroplating. Laboratory experiments include potentiostatic and galvanostatic methods for studying corrosion. Prerequisite: MT 403.

MT 421　Metallurgical Failure Analysis　　1:6:3
Metallurgical principles applied to analyses of in-service failures of materials. Discussions of actual case histories. Laboratory assignments require students to prepare written reports and give oral presentations analyzing six in-service failures. Prerequisites: MT 404 and MT 408.

MT 423　Introduction to Ceramic Refractory Materials　3:0:3
Mineral raw materials. Forming and thermal treatments to obtain ceramic products. Glasses, glazes and enamels on metals. Introduction to physical ceramics. Equilibria and reactions between ceramics. Recrystallization, grain growth and microstructures of ceramics. Plastic and viscous deformations in ceramics. Physical properties of ceramics.

MT 494　Informational Search　　　　　1:3:2
Preparation and presentation by students of papers in metallurgical engineering, physical metallurgy or materials science literature. Topics may be related to bachelor's thesis.

MT 496-497　Bachelor's Thesis in Metallurgical Engineering　　　　　each 3 credits
Carefully planned original investigations on topics approved by head of department. Results must show conclusive evidence of students' abilities to attack and solve problems pertaining to metallurgy. Regular conferences and written reports required during progress of work; examinations given mid-thesis and when thesis is completed. Prerequisite: MT 494.

TECHNICAL ELECTIVE COURSES

MT 409　Materials Selection　　　　　　3:0:3
Knowledge base of metallurgy and materials science applied to engineering materials selections. Value engineering approach and organization for materials selections. Elementary statistics applied to specifications, quality standards, quality controls. Prerequisite: MT 403.

MT 414　Metallurgical Kinetics　　　　　3:0:3
Statistical and empirical approaches to kinetics. Diffusion in metals and alloys. Theories of nucleation and growth. Kinetics of recrystallization, martensitic transformations. Prerequisite: MT 405.

MT 415　Metallurgy of Magnetic Materials　3:0:3
Macroscopic concepts of magnetism. Magnetization curves. Technological requirements for and applications of ferromagnetic materials. Ferromagnetic domains. Properties of ferromagnetic single crystals. Metallurgical factors affecting ferromagnetic properties, iron silicon, iron-nickel and other alloys. Permanent magnet materials. Prerequisite: MT 410 or equivalent.

MT 417　Welding Metallurgy　　　　　　3:0:3
Metallurgical aspects of welding. Theories and applications of arc, gas, resistance and solid state welding processes. Modern methods of procedure, control, tests, inspection. Examinations of micro- and macro-structures of welds and adjacent areas. Applications of welding. Weldability criteria. Prerequisite: MT 302 or MT 401 or equivalent.

MT 418　Powder Metallurgy　　　　　　3:0:3
Characteristics of metal powders. Basic principles of compacting. Porous and dense products. Microstructures. Factors affecting physical and mechanical properties of powder blending, compacting, sintering. Prerequisite: MT 401.

MT 419　Strengthening Mechanisms in Metals and Alloys　　　　　3:0:3
Theories of alloy strengthening. Role of solute distribution on dislocation movement in binary and complex alloys. Multiphase aggregate strengthening. Composite materials and unidirectionally solidified eutectics. Thermomechanical processing and strength. High temperature effects. Prerequisites: MT 403 and MT 406.

INTERDEPARTMENTAL COURSES

MT 301　Mechanical Behavior of Materials　3:0:3
Structure-property relationships of engineering materials. Testing methods and interpretations of tests on mechanical properties of materials. Engineering properties of ferrous and nonferrous alloys. Laboratory experiments on properties, microstructure, fractography. Interdepartmental courses for engineering students.

MT 302　Metallurgy for Engineers　　　　2:0:2
Atomic, microscopic and macroscopic structures of engineering materials. Effects of grain size and boundaries, work hardening and heat treatment on behavior of solids. Discussions of corrosion, creep, fatigue, brittle and ductile fracture of metals, alloys and composites.

MT 303　Nature and Properties of Structural Materials　　　　　1:3:2
Physical and mechanical properties of concrete, metals, plastics and asphaltic materials related to structure. Experimental investigation of mechanical properties of select structural materials and physical properties of cement and concrete mixes. Jointly developed and taught by Civil and Metallurgy Departments.
Also listed under CE 303.

MT 304　Materials Science　　　　　　　2:3:3
Plastic behavior of single and polycrystalline materials. Deformation mechanisms. Effects of temperature and deformation on rate of plastic flow. Strain hardening. Dislocation theories. Fracture mechanics, toughness and crack propagation theories. Technical elective for aerospace, civil and mechanical engineering students

MT 305　Mechanical Properties of Materials　3:0:3
Structure-property relationships of engineering materials. Testing methods and interpretation of tests, mechanical properties of materials. Engineering properties of ferrous and non-ferrous alloys and non-metallic materials including polymers, ceramics, and composites. Strong emphasis is placed on engineering applications and case histories of product and component failures.

MT 340   Manufacturing Processes   **3:0:3**
Mechanical behavior of metals. Properties of materials relating to fabrication methods. Metal cutting mechanics, cutting fluids, thermal and vibrational aspects of machining. Machinability criteria. Deformation processing, hot and cold, mechanics of deformation. Unconventional processing: EDM and ECM. Numerical control. Metrology. Prerequisite: MT 301, MT 302, MT305.
Also listed under IE 340.

MT 375   Semiconductor Technology   **3:0:3**
Principal techniques involved in design and fabrication of semiconductor devices and integrated circuits, including material preparation, junction forming, circuit integration, packaging.
Also listed under EE 119.

MT 399   Senior Honors Work in Metallurgical
**   Engineering   credit to be arranged**
Independent work undertaken by qualified honors students in metallurgical engineering. Course materials arranged by faculty steering committee.

MT 420   Engineering Materials   **3:0:3**
Structures, properties and uses of polymers and metals as engineering materials. Crystal structures, defects, heat treatments, corrosion and its prevention. Manufacture and processing of polymers. Mechanical behavior of polymers and their thermal and electrical properties. Prerequisites: CM 161, CM 162, CM 123 and CM 124.
Also listed under CH 271.

GRADUATE COURSES

MT 540   Survey of Metallurgical Principles   **2½:0:3**
Crystal structures, alloying, phase diagrams, diffusion phenomena, mechanical deformation of metals and alloys, recrystallizations, age hardening. Prerequisite: instructor's consent.

MT 600   Structure-Property
**   Relationships in Materials**   **2½:0:3**
Dependence of properties, e.g., mechanical and electrical, on structure of materials. Crystalline vs. amorphous structure, occurrence and role of defects. Bonding and structure. Anisotropy of properties related to crystal symmetry. Polycrystal vs. single crystal vs. textured polycrystals. Prerequisite: MT 410 or equivalent.

MT 601-602   Special Topics in
**   Structure-Property**
**   Relationships I, II***   **each 2½:0:3**
Advanced or specialized topics in structure-property relationships in materials presented at irregular intervals. Prerequisite: MT 600.

MT 603   Introduction to Electron
**   Microscopy I**   **2½:0:3**
Resolving power. Lens aberrations. Properties of magnetic lenses. Designs of Transmission and Scanning Electron Microscopes, their applications and limitations. Real and Reciprocal lattices. Scattering of fast electrons by atoms. Theories of electron diffraction. Bragg Law. Ewald sphere construction.

MT 604   Introduction to Electron
**   Microscopy II**   **2:2:3**
Image formations. Fresnel half period zones. Kinematical theory of image formation. Column approximation. Images of perfect and imperfect crystals, stacking faults, dislocations, precipitates. Amplitude phase diagram and its applications. Breakdown of Kinematical theory. Introduction to dynamical theory of image formation. Specimen preparation techniques: thin foil, replicas. Uses of the Scanning and Transmission Electron Microscopes.

MT 610   Thermodynamics of Metals
**   and Alloys**   **2½:0:3**
Fundamentals of classical and statistical thermodynamics with emphases on solid states, phenomenology of metallic surfaces, phase equilibria in multicomponent metallic systems, calculations of phase diagrams, thermodynamics of lattice defects and substructure. Prerequisite: MT 405.

MT 611-612   Special Topics in Thermodynamics
**   and Statistical Mechanics of**
**   Metals, I, II***   **each 2½:0:3**
Advanced or specialized topics in thermodynamics and statistical mechanics of metals. Prerequisite: MT 610.

MT 620   Plastic Deformation and Fracture   **2½:0:3**
Classical concepts of slip related to dislocation theories of stress-strain behavior of single crystals. Mechanical twinning and its relationship to crystal structure. Theories of yielding, brittle and ductile fracture in polycrystalline materials. Prerequisite: MT 406.

MT 621-622   Special Topics in Deformation and
**   Fracture I, II***   **each 2½:0:3**
Advanced or specialized topics in deformation and fracture. Prerequisite: MT 620.

MT 630   Theories of Metals   **2½:0:3**
Quantum theory as applied to metals and alloys, theories of thermal properties of metals, theory of alloy phases, theories of electrical conductivity and magnetic properties of metals, influences of structural imperfections on properties of metals and alloys. Prerequisite: MT 410 or equivalent.

MT 631-632   Special Topics in Theory
**   of Metals I, II***   **each 2½:0:3**
Advanced or specialized topics in theories of metals. Prerequisite: MT 630.

MT 640   Reactions in Solids   **2½:0:3**
Mechanisms and kinetics of diffusion-controlled and diffusionless phase transformations in solid metallic systems; diffusion in multiphase, multicomponent metallic systems; theories of precipitation, of grain boundary migration and grain growth, of eutectoid transformation and of martensitic transformations. Prerequisite: MT 414.

MT 641-642   Special Topics in Reactions
**   in Solids I, II***   **each 1½:0:3**
Advanced or specialized topics in reactions in solids. Prerequisite: MT 640 or instructor's consent.

MT 650   Advanced Engineering Metallurgy   **2½:0:3**
Requirements for resistance to stress, oxidation and corrosion, and to structural instability in metals and alloys for low, normal, and high-temperature service, theories of high-temperature deformation and fracture, of alloy designs and designs of alloys for challenging environments. Prerequisite: MT 405.

MT 651-652   Special Topics in Advanced
**   Engineering Metallurgy I, II***   **each 2½:0:3**
Advanced or specialized topics in advanced engineering metallurgy presented at regular intervals. Prerequisite: MT 405.

MT 660   Ceramic Technology   **2½:0:3**
Chemistry, structure, and properties of ceramics and glasses. Emphasis on relation of microstructure to properties and control of microstructure via time-temperature as well as chemistry. Key engineering properties: strength, thermal resistance, dielectric behavior will be analyzed.

MT 700   Welding Metallurgy   **2½:0:3**
Analyses of process variables affecting joining techniques. Studies of arc characteristics, heat flow, gas-metal interactions, solidification mechanics, residual stress effects, distortion controls. Applications of solid-phase bondings, electron and laser welding. Weldability criteria for ferrous and non-ferrous alloys. Prerequisite: instructor's consent.

MT 706   Magnetism and Magnetic
**   Materials***   **2½:0:3**
Origin of magnetism in atoms and solids. Diamagnetic vs. paramagnetic behavior. Ferromagnetic domain theory. Antiferromagnetism and ferrimagnetism. Structure and properties of magnetic materials. Prerequisite: MT 410.

MT 707 Thin Film Technology 2½:0:3
Preparation, structure, evaluation and properties of thin films: metallic, semi-conductor and dielectric film techniques, nucleation and growth considerations, epitaxy, and metastable configurations. Prerequisite: instructor's consent.

MT 708 Semiconductor Materials and Devices 3:0:3
Nature of semiconductor materials, stressing interrelations among band structure, chemistry and microstructure of materials. Elemental, compound, amorphous and polymeric semiconductors. Examples of applications of materials for devices are given to illustrate how materials properties are matched to device characteristics for optimum performance.

MT 709 Integrated Circuit (VLSI) Fabrication Techniques 3:0:3
Study of process technology used to produce integrated circuits. Silicon technology: bipolar, MOS, and VLSI processes. Process requirements defined in terms of circuit structure, i.e., concentration profiles and topographical layout as defined by mask set previously determined. Steps from crystal growth through diffusion, ion implantation, oxidation, photolithography, metallization, interconnection, and packaging to final test are analyzed. The impact of process on design rules are pointed out.
Also listed under EL 646.

MT 710 Powder Metallurgy 2½:0:3
Theoretical and practical aspects of powder metallurgy. Production of metal parts from powder, review of commercial applications. Theories of metal synthesis, compacting, consolidation and sintering. Important patents and commercial processes. Colloquia. Prerequisite: instructor's consent.

MT 714 Electrochemical Processes 2½:0:3
A presentation of the fundamentals of electro-chemical reactions, focussing on those aspects which have application to metals and semiconductors. Electrode reactions; kinetics of electrode processes; theory and applications of chemical etching; corrosion of metals and alloys; electro-solution and deposition.

MT 715 Corrosion and Oxidation Mechanisms in Metals 2½:0:3
Electrochemical principles applied to corrosion. Analysis of corrosion mechanisms. Studies of preventive methods. Effects of temperature, environmental and metallurgical factors. High-temperature oxidation and metal-gas interactions. Testing and analysis of cathodic protection, water treatment, cathodic and anodic coatings. Prerequisite: MT 405 or instructor's consent.

MT 720 Advances in Materials Analyses and Characterizations 2½:0:3
Characterization of microstructure, defects, dopants and impurities, composition profiles. What to use when and why. Hands on uses of selected equipment. Applications discussed based on interest of students.

MT 725 Noble Metal Metallurgy 2½:0:3
Crystal structures and phase equilibria for noble metal alloy systems. Mechanical, electrical, magnetic and optical properties for various alloy systems. Criteria for corrosion and tarnish resistance. Fabrication, joining and application of mobile metal alloys. Prerequisite: instructor's consent.

MT 726 Metallurgy of Nuclear Reactor Materials 2½:0:3
Material requirements for basic parts of nuclear reactors. Metallurgy of fuels, moderator, control and construction materials. Descriptions of handling and fabricating techniques. Prerequisite: instructor's consent.

MT 727 Bioengineering Metallurgy* 2½:0:3
Selection and application of metals and alloys for uses in body environments. The body as a corrosive environment. Examination of major problem areas. Principles and techniques for preparation of dental amalgams and other alloys. Design of alloys for bioengineering applications. Prerequisite: instructor's consent.
Also listed under BE 741.

MT 760-761 Seminar in Metallurgical Engineering each 0:2½:1½
Recent progress in metallurgical engineering addressed in lectures by engineers from industry, research and educational institutions. One or more seminar topics from current literature in metallurgical fields assigned each student for presentation. Students expected to read each assigned topic and to be conversant with topics presented. (Attendance required for two semesters. Part-time students may substitute a three-unit metallurgy course.)

MT 762 Seminar in Metallurgical Engineering 0:2½:0
Preparation and presentation by students of seminars on topics of metallurgical engineering, in which students critically review technical papers selected by students with approval of faculty advisers. For students enrolled in metallurgical engineering degree programs.

MT 763-764 Seminar in Metallurgy and Materials Science each 0:2:½
Preparation and presentation by students of seminars on topics of physical metallurgy, metallurgical engineering, or materials science in which students critically review technical papers selected by students with approval of faculty advisers. For students enrolled in doctoral programs.

MT 788 Case Studies in Electronics Manufacturing 2½:0:3
Contemporary techniques for product design and manufacturing. Topics include robust design of product and processes using orthogonal array techniques, simulation, partitioning and scale-up JIT/TQC, "pull" and flexible manufacturing processes. Financial and other performance metrics pertinent to these new processes will be given. Corporate cultural changes necessary to effect their successful introduction will be discussed. Applications will be illustrated by case studies of successes and anatomy of disasters drawn from a wide variety of design and manufacturing situations.

MT 935 Engineering Projects Related to Public Administration each 3 units
See Cooperative Program with New York University's Graduate School of Public Administration for details.

MT 996 Report Project for the Degree of Master of Science 3-6 units
Independent project demonstrating professional maturity and graduate-level knowledge completed under guidance of departmental advisers. Reports include critical analysis and interpretation of pertinent literature and should represent worthwhile contributions to the field. Oral final examinations and project reports required.

MT 997 Thesis for the Degree of Master of Science 9-12 units
An original topic of research for the master's degree is decided upon by student and faculty advisor. Close contact is to be maintained between student and faculty advisor during the thesis investigation. After the thesis is written up and approved the student is required to defend his thesis during an oral examination.

MT 998 Project for the Engineer Degree 3-6 units
Engineering project at post-master's level pursued with guidance of faculty members. Candidates required to take oral examination on subject matter of project and on related topics.

**MT 999   Dissertation for the Degree of
Doctor of Philosophy   3-6 units**
Dissertation presents results of original research in physical metallurgy. Work must demonstrate originality and creativity and be worthy of publication in recognized scientific journals. Candidates must take oral examinations on thesis subject and related topics. Minimum of 35 units required.

FACULTY

George J. Fischer, Professor of Metallurgy and Head of Metallurgy and Materials Science
B.Met.E., M.Met.E., Polytechnic Institute of Brooklyn
Corrosion and welding metallurgy

Irving B. Cadoff, Professor of Materials Science
B.M.E., C.C.N.Y., M.M.E., D.Eng.Sc., New York University
Electronic materials; liquid metal embrittlement; thin film epitaxy

Louis S. Castleman, Professor of Metallurgy
S.B., Sc.D., Massachusetts Institute of Technology
Diffusion in solids, biomaterials

Carmine D'Antonio, Professor of Metallurgy
B.Met.E., M.Met.E., Polytechnic Institute of Brooklyn
Mechanical properties; thin films; failure analysis

Harold Margolin, Professor of Metallurgy
B.Eng., M.Eng., D.Eng., Yale University
Plastic deformation and fracture; titanium metallurgy; fatigue of metals and alloys

Sung H. Whang, Associate Professor of Metallurgy
B.S., Seoul National University (Korea); M.S., D.Eng.Sc., Columbia University
Alloy phase stability; rapid solidification processing; superconducting materials processing; deformation in ordered intermetallic materials

Said Nourbakhsh, Assistant Professor of Metallurgy
B.S., Arya-Mehr University of Technology (Iran), Ph.D., Leeds University (England)
Phase transformation, electron microscopy and mechanical behavior

ADJUNCT FACULTY

Simon Strauss, Distinguished Visiting Professor of Metallurgy and Fellow of the Polytechnic

Paul Cascone, Adjunct Professor of Metallurgy
B.E., New York University; M.S., Rutgers University

Davendra Gupta, Adjunct Professor of Metallurgy
B.Sc., Delhi University (India); B.Sc., Banaras Hindu University (India); M.S., N.Y.U.; Ph.D., University of Illinois

Henry Hausner, Adjunct Professor of Metallurgy
E.E., Dr.Eng., Technical University (Vienna, Austria)

Ernest Levine, Adjunct Professor of Metallurgy
B.Met.E., Rensselaer Polytechnic; Ph.D., N.Y.U.

James Lloyd, Adjunct Professor of Metallurgy
B.S., M.S., Ph.D., Stevens Institute of Technology

Robert Rosenberg, Adjunct Professor of Metallurgy
B.S., Drexel University; M.S., Ph.D., N.Y.U.

Sankar Sastri, Adjunct Professor of Metallurgy
B.S., Indian Institute of Science (India); M.S., Columbia University; Ph.D., Polytechnic Institute of New York

Anthony Vecchio, Adjunct Professor of Metallurgy
M.Met.E., Polytechnic Institute of Brooklyn

EMERITUS FACULTY

John Nielsen, Professor Emeritus of Metallurgy
M.E., Ph.D., Yale University
Precious metals and alloys, grain growth and recrystallizations, dental materials

MILITARY SCIENCE

The department of military science administers the Reserve Officer Training Corps program and provides college-trained officers for the United States Army, the National Guard and the United States Army Reserve. Best explained in the words of Dr. Lee S. Dreyfus: "The Reserve Officers Training Corps is not the presence of the military in the university, but rather the presence of the university in the military".

Through the Department of Military Science the United States Army gains officers with excellent educational backgrounds and contemporary ideas. Military science graduates have the chance to use their ideas in positions of leadership and enable the Army to remain aligned with our ever-changing society.

Military science enhances a student's education by providing unique leadership and management experience found in few college courses. It helps develop self-discipline, physical stamina and poise. Students develop qualities basic to success in any worthwhile career. They earn commissions as officers in the United States Army while earning their college degrees. As commissioned officers they serve on active duty or as citizen soldiers in the Reserve Forces upon graduation. ROTC graduates provide critical leadership to the U.S. Army, government and industry.

OFFICER EDUCATION PROGRAM

THE FOUR-YEAR PROGRAM

The four-year military science program is divided into two parts—the Basic Course and the Advanced Course.

Basic Course—The Basic Course is usually taken in the freshman and sophomore years. No military commitment is incurred during this time, and students may withdraw at any time through the end of their second year. (Except scholarship contracted students.) Subjects cover the following areas: first aid, national defense, drill and ceremonies, physical conditioning, map reading, survival techniques, tactics, basic rifle marksmanship and leadership development.

Various social and professional enrichment activities are available in conjunction with the military science program. Necessary textbooks and materials are furnished without cost. Students who participate in the Basic Course are excused from physical education requirements.

All students in the Basic Course are organized into the cadet student battalion. Some Saturday or weekend training is included in the coursework. Uniforms may be issued to Basic Course students who are active in military science program, but uniform wear is not mandatory.

Advanced Course—The Advanced Course is normally taken in the final two years of college. Instruction includes further leadership development, organization and management techniques, basic military hands-on skills, tactics, administration, military history and the military justice system. These subjects are taught in the classroom, in laboratories and during field training exercises. A paid six-

week advanced camp is held during the summer between the junior and senior years. This camp permits the cadets to put into practice the principles and theories they have acquired in the classroom. It also exposes them to the conditions of Army life in a tactical and field environment.

All cadets in the Advanced Course receive uniforms, necessary military science textbooks and pay for Advanced Camp. Contracted U.S. citizens also receive a living allowance each school year.

To be selected for the Advanced Course, a student must:

1. Be a citizen of the United States. Permanent residents may participate in the Advanced Course and may possibly obtain a commission once they obtain U.S. citizenship.

2. Qualify for appointment as a second lieutenant prior to reaching 30 years of age.

3. Be approved by the Professor of Military Science.

4. Successfully pass a prescribed medical examination.

5. Successfully pass an educational level examination and a leadership assessment program.

6. Have successfully completed the two-year Basic Course or its equivalent. Minimum Basic Course requirements consist of successful completion of MS 101, 102, 201 and 202.

7. Sign a contract with the U.S. Army agreeing to pursue the standards required for Commissioning.

THE TWO-YEAR PROGRAM

The two-year program is designed for undergraduate and graduate students who have not taken the Basic Course and have two years remaining in school. Students can take advantage of this opportunity by successfully completing a paid, six-week basic camp offered at Fort Knox, Kentucky, during the summer. Students may then enroll in the Advanced Course in their last two years, provided they otherwise meet enrollment requirements.

OBLIGATIONS

Cadets must successfully meet ROTC standards. Upon commissioning, students may fulfill their contract obligations by either serving on active duty or by becoming a member of a local United States Army Reserve or National Guard unit.

Based upon the current manning requirements, approximately two thirds of those students requesting active duty are selected for active duty. Therefore competition for these slots is intense. For students interested in remaining in the local area and pursuing a civilian career, Reserve Forces duty would be their choice. This consists of one weekend drill per month and a two-week period of active duty each summer. Qualified students may be guaranteed Reserve Forces duty prior to committing themselves to the

Advanced Course by electing to sign a guaranteed Reserve Forces duty contract.

The Professor of Military Science may designate outstanding cadets as Distinguished Military Graduates. Students so designated may apply for a commission in the Regular Army of the United States.

MILITARY SCIENCE SCHOLARSHIPS

The Department of Military Science offers two-, three- and four-year scholarships. The four-year scholarships are awarded on a worldwide competitive basis to U.S. citizens who will be entering college as freshmen. The two- and three-year scholarships are awarded competitively to students who are enrolled in college and are academically aligned with military science.

Students who attend the Basic Camp of the two-year program may also compete for two-year scholarships.

All scholarships pay for tuition, a stipend for textbooks, lab fees, plus a living allowance each year the scholarship is in effect.

REQUIREMENTS FOR COMMISSIONING

1. Completion of the Basic Course or Equivalent

2. Completion of the Advanced Course
   a. MS 301, 302, 303 (or approved history course determined by the Department Head), 304.
   b. MS 401, 402, 403
   c. Advanced Camp
   d. Meet Army Physical Fitness Standards
   e. For Scholarship Students—One semester of a Foreign Language

CREDITS TOWARD POLYTECHNIC DEGREES

BASIC COURSE

Students enrolled in any of the Basic Course courses (MS 101, 102, 201, or 202) may substitute these courses for the mandatory physical education requirements.

ADVANCED COURSE

The number of military science credits which are applicable toward Polytechnic degrees depends upon the student's academic major and upon which courses the student chooses to replace with MS courses.

A student may substitute up to six credits from the four two-credit courses (MS 301, 303, 401 or 403) for free/technical electives as authorized by the individual departments.

PROFESSIONAL ACTIVITIES

The military science program offers a variety of social and professional activities:

Scabbard and Blade is the national military honor society, whose local chapter is active in service to the Military Science Department and to Polytechnic. An annual military ball is sponsored by the local chapter.

The Pershing Rifles promotes military ideals as exemplified by General John J. Pershing. The local chapter is active in drill and ceremonies, military training and in organizing ceremonial color-guards.

The Society of American Military Engineers promotes the national engineering potential for defense. The local student chapter is active in guest presentations in military and civilian engineering.

The National Association of Rigorous Training Units (Sappers) offers instruction in adventure training, such as mountaineering, rappelling, orienteering and tactics.

HOW TO ENROLL IN MILITARY SCIENCE (ROTC)

Students interested in the two-year program should contact the department early in their sophomore year for application deadlines. If students have any questions concerning the military science program, they should telephone (718) 260-3150. Students should visit the Department of Military Science during the registration period so that the desired course can be integrated with normal registration procedures.

BASIC COURSE

MS 101 Introduction to Military Science I   1:1:0
History and organization of the Reserve Officer Training Corps; organization and purpose of the United States defense establishment; the roles of key government organizations and officials in defense matters. Introduction to physical fitness training and planning, land navigation, and basic rifle marksmanship. The course also includes several lab periods or field trips which allow for application of skills taught. Extra credit field training exercises are available.

MS 102 Introduction to Military Science II   1:1:0
Development of self-confidence in students, as well as skills necessary to navigate using a map and compass, and continued development of physical fitness. First aid measures consisting of basic lifesaving steps are included in this course. Extra credit field training exercises are available. Prerequisite: MS 101 or permission of department head.

MS 201 Military Skills I   1:1:0
Basic skills associated with small unit leaders; tactics and communications skills; theoretical and practical applications of military marksmanship; basic marksmanship including the firing of the M16 rifle during an off campus field trip. Oral and written communication techniques and skills required of successful leaders. Students are required to participate in practical exercises which apply all military skills from previous classes and several labs. Extra credit field training exercises are available. Prerequisite: MS 101 and 102 or permission of department head.

MS 202   Military Skills II   **1:1:0**
This course is a continuation of MS 201. A large portion is devoted to the study of leadership on an individual level. Principles and traits of leadership, human behavior and psychology, command, discipline, decision making, the leadership assessment program, and how to prepare to conduct performance-oriented training. The course also includes a field trip which applies all military skills and several laboratories previously taught. Extra credit field training exercises are available. Prerequisite: MS 201 or permission of the department head.

ADVANCED COURSE

MS 301   Leadership and Management Techniques   2:0:2 or
nc as arranged
Theory and techniques used by successful leaders and managers are taught. Within the management portion of the course, problem analysis, decision-making, planning, organizing, delegation and control are developed and applied within context of realistic situations. Within the leadership portion, the interpersonal skills needed to lead and work with others are developed and practiced by individuals in small group practical exercises. Prerequisite: Completion of the Basic Course or its equivalent and permission of the department head.

MS 302   Leadership Skills I   **2:2:0**
Soldier skills, physical capabilities and high motivational attitudes required to meet demands of today's modern army officers. Cadets receive hands-on instruction on military equipment and practical work experience emphasizing their roles as group leaders. Students work as a team, building individual confidence as well as team reliance. A six-week leadership camp follows this course during the summer months. Students are required to attend various field training exercises to reinforce classroom training and to meet standards in land navigation and physical training. Prerequisite: enrollment in MS 301.

MS 303   American Military History   2:1:2 or nc as arranged
Interrelationship between the American military establishment and American society: development of the American military system; study of American wars — their causes, conduct and results; study of selected campaigns and battles; role of technology in evolution of tactics and strategy. This course includes a one-day trip to a local battlesite. Prerequisite: none.

MS 304   Leadership Skills II   **2:2:0**
This course is a continuation of MS 302. Students are required to attend various field training exercises to reinforce classroom training, plus a five-day training session conducted prior to Advanced Camp. Students must meet standards in required military skills to attend Advanced Camp. Prerequisite: MS 302.

Advanced Summer Camp   **nc**
All candidates for commission through military science are required to successfully complete advanced camp, held at Fort Bragg, North Carolina. Stresses leadership and command responsibility, implemented by a command rotation system that places each student in varying positions of authority during the course of the normal military training and field operations. Emphasis on weapons training and field operations. Camp lasts six weeks and normally is attended between the third and fourth years of college. Students receive travel expenses and pay while at camp. Prerequisites: MS 301, 302 and 304.

MS 401   Military Law, Ethics and Professionalism   2:0:2 or
nc as arranged
The military justice system to include jurisdiction, military crimes and rights of individuals, as well as the non-judicial and judicial options available to maintain discipline in the Army are examined. Ethics and professionalism in the military environment are discussed. Ethical reasoning and decision-making processes are developed and utilized in relation to case studies. Prerequisite: Permission of the department head.

MS 402   Applied Leadership   **2:2:0**
Leadership skills necessary for cadet officers to function in areas such as formal classroom instruction, planning and conducting field training exercises, and administration of the cadet battalion are stressed. The course is structured to permit formal instruction followed by a laboratory each week for practical application. Students are required to attend various field training exercises to reinforce classroom training. Prerequisite: MS IV cadet standing.

MS 403   Pre-Commissioning Seminar
2:2:2 or
nc as arranged
Prepares senior cadets for commissioning as second lieutenants in the U.S. Army. Studies include effective communication emphasizing military correspondence and staff writing, interpersonal relations, personnel management, career planning, Army logistics and administration; duties of the junior officer. Students are required to attend various field training exercises to reinforce classroom training. Prerequisite: MS IV cadet standing, permission of the department head.

FACULTY

LTC Thomas A. Henderson, Professor of Military Science
B.S. U.S. Military Academy; M.S. at George Washington University

MAJ Paul W. Bugge, Assistant Professor of Military Science
B.S. Bethany College

CPT Dale A. Fye, Assistant Professor of Military Science
B.S. U.S. Military Academy

CPT John W. Tarver, Assistant Professor of Military Science
B.A. Hardin-Baylor

CPT Douglas L. Weiser, Assistant Professor of Military Science
B.A. University of Toledo

CPT Ralph S. Zellem, Assistant Professor of Military Science
B.S., St. John's University; M.B.A., Central Michigan University

SGM Morgan Highsmith, Detachment SGM, Chief NCO Instructor

MSG William B. Tate, Operations NCO, Instructor

SSG Edgardo Jimenez, Supply NCO, Instructor

SSG David M. Lange, Administrative NCO, Instructor

OPERATIONS MANAGEMENT

The master's degree program in operations management addresses the productivity needs of manufacturing and service operations. It is a unique 36 unit curriculum that requires the student to view the productivity of the organization from financial, engineering, marketing, and production perspectives. The MSOM graduate is equipped with a working knowledge of quantitative methods that can enhance decision-making effectiveness in the areas of project planning, resource allocation, inventory management, workforce management, and quality control — with the area of workforce management further supported by coursework in the behavioral science and organizational theory domains.

In addition to their prevalence in manufacturing industries, operations managers are found in health care organizations, financial institutions, insurance companies, mass transit systems, hotels, distribution outlets, etc.; and, often having the title of "vice-president of operations".

This interdisciplinary program is administered by the Division of Management, and is built on Polytechnic's recognized strengths in management and industrial engineering. Through the choice of three electives within the major, the student may tailor a program of study that will focus on his or her specific professional needs.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE

To be eligible for admission into this program, applicants must hold a baccalaureate degree or its equivalent from an accredited institution. This degree may be in any area except industrial engineering. The applicant is expected to have adequate preparation in mathematics, computer usage, and English composition. Deficiencies in these subject areas can be relieved by the taking of appropriate math, computer (MG 502 or IE 501), and report writing (HU 605) courses at Polytechnic. Such courses would be in addition to the degree requirements appearing below.

			Units
A. Basic required courses*			12
MA	551	Applied Statistics I(Data Analysis)	
IE	600	Engineering Economy	
IE	606	Work Design and Measurement	
MG	504	Managerial Accounting	
MG	600	Management Process	
B. Required courses			15
MG	601	Organizational Behavior	
MG	630**	Operations Management	
MG	810	Project Planning and Control	
MG	645	Productivity Management	
IE	611	Statistical Quality Control	
C. Major electives (Choose Three)***			9
MG	608	Managerial Economics	
IE	776	Manufacturing Resource Planning	
IE	777	Manufacturing Improvement Curves	
MG	607	Marketing Management	
MG	850	Cost Systems	
IE	765	Human Factors in Engineering Design	
IE	775	Industrial Safety Engineering	
SS	920	Proseminar in Psychology	
SS	926	Environmental Psychology	
MG	624	Organization Development	

Total: 36

FACULTY

This interdisciplinary program is administered by the Division of Management. The faculties of industrial engineering, computer science, social sciences and mathematics participate in delivering this program.

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*All group A courses are required unless they are specifically waived by advisers because students either (a) have taken equivalent undergraduate or graduate courses, or (b) pass validation examinations for these courses Up to four group A courses actually taken may be credited toward degree requirements; if more than four must be taken, degree requirements are increased accordingly.

**May substitute IE 619 (prerequisite IE 627)
***Only one of each bracketed set of courses are counted in the group in which it is listed.

OPERATIONS RESEARCH

The Department of Mechanical and Industrial Engineering offer programs in operations research at the bachelor's, master's and doctoral levels.

Operations research is concerned with the development and application of advanced analytical techniques to the operation of complex systems and the optimal allocation of resources. The last few decades have witnessed increasing use of mathematical models in nearly all fields. Trained professionals are needed who can play important roles in the development of quantitative models and solution techniques for challenging problems.

Operations researchers address problems in production, distribution and marketing, allocation of urban resources, industrial and government operations and economic theory. They deal with analysis, design and utilization of modern large-scale systems, ranging from completely automated processing plants through urban systems—transportation, justice and health care, for example—to managerial systems composed solely of human beings. They concern themselves with those areas in which the systems approach, engineering knowledge, and analytical techniques are applied directly to the most urgent problems of society.

Operations research is a rapidly developing professional field with opportunities in many diverse areas. For example, practitioners are called on to:
- Analyze and plan production schedules and inventories
- Devise ways of maximizing the effectiveness of hospitals and other health care facilities
- Study the feasibility of equipment replacement
- Evaluate proposed traffic control procedures
- Locate new plants and design their physical layout
- Measure the effectiveness of advertising and marketing policies
- Evaluate effectiveness of urban solid waste collection and removal systems
- Develop computer simulations of man-machine systems
- Study the effects of feedback and automation in society and industry

Operations researchers seek to allocate limited resources in an optimal manner. A unifying theme focusing this body of knowledge and methods into a coherent entity is the system point of view. The search for similarity among concepts, laws and models of different disciplines, the emphasis on the adaptation, integration and exploitation of existing techniques in areas other than their fields of origin, and, above all, a unique point of view dealing with relationships rather than with components—these characterize this orientation.

LABORATORIES AND COMPUTING FACILITIES

The department operates laboratories in the areas of work design and measurements, human factors, plant layout, robotics, automation, and noise measurement; these laboratories have the latest equipment, including numerically controlled lathes and a Fischerteck automated production line model. Besides direct experimentation, students engage in simulated experimentation and decision making using a broad range of computers.

In addition to the computing facilities described elsewhere in this catalog, the department maintains its own bank of IBM and compatible microcomputers and graphic workstations, as well as direct access and UNIX terminals connecting with the Polytechnic IBM 4341 and DEC-11 computers. Students use existing software packages or may write their own.

UNDERGRADUATE PROGRAM

The undergraduate program leads to the degree of bachelor of science in operations research.

It requires 128 credit hours of work, including mathematics, chemistry, physics, humanities, social science, required departmental courses, and technical and free electives. The humanities, technical and free electives permit an extremely flexible program of study in which the student has the opportunity to pursue individual interests which build on the core requirements. Some possible elective sequences are listed after the curricula; these are mere suggestions, not required sequences of study.

Students entering this field should normally be prepared to continue studies beyond the bachelor's level. Accordingly, undergraduate training places heavy emphasis on mathematics and the basic physical and social sciences necessary for graduate study in this area.

Computer Science Option

Operations research is affected by the availability and use of computers, perhaps even more so than most other scientific and engineering disciplines. Hence the department, in cooperation with the Computer Science Division, has developed a computer science option in the operations research program. This option comprises virtually a dual major in operations research and computer science. The two fields complement each other most advantageously and, therefore, give students particularly effective preparation for professional careers.

Graduate Courses
Qualified juniors and seniors with at least a B average, may take graduate courses as electives, if they obtain their adviser's approval. If the total number of credits exceeds those required for the bachelor's degree, these graduate credits may be credited toward a graduate degree in accordance with current policy, if the student is admitted to graduate study.

TRANSFER STUDENTS

Transfer students who have completed two years of study at a college of liberal arts and science or a community college may ordinarily complete the requirements for the bachelor's degree in two additional years of study. Assuming that they have completed 64 credits equivalent to MA 101-104, PH 104-106, PH 115-116, CM 101-102, CM 111-112, CS 112, HU 200, SS 104, SS 251, plus 19 credits of acceptable electives, students can complete the requirements shown on page 233.

EVENING STUDY

Many of the courses for the operations research program are available in the evening or late afternoon for the convenience of part-time students. Part-time students usually can finish the program in eight years, without summer work, by averaging eight credits per semester. Students can, however, change their pace readily to suit their educational needs, provided they do not violate prerequisites and Polytechnic time limts.

REQUIREMENTS FOR THE DEGREE BACHELOR OF SCIENCE IN OPERATIONS RESEARCH

		Credits
Mathematics	MA 101, MA 102, MA 103, MA 104, MA 153, MA 223, MA 224, MA 555	26
Science	CM 101, CM 102, CM 111, CM 112, CS 112[1], PH 104, PH 105, PH 106, PH 115, PH 116	19
Humanities	HU 101, HU 200,[1], SS 104,[1], SS 251	12
Physical Ed[3]	PE 101, PE 102, PE 103, PE 104	0
Major	IE 254[1], IE 300, IE 319, IE 327, IE 328, IE 346, IE 380	21
Electives[2]	Chosen by the student in consultation with department adviser	50
	Total	128

REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE IN OPERATIONS RESEARCH (Computer Science Option)

		Credits
Mathematics	MA 101, MA 102, MA 103, MA 104, MA 153, MA 223, MA 224	23
Science	CM 101, CM 102, CM 111, CM 112, EE 377, PH 104, PH 105, PH 106, PH 115, PH 116	19
Humanities	HU 101, HU 110, HU 200[1], LA 143, SS 104[1], SS 251	18
Physical Ed[2]	PE 101, PE 102, PE 103, PE 104	0
Industrial Engrg	IE 254[1], IE 300, IE 319, IE 327, IE 328, IE 346, IE 380	21
Computer Science	CS 112, CS 204, CS 205, CS 212, CS 236, CS 238, CS 296, CS 297, CS 337	26
Electives	6 credits Industrial Engineering, 12 credits Humanities/Social Science, 3 credits free	21
	Total	128

See next page for notes.

Typical Course of Study for the Degree of
Bachelor of Science in Operations Research

A typical program sequence covering eight semesters is shown below. Students may rearrange courses and increase or decrease loads per semester to suit their educational needs, provided prerequisites are not violated.

In particular, the actual number of electives and total credits in any given semester will vary by one or two credits because most electives are three credits.

Freshman Year

No.		First Semester Subject	Cl.	Lab.	Cr.
CM	101	General Chemistry I	2½	0	2½
CM	111	General Chemistry Lab I	0	1½	½
CS	112	Programming in Pascal[1]	3	0	3
HU	101	Writing & the Humanities I	3	0	3
MA	101	Calculus I	4	0	4
SS	104	Contemporary World History	3	0	3
SL	101	Student Survival	0	1	0
PE	101	Physical Education I[3]	0	2	0
					16

No.		Second Semester Subject	Cl.	Lab.	Cr.
CM	102	General Chemistry II	2½	0	2½
CM	112	General Chemistry Lab. II	0	1½	½
HU	200	Writing & the Humanities II[1]	3	0	3
MA	102	Calculus II	4	0	4
PH	104	Introductory Physics I	3	0	3
PE	102	Physical Education II[3]	0	2	0
		Electives[2]			3
					16

Sophomore Year

No.		Subject	Cl.	Lab.	Cr.
IE	254	Intro. to Industrial Engrg.[1]	3	0	3
MA	104	Appl. Differential Eqns.	3	0	3
PH	105	Introductory Physics II	3½	0	3½
PH	115	Physics Laboratory I	0	1½	½
SS	251	Microeconomics	3	0	3
PE	103	Physical Education III[3]	0	2	0
		Electives[2]			3
					16

No.		Subject	Cl.	Lab.	Cr.
MA	103	Calculus III	3	0	3
MA	153	Elem. of Linear Algebra	3	0	3
PH	106	Introductory Physics III	2½	0	2½
PH	116	Physics Laboratory II	0	1½	½
PE	104	Physical Education IV[3]	0	2	0
		Electives[2]			7
					16

Junior Year

No.		Subject	Cl.	Lab.	Cr.
IE	327	Operations Research I	3	0	3
MA	223	Intro. to Probability	3	0	3
		Electives[2]			10
					16

No.		Subject	Cl.	Lab.	Cr.
IE	300	Engineering Economy	3	0	3
IE	328	Operations Research II	3	0	3
MA	224	Intro. to Math. Statistics	3	0	3
		Electives[2]			7
					16

Senior Year

No.		Subject	Cl.	Lab.	Cr.
IE	319	Prodctn. Planng. & Control	3	0	3
IE	380	System Simulation	3	0	3
MA	555	Design of Experiments	3	0	3
		Electives[2]			7
					16

No.		Subject	Cl.	Lab.	Cr.
IE	346	Oper. Des. of Public Syst.	3	0	3
		Electives[2]			13
					16

Total credits required for graduation: 128

[1]Students may substitute IS 140, IS 141 for HU 200, SS 104.
Students may substitute CS 100 for CS 112, and make up the missing credit with an additional credit of technical elective. This substitution is not recommended for students who expect to take additional CS courses; students who have taken a course in a high-level language (e.g., Pascal, FORTRAN, PL/1, BASIC) may apply to their adviser for permission to substitute 3 credits of technical elective.
If scheduling of transfer students necessitates taking principal IE courses before IE 254 can be taken, then an approved IE elective may be substituted for IE 254.

[2]The 50 credits of electives are to be distributed as follows:
    12 credits of operations research and industrial engineering.
    11 credits of technical electives: engineering or science or math.
    18 credits of humanities and social science.
    9 credits of free electives: normally any course that does not duplicate others.

[3]ROTC freshman and sophomores may substitute zero-credit military science courses for PE 101-104 (physical education); juniors and seniors may substitute three of the following two-credit courses: MS 301, 303, 401 or 403, for six credits of technical electives.

Typical Course of Study for Transfer Students

Junior Year

First Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
IE	254	Intro. to Industrial Engrg.[1]	3	0	3
IE	327	Operations Research I	3	0	3
MA	223	Intro. to Probability	3	0	3
		Electives[2]			7
					16

Second Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
IE	300	Engineering Economy	3	0	3
IE	328	Operations Research II	3	0	3
MA	153	Elem. of Linear Algebra	3	0	3
MA	224	Intro. to Math. Statistics	3	0	3
		Electives[2]			4
					16

Senior Year

IE	319	Prodctn. Planng. & Control	3	0	3
IE	380	System Simulation	3	0	3
MA	555	Design of Experiments	3	0	3
		Electives[2]			7
					16

IE	346	Oper. Des. of Public Syst.	3	0	3
		Electives[2]	0	0	13
					16

Total credits required for graduation: 128

Footnotes See previous page.

SUGGESTED ELECTIVE SEQUENCES

Students often seek guidance in using permitted electives to develop meaningful sequences for concentration. Some suggested groupings are shown below from which students may select electives. Courses numbered 600 or above are graduate courses requiring a B or better average and the adviser's special permission. Since these suggestions are addressed to both industrial engineering and operations research students, some of the electives may duplicate required courses. These are merely suggestions, not required sequences of study.

Behavioral Science
SS 175 Introduction to Sociology
SS 185 Anthropology: Physical
SS 189 Introduction to Psychology
SS 191 Social Psychology
SS 192 Experimental Psychology I
SS 193 Experimental Psychology II
SS 198 Psychology of Human Development
SS 199 Organizational Behavior

Computer Science
CS 204 Data Structures & Algorithms
CS 205 Assembly & Machine Languages
CS 212 Software Development
CS 236 Switching Digital Syst.
CS 238 Operating Systems
CS 337 Computer Architecture & Organization

Control Systems
EE 101 Electrical Circuits I
EE 102 Electrical Circuits II
EE 103 Signals & Transforms
EE 104 Feedback System Principles
EE 107 Control System Design

Economics
SS 255 The Contemporary Amer. Economy
SS 257 History of Economic Thought
SS 258 Comparative Economic Systems
SS 259 Economic Development
SS 263 Labor Economics
SS 264 Urban Economics
SS 265 Money and Banking

Management
MG 300 Management Process
MG 304 Accounting Fundamentals
MG 606 Managerial Finance
MG 607 Marketing Management
MG 612 Human Resources Management
MG 664 Management and the Legal System
SS 199 Organizational Behavior

Mathematics, Applied
MA 153 Elements of Linear Algebra
MA 154 Elements of Abstract Algebra
MA 201 Applied Analysis I
MA 202 Applied Analysis II
MA 217 Complex Variables
MA 333 Partial Differential Equations
MA 358 Introductory Numerical Analysis

Operations Research, Advanced
MA 153 Elements of Linear Algebra
IE 618 Inventory Models
IE 631 Linear Programming
IE 632 Nonlinear Programming
IE 650 Queuing Systems I

Statistics and Probability
IE 311 Statistical Quality Control
MA 232 Statistical Methods II
MA 238 Applied Probability
MA 554 Applied Decision Theory
MA 556 Correlation & Multivariate Models
MA 557 Sampling
IE 852 Regression & Analysis of Variance
IE 853 Design of Experiments

Transportation Systems
IE 350 Logistics
TR 360 Traffic Planning & Operations
TR 362 Public Transportation

Urban Systems
IE 346 Oper. Design of Urban Systems
LS 140 Environmental Biology
SS 180 Sociology of Urbanization
SS 190 Environmental Psychology
SS 264 Urban Economics
TR 600 Char. of Transp. Demand & Syst.
TR 602 Urban Transportation Planning

Typical Course of Study for the Degree of Bachelor of Science in Operations Research (Computer Science Option)

A typical program sequence covering eight semesters is shown below. Students may rearrange courses and increase or decrease loads per semester to suit their educational needs, provided prerequisites are not violated.

In particular, the actual number of electives and total credits in any given semester will vary by one or two credits because most electives are three credits.

Freshman Year

First Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
CM	101	General Chemistry I	2½	0	2½
CM	111	General Chem Lab I	0	1½	½
CS	112	Programming in Pascal	3	0	3
HU	101	Writing & the Humanities I	3	0	3
MA	101	Calculus I	4	0	4
SL	101	Student Survival	0	1	0
SS	104[1]	Contemporary World History	3	0	3
PE	101[3]	Physical Education I	0	2	0
					16

Second Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr
CM	102	General Chemistry II	2½	0	2½
CM	112	General Chem Lab II	0	1½	½
CS	204	Data Structures and Algorithms	3	0	3
HU	200[1]	Writing & the Humanities II	3	0	3
MA	102	Calculus II	4	0	4
PH	104	Introductory Physics I	3½	0	3
PE	102[3]	Physical Education II	0	2	0
					16

Sophomore Year

CS	236	Switching and Digital Systems	3	0	3
HU	110	Basic Report Writing I	3	0	3
IE	254[1]	Intro. to Industrial Engrg.	3	0	3
MA	104	Appl. Differential Eqns.	3	0	3
PH	105	Introductory Physics II	3½	0	3½
PH	115	Physics Laboratory I	0	1½	½
PE	103[3]	Physical Education III	0	2	0
					16

CS	205	Assembly and Machine Lang.	3	0	3
EE	377	Introduction to Electronics	2½	1½	3
MA	103	Calculus III	3	0	3
MA	153	Elem. of Linear Algebra	3	0	3
PH	106	Introductory Physics III	2½	0	2½
PH	116	Physics Laboratory II	0	1½	½
PE	104[3]	Physical Education IV	0	2	0
					15

Junior Year

CS	212	Software Development	3	0	3
CS	337	Comput. Arch. and Organ.	3	0	3
IE	327	Operations Research I	3	0	3
MA	223	Intro. to Probability	3	0	3
SS	251	Microeconomics	3	0	3
		Electives			2
					17

CS	296	Computer Lab I	1	3	2
IE	300	Engineering Economy	3	0	3
IE	328	Operations Research II	3	0	3
MA	224	Intro. to Math. Statistics	3	0	3
		Electives			6
					17

Senior Year

CS	297	Computer Laboratory II	1	6	3
IE	319	Prodctn. Plannng. & Control	3	0	3
IE	380	System Simulation	2	3	3
		Electives			7
					16

CS	238	Operating Systems	3	0	3
IE	346	Oper. Des. of Public Syst.	3	0	3
		Electives			9
					15

Total credits required for graduation: 128

Footnotes See page 232.

GRADUATE STUDY

The department offers master of science and doctor of philosophy degree programs in operations research.

This curriculum encompasses the related fields of operations research and management science. It is directed toward the analysis and design of managerial systems comprised of human, technological and economic resources.

Operations analysts address themselves to problems of production, distribution, marketing, industrial and governmental operations, public planning and services, military analysis and others. Their services are sought by all levels of government, public agencies, industry and non-profit research organizations.

Students may pursue graduate studies in specialized areas such as system simulation, management science, experimental design, mathematical programming, production engineering, production and inventory models, queuing theory and applications, reliability and maintainability.

Certificate programs are available for more limited graduate study in a wide range of specialized topics.

Graduate students come with diverse academic training. Most professionals in these areas of specialization receive the major part of their training at the graduate level. One ingredient common to our students is the desire to develop techniques for problem-solving and decision-making in a techonological world.

MASTER OF SCIENCE DEGREE

The graduate curriculum leading to the degree of master of science in operations research is designed for engineers, scientists and mathematicians who wish to broaden their prior training with work in operations research and for students with undergraduate background in this field who wish to pursue advnced studies.

A bachelor's degree and competence in calculus (equivalent to MA 103) are required for admission to the program. Knowledge of computer programming is assumed; students lacking this must take CS 530 without

credit. Applications should be made to the department with operations research indicated as the area of specialization.

Students are encouraged to seek waivers for all required courses in which they can demonstrate competence so that they can use their time most effectively.

REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN OPERATIONS RESEARCH

A. Basic Required Courses[1]
MA 153 Elements of Linear Algebra[4]
MA 561 Elements of Probability[5]
IE 600 Engineering Economy
IE 608 Statistics[6]
IE 627 Oper. Res.: Deterministic Models[4]
IE 628 Oper. Res.: Stochastic Models[4]

B. Required Courses   9 units
IE 631 Linear Programming
IE 632 Nonlinear Programming
IE 650 Queuing Systems I

C. Major Electives: Select four courses[2]   12 units
{IE 611 Statistical Quality Control
{IE 686 Component Reliability

{IE 614 Modeling of Social & Mngrl. Systems
{IE 680 Discrete System Simulation

{IE 618 Inventory Models
{IE 619 Production Planning & Control

{IE 634 Dynamic Programming
{IE 636 Network Flows & Applications
{IE 720 Optimum Seeking Methods

{IE 851 Stochastic Processes
{IE 852 Applied Regression & ANOVA

D. Other Relevant Electives[3]   <u>15 units</u>
            Minimum total   36 units

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[1]All group A courses are required unless they are specifically waived by the adviser because the student either (a) has taken an equivalent undergraduate or graduate course, or (b) passes a validation examination for the course. Up to three group A courses actually taken may be credited toward the degree requirements; if more than three must be taken, the degree requirements are increased accordingly.

[2]Only one of each bracketed set of courses will be counted in group C; the other courses may be counted under group D

[3]Group D electives are chosen with adviser's approval to bring total units to 36 plus any excess of group A courses beyond 9 units. They may include thesis, additional courses from group C, or other graduate courses in this or other departments. Because of substantial overlap with IE courses, no credit will be given for MG 502, MG 503, MG 505, and MG 630.

COMPUTER SCIENCE/ OPERATIONS RESEARCH DUAL MASTER'S DEGREE PROGRAM

The disciplines of computer science and operations research complement each other academically and professionally. Any eligible students may pursue master's degrees individually in these two areas. By taking advantage of the reduced credit requirement for a second M.S., however, qualified students can earn the two degrees with a total of 63 credits. (If a student must take more than four of the CS 500 series courses, the minimum total number of credits required is increased correspondingly.)

Students whose undergraduate backgrounds are in other scientific and engineering disciplines and who need the computer science "orientation" courses and the operations research "basic required" courses would ordinarily require many more credits. For these students, the operations research faculty, in cooperation with the Computer Science Division, has developed a combination of courses which simultaneously satisfy requirements for the master of science in computer science and the master of science in operations research. By assigning credit in one program for basic core courses in the other, the requirements of both programs can be satisifed with a considerable saving in credits. Students with superior preparation would have a greater choice of electives.

Students are assigned an adviser in each program. Upon completion, students are awarded both the master of science in operations research and the master of science in computer science.

The requirements for admission to the dual program are a bachelor's degree in science, mathematics or engineering from an accredited school and a superior academic record. Students must have completed calculus (through MA 103) and a year of university-level science.

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[4]Certain introductory courses will be waived if the student takes specified advanced courses, for which full credit is given.
     For IE 627: IE 631 and IE 632
     For IE 628: IE 650 and either IE 618 or IE 619
     For MA 153: MA 705 or MA 837 or MA 838

[5]Students who have not had a full course in probability are urged to take MA 561 or an equivalent course during the summer preceding their first term.

[6]Students who have not had a full course in statistics are urged to take IE 608 or an equivalent course during the summer preceding their first term.

REQUIREMENTS FOR THE DUAL DEGREES MASTER OF SCIENCE IN COMPUTER SCIENCE AND MASTER OF SCIENCE IN OPERATIONS RESEARCH

CS 530	Introduction to Computer Science
CS 540	Elements of Data Structures
CS 550	Assembly Language Programming
CS 560	Introduction to Logic & Automata
CS 580	Introduction to Computer Architecture
CS 590	Introduction to Operating Systems

CS 603	Design and Analysis of Algorithms I
CS 613	Computer Architecture I
CS 623	Operating Systems I
CS 637	Programming Languages
CS 641	Compiler Design & Construction I

Two of the following four:

CS 604	Design & Analysis of Algorithms II
CS 614	Computer Architecture II
CS 624	Operating Systems II
CS 642	Compiler Design & Construction II

MA 153	Elements of Linear Algebra
MA 561	Elements of Probability
IE 600	Engineering Economy
IE 608	Statistics

IE 631	Linear Programming
IE 632	Nonlinear Programming
IE 650	Queuing Systems I
IE 680	System Simulation I

One of the following two:

| IE 618 | Inventory Models |
| IE 619 | Production Planning and Control |

One course chosen from the bracketed sets in the M.S. (O.R.) program not already represented above.

Minimum Total*:   63 credits

THE DOCTOR OF PHILOSOPHY DEGREE

The department offers a program leading to the degree of doctor of philosophy in operations research and industrial engineering. The general Polytechnic requirements for doctor of philosophy degrees are stated in this catalog under Degree Requirements. Specific requirements for the doctoral program may be found in the department's doctoral brochure.

Entrance to the doctoral program is contingent on passing the qualifying examination. This consists of the Part I preliminary written examination, and the Part II major field written examination; an oral examination may also be required.

The doctoral program requires a minimum of 90 units beyond the bachelor's degree, including a minimum of 24 units of dissertation. No more than 30 units of dissertation may be counted in the minimum total.

After passing the written qualifying examination, the candidate selects a thesis adviser and prepares a formal proposal for the dissertation research. A thesis committee is then appointed to judge the merits of the proposed research. After approval of this proposal, the doctoral candidate registers for research. On completion of the dissertation, the candidate must pass an examination in its defense.

CERTIFICATE PROGRAMS

The department offers certificate programs designed for professionals with work experience. A certificate program requires five courses selected according to the individual's needs. Applicants for a certificate program must hold a bachelor's degree. On completion of the sequence with a B average or better, a certificate is issued. A student who chooses to work towards a master's degree is usually able, on admission, to apply all courses taken for a certificate toward a degree program.

If a student has taken the equivalent of any required course as an undergraduate, or more than one as a graduate student, then substitute courses must be selected in consultation with the adviser. Additional information may be obtained from the department.

The certificate programs are shown below. Additional certificates are shown in the Industrial Engineering section of this catalog.

Basic Operations Research

MA 153	Elements of Linear Algebra
MA 561	Elements of Probability
IE 608	Statistics
IE 627	Op. Res.: Deterministic Models
IE 628	Op. Res.: Stochastic Models

Advanced Operations Research

IE 631	Linear Programming
IE 650	Queuing Systems I
IE 680	System Simulation

Two of the following:

IE 618	Inventory Models
IE 619	Production Planning & Control
IE 632	Nonlinear Programming

Basic Engineering Statistics

MA 561	Elements of Probability
IE 608	Statistics
IE 852	Appl. Regression & ANOVA

Two of the following:

IE 611	Statistical Quality Control
IE 851	Stochastic Processes
IE 853	Design of Experiments
IE 870	Games and Decisions

Mathematical Programming

| IE 631 | Linear Programming |
| IE 632 | Nonlinear Programming |

Three of the following:

IE 633	Integer Programming
IE 634	Dynamic Programming
IE 635	Advanced Linear Programming
IE 720	Optimum Seeking Methods
IE xxx	Approved elective

UNDERGRADUATE COURSES

All undergraduate courses in operations research are listed in the Industrial Engineering section of this catalog.

GRADUATE COURSES

All graduate lecture and laboratory courses in operations research are listed in the Industrial Engineering section of this catalog.

OR 930-931 **Readings in**
Operations Research I, II **each 3 units**
Individual reading of selected papers and current literature in specialized area of study, guided by faculty member. Prerequisites: approval of adviser, instructor and department head.

OR 935 **Engineering Projects Related to**
Public Administration **each 3 units**
See Cooperative Program with New York University Graduate School of Public Administration for details.

OR 997 **Thesis for Degree of**
Master of Science **each 3 units**
Original investigation on topic chosen by student. Conferences and progress reports required during work, and final written report required at completion; oral examination may be requested by department. Registration and degree credit beyond first six units require separate approval. Prerequisites: degree status and approval of supervising professor, adviser and department head.

OR 999 **Dissertation for Degree of**
Doctor of Philosophy **each 3 units**
Doctoral dissertation must give evidence of and embody results of extended research in a specific field of operations research, constituting original contribution. Candidate required to take oral examination on subject of thesis and on related topics. Minimum of 24 units required. Prerequisites: passing of qualifying examination and guidance committee's approval.

FACULTY

William R. McShane, P.E., Professor of Transportation and Industrial Engineering; Head, Department of Mechanical and Industrial Engineering; Director, Transportation Training and Research Center.
B.E.E., Manhattan College; M.S., Ph.D., Polytechnic Institute of Brooklyn; Professional Engineer (New York, California (Traffic))
Traffic Engineering, highway capacity, expert systems in transportation, PC applications and models, economics and finance.

Norbert Hauser, Professor of Industrial Engineering and Management Science
B.M.E., Cooper Union; M.I.E., Eng.Sc.D., New York University
Modeling of social systems, computer simulation, quality control

Walter Helly, Professor of Operations Research
B.A., Cornell University; M.S., University of Illinois; Ph.D., Massachusetts Institute of Technology
Stochastic modeling, tele- and vehicular traffic, urban systems

Frank Kozin, Professor of System Engineering
B.S., M.S., Ph.D., Illinois Institute of Technology
Stochastic Systems

Joachim I. Weindling, P.E., Professor of Operations Research and System Engineering, and Director of Operations Research Program
B.M.E., City College of New York; M.S., Ph.D., Columbia University; Professional Engineer (New York, Pennsylvania)
Mathematical programming, optimum design, economic evaluation

Herman Grau, Associate Professor of Industrial Engineering
B.M.E., Polytechnic Institute of New York; M.I.E., New York University
Methods, work measurement, project management, manufacturing engineering, industrial management

Ravinder Nanda, Associate Professor of Industrial Engineering and Operations Management
B.Sc., Banaras Hindu University (India); M.S., Ph.D., University of Illinois
Production and operations planning, productivity analysis, project control

John S. Zuk, Instructor in Industrial and Manufacturing Engineering
B.M.E., Union College; M.S. (IE), Polytechnic University
Modeling of manufacturing systems, computer simulation, robotics

ADJUNCT FACULTY

James Brown, Adjunct Professor
B.A., St. John's University; M.A., Brooklyn College

Johnson Edosomwan, Adjunct Professor
B.S., M.S., University of Miami; D.Sc., George Washington University; P. Engr., Columbia University

Owen Hill, Adjunct Professor
B.S., Texas A&M University; M.S., Ph.D., University of California at Berkeley

John H. K. Kao, Adjunct Professor
B.S., National Central University (China); M.S., Eng. Sci. D., Columbia University

Sambhu Mukho, Adjunct Professor
B.S., Jadav Pau University; M.S., City College of New York; M.B.A., New York University

Maureen Dolan, Adjunct Assistant Professor
B.A., Molloy College; M.S., Stevens Institute of Technology; M.S., Polytechnic Institute of New York

Fred Fenster, Adjunct Lecturer
B.S., Drexel University

Margaret Gaudet, Adjunct Lecturer
B.S., Polytechnic University

Peter Martino, Adjunct Lecturer
B.E.E., Manhattan College; M.S., Stevens Institute; Engineer's Degree, Polytechnic University

William Ronai, Adjunct Lecturer
B.S., City College of New York; M.S., C.W. Post

PHYSICAL EDUCATION AND ATHLETICS

The major goal of the required physical education program is to educate and interest students in a wide variety of physical activities. With guidance from their instructors, students can develop skill and success in a chosen activity while experiencing an optimum condition of physical fitness in terms of strength, speed, ability and endurance. The program offers instruction in racquetball, weight training on Nautilus machines, martial arts (judo and karate), and team sports. An innovative "wellness" program has been added as part of the physical education program which centers around nutrition, fitness and stress management.

Intercollegiate Athletics

All full-time undergraduate students who are in good academic standing are eligible for team membership, and are encouraged to participate and win their varsity letter.

Polytechnic is a member of the N.C.A.A., E.C.A.C., and the I.A.C. and field varsity teams in men's basketball, baseball, cross country, judo, lacrosse, soccer, tennis, wrestling, women's cross country, judo, tennis and volleyball.

Intramurals

Intramural sports enjoy substantial success at Polytechnic. All students, both undergraduate and graduate, are eligible for competition in badminton, basketball, football, tennis, handball, hockey, paddleball, softball, volleyball and wrestling. Winners of the intramural basketball and volleyball tournaments compete in the tristate area college intramural championships.

PHYSICAL EDUCATION COURSES

The department's aim is to provide sound programs of instruction and participation for all students in physical education.

Physical Education Courses

All undergraduate students are required to complete four semesters of physical education in any of the listed courses. A student may elect to take a course with the same number for more than one semester, for example, PE 101 may be taken four times. Courses may be selected in any sequence.

PE 101   Racquetball   **0:2:0**
Fundamentals for beginners, leading to interclass tournament play for novice and advanced players.

PE 102   Weight Training   **0:2:0**
Individualized weight training program developed on Nautilus weight training equipment. The Nautilus machines allow for rotary movement; they exercise specific muscles throughout the students full range of motion.

PE 103   Team Sports   **0:2:0**
Basic skills, conditioning and strategy needed while participating in team and carry over sports, volleyball, basketball and badminton.

PE 104M1   Karate   **0:2:0**
Fundamental principles and basic karate techniques including katas and light sparring.

PE 104M2   Judo   **0:2:0**
Fundamental principles of sport judo. Includes throwing techniques, matwork, and rules leading to tournament play.

PE 104W   Wellness   **0:2:0**
Wellness, achieving optimum physical and mental health through nutrition, fitness and stress management.

Note: PE 101, 102 and 103 are held at the St. George Health and Racquetball Club. The Club, located at 43 Clark Street, features 5 racquetball courts, a 30 unit Nautilus weight training circuit and a gymnasium.

Note: military science courses (MS 101, 102, 202) may be substituted for PE 101-104.

FACULTY

Joseph Martini, Director of Physical Education and Athletics
B.S., Long Island University; M.S., Brooklyn College

Maureen Braziel, Associate Director of Athletics
B.A., Hunter College; M.S., Hunter College

Massimo Gargiulo, Associate Director of Athletics
B.S., St. Francis College

Louis Zinser, Assistant Director of Athletics
B.S., University of Balitmore; M.S., Hofstra Unversity

Coaching Staff: Varsity Teams

Joseph Martini, Baseball Head Coach

Denis Murphy, Assistant Baseball Coach

Laddy Baldwin, Basketball Coach

Kenny Wilson, Assistant Basketball Coach

Maureen Braziel, Men's & Women's Judo Coach
Women's Volleyball Coach

Massimo Gargiulo, Men's & Women's Tennis Coach
Men's & Women's Cross Country Coach

Louis Zinser, Soccer Coach

Don Annino, Lacrosse Coach

PHYSICS

Physics is the basic science of the natural world — the science of matter, energy and motion. It is indispensable for any engineering or scientific career.

The training of physics majors, at both the undergraduate and graduate levels, is basic and general. This broad preparation makes graduates less subject to the risks of obsolescence produced by the rapidity of technological change in modern life. Curricula are designed to provide backgrounds for careers in industry, government and education. Some physicists go into university teaching and research when they have completed their graduate education. Others go into science teaching at many different levels. Physics graduates at all levels are employed in private industry, government agencies and research foundations for fundamental research and engineering. Training in physics serves as valuable preparation for any science-based or science-connected careers.

Besides the very active field of solid-state and nuclear physics, other general areas in which physicists are now employed are the radio/television and electronics, the chemical industry and biophysics, space science and medical physics.

The Department of Physics grants the degrees of bachelor of science, master of science, and doctor of philosophy in physics.

UNDERGRADUATE PROGRAM

The aim of the four-year undergraduate program in physics is to prepare students thoroughly for any one of the many careers for which a concentration in physics forms the base. For some students, this means preparation for graduate school and further study leading to master's or doctor's degree. For many others, it means professional work in industry, government or in high school teaching. Some students use their major in physics as preparation for work in mathematics, chemistry, biology, medicine, engineering, law, history of science, writing, or business.

The program's emphasis on fundamental knowledge, on thorough analytic training and on the universal logic of science enables physics students to take these different paths.

The structure of the undergraduate program is four-fold: formal instruction in the sciences; instruction in the humanities and social sciences; informal instruction; and additional activities.

Formal instruction in the sciences is described by its program of courses. This program includes — after the freshman year with its beginning courses in physics, chemistry and mathematics — a spiraling sequence of courses in the three broad areas of mechanics, electromagnetic theory and modern physics, matched at each level to the student's increasing mathematical maturity. With this background, a senior is ready for theoretical physics and electives in solid-state, x-ray, nuclear physics or quantum theory. Specialized courses such as optics, thermodynamics, computing and electronics are required, and additional courses in mathematics, chemistry or life sciences may be elected.

Instruction in the humanities and social sciences is built around the 32 credit hours of courses in the humanities and social sciences required of all physics majors. This department urges students to choose additional courses in these areas. It believes that the natural curiosity which brought students to choose physics as a major should also be stimulated in other areas of intellectual activity such as literature, psychology, poetry, music, economics and history.

Informal instruction accompanying the formal course work takes a variety of forms. All students meet regularly with members of the physics faculty for informal conferences to discuss their work, review problems or talk physics.

All physics freshmen take a seminar on current advances in physics; all seniors participate in another seminar. In both, students prepare talks on aspects of advanced topics in physics and present them to the critical audiences of their peers and professors.

Many students spend some time in research, either assisting in the various research programs performed by the faculty or working on relatively independent research projects assigned after consultation with their adviser. Undergraduate participation in research with graduate students and professors is becoming so important that it will probably soon enter the department's formal education structure. A number of juniors and seniors in the physics department now spend ten weeks each summer in such full-time research activity. Opportunities for guided research during the academic year also exist.

The department offers opportunities for individual reading and advanced study under professional guidance and accepts satisfactory performance in regular course examinations as fulfillment of course requirements.

Physics students have a common study area in which they meet with other students for shop talk, for problem-solving and for the exchange of ideas.

Information about advanced placement of freshmen is included in the section of this catalog on Admissions.

Additional activities, in which all physics students are urged to participate, include the programs organized by the Physics-Math Society, by the chapter of Sigma Pi Sigma (the physics honor society) and by the local student chapter of the American Physical Society. Here the students listen to and meet speakers on various topics and participate in trips to industrial and government laboratories. Undergraduates are encouraged to come to the regular research colloquia where invited scientists discuss the latest advances in physics. They also attend meetings of the American Physical Society and other professional societies associated with the American Institute of Physics.

By means of these activities and through the structure of the department, students have a wide range of opportunities for interacting with their professors, their fellow students and with the world of physics. Such interaction is

PHYSICS

the mos valuable preparation for any careers in physics. This blending of experiences leads to appreciation of the intellectual impact of physics and to understanding why so many important thinkers have been attracted to physics and have added to its achievements.

REQUIREMENTS FOR THE BACHELOR OF SCIENCE DEGREE IN PHYSICS

The program requires 128 credits, including 56 credits of required courses in physics. The remaining credits are distributed among required technical courses, required humanities, social sciences courses, a foreign language requirement and restricted electives. (See Typical Course of Study on the following page.) The distribution is as follows:

	Credits
PH 104, 105, 106, 113, 115, 116, 210, 234, 236, 250, 302, 311, 323, 324, 335, 336, 340, 347, 360, 373, 374, 390	56

CM 101, 102, 111, 112; MA 101, 102, 103, 104, 153, 260, 217; CS 112 — 33
HU 101, HU 200; SS 104 — 9
Language (or equivalent) — 12
Electives (6 PH, 12 Hum./Soc. Sci.) — 18
128

Required Physics Courses

The course format of the required courses may be lectures, recitations or guided reading. Any substitutions require the permission of the undergraduate adviser.

Electives

Elective courses are chosen in consultation with the departmental adviser.

Typical Course of Study for the Bachelor of Science Degree in Physics

Freshman Year

First Semester		Hours/Week			Second Semester		Hours/Week		
No.	Subject	Cl.	Lab.	Cr.	No.	Subject	Cl.	Lab.	Cr.
CS 112	Programming in Pascal	3	0	3	CM 102	General Chemistry I	2½	0	2½
CM 101	General Chemistry I	2½	0	2½	CM 112	General Chemistry Lab.	0	1½	½
CM 111	General Chemistry Lab I	0	1½	½	MA 102	Calculus II	4	0	4
MA 101	Calculus I or MA 100	4	0	4	PH 104	Intro. to Physics I	3	0	3
PH 113	Seminar in Current Physics	2	0	2		Hum./Soc. Sci. elective[1]	6	0	6
	Hum./Soc. Sci. elective[1]	6	0	6	PE 102	Physical Education	0	2	0
SL 101	Student Survival	0	1	0					16
PE 10x	Physical Education	0	2	0					
				18					

Sophomore Year

		Cl.	Lab.	Cr.			Cl.	Lab.	Cr.
MA 103	Calculus III	3	0	3	MA 153	Elem. Linear Alg.	3	0	3
MA 104	Appl. Diff. Equations	3	0	3	PH 106	Intro. to Physics III	2½	0	2½
PH 105	Intro. Physics II	3½	0	3½	PH 116	Physics Laboratory II	0	1½	½
PH 115	Physics Laboratory I	0	1½	½	PH 234	Intro. to Modern Physics	2	0	2
PH 210	Analyt. Mechanics	3	0	3	PH 236	Physics Laboratory III	½	1½	1
	Hum./Soc. Sci. elective[1]	3	0	3	PH 250	Electronics for Physical Scientists	3	3	4
PE 10x	Physical Education	0	2	0		Hum./Soc. Sci. elective[1]	3	0	3
				16	PE 10x	Physical Education	0	2	0
									16

Junior Year

		Cl.	Lab.	Cr.			Cl.	Lab.	Cr.
PH 311	Thermodynamics	3	0	3	PH 302	Advanced Lab.	1	3	2
PH 323	Electricity and Magnetism I	2	0	2	PH 324	Electricity and Magnetism II	2	0	2
PH 335	Quantum Phys. II	3	0	3	PH 336	Quantum Mechanics	3	0	3
MA 260	Vector Anal. & PDE	4	0	4	PH 340	Computer Methods in Physics	3	3	4
	Hum./Soc. Sci. elective[1]	3	0	3	PH 360	Special Topics	3	0	3
				15		Hum./Soc. Sci. elective[1]	3	0	3
									17

Senior Year

		Cl.	Lab.	Cr.			Cl.	Lab.	Cr.
MA 217	Complex Variables	3	0	3	PH 374	Intro. Theo. Phys. II	3	0	3
PH 347	Modern Optics	3	3	4	PH 390	Senior Seminar	2	0	2
PH 373	Intro. Theo. Phys. I	3	0	3	PH 664	Stat. Mech. II[2]			
PH 663	Stat. Mech. I[2]					**or**			
	or				PH 668	Quantum Mechanics II[2]	3	0	3
PH 667	Quantum Mech. I[2]	3	0	3		Hum./Soc. Sci. elective[2]	6	0	6
	Hum./Soc. Sci. elective[1]	3	0	3					14
				16					

[1]Humanities and Social Sciences: Required courses (21 credits), include HU 101 and either HU 200, SS 104 or IS 140, 141 (9 credits): and ML 1x1 through 1x4 (12 credits). The modern language requirement must be satisfied in German, French, or Russian. Based on performances in prior language studies, the language requirement may, with approval of the Department of Physics, be replaced by other humanities or social sciences electives. Elective courses (11 credits): The student is strongly urged to select two or three courses from an area of concentration such as literature, communications, the arts, philosophy, comparative religion, political science, economics, history, anthropology, or psychology. Electives are chosen with the adviser's approval.

[2]Advanced Electives strongly recommended for students intending to pursue graduate studies in physics. Other possible electives include Advanced Lab. II (PH 303), X-ray Diffraction (PH 372), Readings in Physics (PH 381-2), courses in PH 6xx sequence.

REQUIREMENTS FOR THE BACHELOR OF SCIENCE DEGREE IN PHYSICS WITH OPTIONS IN MATHEMATICS, ELECTRONICS, MATERIALS AND BIOLOGY

These programs offer the student an opportunity to gain competence in two different and substantial fields of science, to such an extent that upon earning a Bachelor's degree he or she may be able to qualify for industrial positions in two distinct areas, or to go on to graduate studies in either of the two subjects.

The option in Mathematics provides a strong training in both Physics and Mathematics, approaching the requirements for separate degrees in each subject. The options in Electronics, Materials, and Biology may be viewed as similar to Applied Physics programs with concentrations in the respective areas. In all cases the student benefits from the strong basic training in Physics and positions himself for further training or direct employment in the area of his option.

Electronics, Materials Science and Biology are areas of immense importance in today's technology, providing a wide range of employment opportunities in addition to those available in Physics. As examples, in the active technology areas of Microelectronics and High Temperature Superconductivity, combined knowledge of Physics and Electronics or Materials opens many opportunities for employment. A student with a strong basic training in Physics, in addition to that in his option, may enjoy in his career more flexibility and greater ability to adjust to changing requirements in technology.

The changes in course requirements for each Option from that of the B.S. in Physics are listed below.

MATHEMATICS OPTION

Require:

MA 101 (4:0:4), MA 102 (4:0:4), MA 103 (3:0:3), MA 104 (3:0:3), MA 153 (3:0:3), MA 201 (3:0:3), MA 202 (3:0:3), MA 224 (3:0:3), MA 333 (3:0:3), MA 358.

Drop:

PH 113 (2:0:0), PH 250 (3:3:4), PH 340 (2:2:4), PH 360 (3:0:3), Sr. Electives (6:0:6)

ELECTRONICS OPTION

Require:

EE 101 (3:0:3), EE 102 (3:0:3), EE 109 (4:0:4), EE 110 (3:0:3), EE 103 (4:0:4), EE 193 (0½:1½:1), EE 194 (0½:1½:1), EE 195 (1:3:2) — 21 cr.

Elect:

EE 395 (½:1½:1), and EE xxx Senior Lab/Project (3 cr.) or other technical electives — 4 to 7 cr.

Drop:

PH 250 (3:3:4), PH 360 (3:0:3), Sr. electives (6:0:6), PH 373 - 4 (6:0:6), PH 340 (3:3:4).

MATERIALS OPTION

Require:

MT 401 (3:0:3), MT 403 (3:0:3), MT 404 (0:6:2), MT 408 (0:6:2) — 10 cr.

Elect:

PH 372 MT 412 (2:3:3) or MT 375 (3:0:3) or MT 603/4 (4½:2:6) — 3 or 6 cr.

Drop up to the same number of total credits from the following list:
PH 360 (3:0:3), Sr. electives (6:0:6), PH 373 - 4 (6:0:6).

BIOLOGY OPTION

Require:

LS 105-6 (6:0:6), LS 115-6 (2:6:4) — 10 cr.

Drop up to the same number of total credits from the following list:
PH 360 (3:0:3), Sr. electives (6:0:6), PH 373 - 4 (6:0:6).

(See Typical Courses of Study on the following pages.)

Typical Course of Study for the Bachelor of Science Degree in Physics
(Mathematics Option)

Freshman Year

First Semester

No.		Subject	Cl.	Lab.	Cr.
CS	112	Programming in Pascal	3	0	3
CM	101	Gen. Chemistry I	2½	0	2½
CM	111	Gen. Chem. Lab I	0	1½	½
MA	101	Calculus I	4	0	4
		Hum./Soc. Sci. elective	6	0	6
SL	101	Student Survival	0	1	0
PE	10x	Physical Education	0	2	0
					16

Second Semester

No.		Subject	Cl.	Lab.	Cr.
CM	102	Gen. Chemistry II	2½	0	2½
CM	112	Gen. Chem. Lab II	0	1½	½
MA	102	Calculus II	4	0	4
PH	104	Intro. to Physics I	3	0	3
		Hum./Soc. Sci. elective	6	0	6
PE	10x	Physical Education	0	2	0
					16

Sophomore Year

MA	103	Calculus III	3	0	3
MA	223	Probability	3	0	3
PH	105	Intro. to Physics II	3½	0	3½
PH	115	Physics Lab I	0	1½	½
PH	210	Analyt. Mechanics	3	0	3
		Hum./Soc. Sci. elective	3	0	3
PE	10x	Physical Education	0	2	0
					16

MA	104	Appl. Diff. Eqns.	3	0	9
MA	153	Elem. Lin. Algebra	3	0	3
PH	106	Intro. to Physics III	2½	0	2½
PH	116	Physics Lab II	0	1½	½
PH	234	Intro. to Mod. Phys.	2	0	2
PH	236	Physics Lab III	½	1½	1
		Hum./Soc. Sci. elective	3	0	3
PE	10x	Physical Education	0	2	0
					15

Junior Year

MA	201	Appl. Analysis I	3	0	3
MA	333	Part. Diff. Eqns.	3	0	3
MA	224	Statistics	3	0	3
PH	323	El. & Magnetism I	2	0	2
PH	335	Quantum Physics	3	0	3
		Hum./Soc. Sci. elective	3	0	3
					17

MA	202	Appl. Analysis II	3	0	3
MA	358	Numerical Analysis	3	0	3
PH	302	Advanced Lab	1	3	2
PH	324	Elect. & Magnetism II	2	0	2
PH	336	Quantum Mechanics	3	0	3
		Hum./Soc. Sci. elective	3	0	3
					16

Senior Year

MA	217	Complex Variables	3	0	3
PH	311	Thermodynamics	3	0	3
PH	373	Intro. Theor. Ph. I	3	0	3
PH	347	Modern Optics	3	3	4
		Hum./Soc. Sci. elective	3	0	3
					16

PH	374	Intro. Theor. Ph. II	3	0	3
PH	390	Senior Seminar	2	0	2
		Hum./Soc. Sci. elective	3	0	3
		Free elective	8	0	8
					16

Typical Course of Study for the Bachelor of Science Degree in Physics.
(Electronics Option)

Freshman Year

First Semester			Hours/Week			Second Semester				Cl.	Lab.	Cr.
No.		Subject	Cl.	Lab.	Cr.	No.		Subject				
CS	112	Programming in Pascal	3	0	3	CM	102	Gen. Chemistry II		2½	0	2½
CM	101	Gen. Chemistry I	2½	0	2½	CM	112	Gen. Chemistry Lab II		0	1½	½
CM	111	Gen. Chemistry Lab I	0	1½	½	MA	102	Calculus II (or MA 110)		4	0	4
MA	101	Calculus I (or MA 100)	4	0	4	PH	104	Intro. to Physics I		3	0	3
PH	113	Seminar in Current Physics	2	0	2			Hum./Soc. Sci. elective[1]		6	0	6
		Hum./Soc. Sci. elective[1]	6	0	6	PE	10x	Physical Education		0	2	0
SL	101	Student Survival	0	1	0							16
PE	10x	Physical Education	0	2	0							
					18							

Sophomore Year

No.		Subject	Cl.	Lab.	Cr.	No.		Subject	Cl.	Lab.	Cr.
MA	103	Calculus III	3	0	3	MA	153	Elem. Linear Algebra	3	0	3
MA	104	Appl. Diff. Equations	3	0	3	PH	106	Intro. to Physics III	2½	0	2½
PH	105	Intro. to Physics II	3½	0	3½	PH	116	Physics Laboratory II	0	1½	½
PH	115	Physics Laboratory I	0	1½	½	PH	234	Intro to Modern Phys.	2	0	2
PH	210	Analyt. Mechanics	3	0	3	PH	236	Physics Lab. III	½	1½	1
EE	101	Electric Circuits I	3	0	3	EE	102	Electric Circuits II	3	0	3
EE	193	Sophomore EE Lab I	½	1½	1	EE	194	Sophomore EE Lab II	½	1½	1
PE	10x	Physical Education	0	2	0			Hum./Soc. Sci. elective[1]	3	0	3
					17	PE	10x	Physical Education	0	2	0
											16

Junior Year

No.		Subject	Cl.	Lab.	Cr.	No.		Subject	Cl.	Lab.	Cr.
EE	109	Solid State Dev&Ccts I	4	0	4	EE	110	Solid State Dev&Ccts II	3	0	3
EE	195	Junior EE Laboratory I	1	3	2	EE	103	Signals and Transforms	4	0	4
PH	311	Thermodynamics	3	0	3	PH	302	Advanced Lab.	1	3	2
PH	323	Electricity and Magnetism I	2	0	2	PH	324	Electricity and Magnetism II	2	0	2
MA	260	Vector Anal. & PDE	4	0	4			Hum./Soc. Sci. elective[1]	3	0	3
		Hum./Soc. Sci. elective[1]	3	0	3						14
					18						

Senior Year

No.		Subject	Cl.	Lab.	Cr.	No.		Subject	Cl.	Lab.	Cr.
MA	217	Complex Variables	3	0	3	EE	xxx	Senior EE Lab/Proj.[2]	x	x	3
PH	335	Quantum Physics	3	0	3	PH	336	Quantum Mechanics	3	0	3
PH	347	Modern Optics	3	3	4	PH	390	Senior Seminar	2	0	2
EE	395	Intro to Project[2]	½	1½	1			Hum./Soc. Sci. elective[1]	6	0	6
		Hum./Soc. Sci. elective[1]	6	0	6						14
					17						

[1]Humanities and Social Sciences Required Courses (21 credits), include HU 101 and either HU 200, SS 104 or IS 140, 141 (9 credits) and ML 1x1 through 1x4 (12 credits). The modern language requirement must be satisfied in German, French, or Russian. Based on performances in prior language studies, the language requirement may, with approval of the Department of Physics, be replaced by other Humanities or Social Sciences electives. Elective courses (11 credits): The student is strongly urged to select two or three courses from an area of concentration such as literature, communications, the arts, philosophy, comparative religion, political science, economics, history, anthropology, or psychology. Electives are chosen with the adviser's approval

[2]EE 395 - EE xxx is an elective sequence of 4 to 7 credits. Specific electives may be chosen with the help/approval of the departmental adviser. For a strong semiconductor device concentration, the sequence EE 395 - EE 206 is desirable. (EE 206 is currently offered only on the Long Island campus, and has EE 119 as a prerequisite.) Please consult the Departmental Standards section in the EE catalog listing for minimum grades required for various EE courses.

Typical Course of Study for the Bachelor of Science Degree in Physics.
(Materials Option)

Freshman Year

First Semester			Hours/Week			Second Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.	No.		Subject	Cl.	Lab.	Cr.
CS	112	Programming in Pascal	3	0	3	CM	102	Gen. Chemistry II	2½	0	2½
CM	101	Gen. Chemistry I	2½	0	2½	CM	112	Gen. Chemistry Lab II	0	1½	½
CM	111	Gen. Chemistry Lab I	0	1½	½	MA	102	Calculus II (or MA 110)	4	0	4
MA	101	Calculus I (or MA 100)	4	0	4	PH	104	Intro. to Physics I	3	0	3
PH	113	Seminar in Current Physics	2	0	2			Hum./Soc. Sci. elective[1]	6	0	6
		Hum./Soc. Sci. elective[1]	6	0	6	PE	10x	Physical Education	0	2	0
SL	101	Student Survival	0	1	0						16
PE	10x	Physical Education	0	2	0						
					18						

Sophomore Year

MA	103	Calculus III	3	0	3	MA	153	Elem. Linear Algebra	3	0	3
MA	104	Appl. Diff. Equations	3	0	3	PH	106	Intro. to Physics III	2½	0	2½
PH	105	Intro. to Physics II	3½	0	3½	PH	116	Physics Laboratory II	0	1½	½
PH	115	Physics Laboratory I	0	1½	½	PH	234	Intro to Modern Phys.	2	0	2
PH	210	Analyt. Mechanics	3	0	3	PH	236	Physics Lab III	½	1½	1
		Hum./Soc. Sci. elective[1]	3	0	3	PH	250	Electronics for Physical Scientists	3	3	4
PE	10x	Physical Education	0	2	0			Hum./Soc. Sci. elective[1]	3	0	3
					16	PE	10x	Physical Education	0	2	0
											16

Junior Year

PH	311	Thermodynamics	3	0	3	PH	302	Advanced Lab.	1	3	2
PH	323	Electricity and Magnetism I	2	0	2	PH	324	Electricity and Magnetism II	2	0	2
MT	401	Physical Metallurgy I	3	0	3	MT	403	Physical Metallurgy II	3	0	3
MT	404	Metallography Lab.	0	6	2	MT	408	Physical Metallurgy Lab.	0	6	2
MA	260	Vector Anal. & PDE	4	0	4	PH	340	Computer Methods in Physics	3	3	4
		Hum./Soc. Sci. elective[1]	3	0	3			Hum./Soc. Sci. elective[1]	3	0	3
					17						16

Senior Year

MA	217	Complex Variables	3	0	3	PH	336	Quantum Mechanics	3	0	3
PH	335	Quantum Physics	3	0	3	PH	390	Senior Seminar	2	0	2
PH	347	Modern Optics	3	3	4	MT	604	Intro. to Electron Microscopy II[2]	2	2	3
MT	603	Intro. to Electron Microscopy I[2]	2½	0	3			Hum./Soc. Sci. elective[1]	6	0	6
		Hum./Soc. Sci. elective[1]	6	0	6						14
					16						

[1]Humanities and Social Sciences: Required Courses (21 credits), include HU 101 and either HU 200, SS 104 or IS 140, 141 (9 credits); and ML 1x1 through 1x4 (12 credits). The modern language requirement must be satisfied in German, French, or Russian. Based on performances in prior language studies, the language requirement may, with approval of the Department of Physics, be replaced by other Humanities or Social Sciences electives. Elective courses (11 credits): The student is strongly urged to select two or three courses from an area of concentration such as literature, communications, the arts, philosophy, comparative religion, political science, economics, history, anthropology, or psychology. Electives are chosen with the adviser's approval.

[2]MT 603-4 is an elective strongly recommended. Other possible electives include PH 372/MT 412 X-ray Diffraction (2:3:3), MT 423 Introduction to Ceramic Refractory Materials (3:0:3), or others chosen with the advisers approval.

Typical Course of Study for the Bachelor of Science Degree in Physics.
(Biology Option)

Freshman Year

First Semester				Hour/Week		Second Semester				Hour/Week	
No.		Subject	Cl.	Lab.	Cr.	No.		Subject	Cl.	Lab.	Cr.
CS	112	Programming in Pascal	3	0	3	CM	102	Gen. Chemistry II	2½	0	2½
CM	101	Gen. Chemistry I	2½	0	2½	CM	112	Gen. Chemistry Lab II	0	1½	½
CM	111	Gen. Chemistry Lab I	0	1½	½	MA	102	Calculus II (or MA 110)	4	0	4
MA	101	Calculus I (or MA 100)	4	0	4	PH	104	Intro. to Physics I	3	0	3
PH	113	Seminar in Current Physics	2	0	2			Hum./Soc. Sci. elective[1]	6	0	6
		Hum./Soc. Sci. elective[1]	6	0	6	PE	10x	Physical Education	0	2	0
SL	101	Student Survival	0	1	0						16
PE	10x	Physical Education	0	2	0						
					18						

Sophomore Year

			Cl.	Lab.	Cr.				Cl.	Lab.	Cr.
MA	103	Calculus III	3	0	3	MA	153	Elem. Linear Algebra	3	0	3
MA	104	Appl. Diff. Equations	3	0	3	PH	106	Intro. to Physics III	2½	0	2½
PH	105	Intro. to Physics II	3½	0	3½	PH	116	Physics Laboratory II	0	1½	½
PH	115	Physics Laboratory I	0	1½	1½	PH	234	Intro to Modern Phys.	2	0	2
PH	210	Analyt. Mechanics	3	0	3	PH	236	Physics Lab. III	½	1½	1
		Hum./Soc. Sci. elective[1]	3	0	3	PH	250	Electronics for Physical Scientists	3	3	4
PE	10x	Physical Education	0	2	0			Hum./Soc. Sci. elective[1]	3	0	3
					16	PE	10x	Physical Education	0	2	0
											16

Junior Year

			Cl.	Lab.	Cr.				Cl.	Lab.	Cr.
LS	105	General Biology I	3	0	3	LS	106	General Biology II	3	0	3
LS	115	Gen. Biology Lab. I	1	3	2	LS	116	Gen. Biology Lab. II	1	3	2
PH	311	Thermodynamics	3	0	3	PH	302	Advanced Lab.	1	3	2
PH	323	Electricity and Magnetism I	2	0	2	PH	324	Electricity and Magnetism II	2	0	2
MA	260	Vector Anal. & PDE	4	0	4	PH	340	Computer Methods in Physics	3	3	4
		Hum./Soc. Sci. elective[1]	3	0	3			Hum./Soc. Sci. elective[1]	3	0	3
					17						16

Senior Year

			Cl.	Lab.	Cr.				Cl.	Lab.	Cr.
MA	217	Complex Variables	3	0	3	PH	336	Quantum Mechanics	3	0	3
PH	335	Quantum Physics	3	0	3	PH	390	Senior Seminar	2	0	2
PH	347	Modern Optics	3	3	4	PH	664	Stat. Mech. II[2]			
PH	663	Stat. Mech. I[2]						or			
		or				PH	668	Quantum Mech. II[2]	3	0	3
PH	667	Quantum Mech. I[2]	3	0	3			Hum./Soc. Sci. elective[1]	6	0	6
		Hum./Soc. Sci. elective[1]	3	0	3						14
					16						

[1]Humanities and Social Sciences: Required Courses (21 credits), include HU 101 and either HU 200, SS 104 or IS 140, 141 (9 credits); and ML 1x1 through 1x4 (12 credits) The modern language requirement must be satisfied in German, French, or Russian. Based on performances in prior language studies, the language requirement may, with approval of the Department of Physics, be replaced by other Humanities or Social Sciences electives. Elective courses (11 credits): The student is strongly urged to select two or three courses from an area of concentration such as literature, communications, the arts, philosophy, comparative religion, political science, economics, history, anthropology, or psychology. Electives are chosen with the adviser's approval

[2]Advanced electives strongly recommended for students intending to pursue graduate studies in physics. Other possible electives include Advanced Lab. (PH 303), X-ray Diffraction (PH 372), Readings in Physics (PH 381-2), courses in PH 600 sequence

GRADUATE PROGRAMS

The Department of Physics offers graduate programs leading to the degrees of master of science and doctor of philosophy in physics. In addition, the Department of Physics cooperates with the Department of Chemistry in offering an interdisciplinary program leading to degrees in chemical physics.

Experimental research programs are offered in solid state physics, low temperature physics, surface physics, x-ray physics, quantum optics, radiation physics, and medical physics in modern well equipped laboratories. The x-ray diffraction laboratory, is equipped for all types of crystal analysis and has unique capabilities in high resolution x-ray interferometry. Surface physics studies are performed both in the department's extensive surface science laboratories and at various synchrotron radiation facilities (e.g., National Synchrotron Light Source at Brookhaven National Laboratories and Cornell High Energy Synchrotron Source). Areas of current theoretical research are in solid state physics and statistical mechanics within the theoretical condensed matter group, and also field-matter interactions, image restoration, and nuclear theory.

For admission to graduate study in physics, a bachelor's degree in physics is required with preparation equivalent to intermediate courses in mechanics, electromagnetic theory, optics, thermodynamics, quantum mechanics, and atomic physics. Applicants with degrees in physics of different emphasis, or with a degree in another field, may be admitted with undergraduate deficiencies if approved by the department adviser. All applicants are requested to take the Graduate Record Examination.

Applicants can apply for teaching fellowships, research fellowships, or partial tuition remission.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE

The requirements for the master of science degree in physics conform to the general Polytechnic requirements. (see Degree Requirements)

The minimum course requirements for the master's degree are as follows:

No.	Subject	Units
PH 667	Quantum Mechanics I	3
PH 953-954	Graduate Seminar I, II	3
PH 901-902	Physics Colloquium I, II	0
	Elective Courses	30

With the approval of the graduate adviser, up to nine units of equivalent courses taken elsewhere may be used to fulfill individual course requirements. Registration for PH 901-902 Physics Colloquium is required each semester for all full-time graduate students. Elective courses may include a 6-unit project in physics or a 12-unit thesis in physics. Choices of a project or thesis option and of elective courses should be made with the approval of the graduate adviser. No comprehensive examination is required for the master's degree in physics.

REQUIREMENTS FOR THE DOCTOR OF PHILOSOPHY DEGREE

Requirements for the Ph.D. degree in physics conform to general Polytechnic requirements. Entrance into the doctoral program of study and research is contingent upon passing the department qualifying examination. The student entering with a bachelor's degree normally takes the qualifying examination after one year of study. The examination, given once a year at the beginning of the fall semester, consists of written questions in classical mechanics, electromagnetic theory, statistical mechanics, and quantum mechanics followed by an oral examination. Sample examination questions are available in the departmental office.

After passing the qualifying examination, the candidate suggests a guidance committee consisting of a prospective research director, a minor adviser, and at least one additional member of the physics faculty. The guidance committee must approve the candidate's choice of courses, conducts the dissertation, precis examination and the final dissertation oral examination, and must approve the dissertation, before the degree can be awarded.

The minimum course requirement for the Ph.D. degree in physics are:

No.	Subject	Units
PH 669-670	Quantum Mechanics III, IV	6
PH 953-954	Graduate Seminar I, II	3
PH 901-902	Physics Colloquium I, II	0
PH 999	Research in Physics	24
	Additional Physics Courses	33
	Minor Courses	12
	Elective Courses **or**	
	Additional Research in Physics	12
	Total:	90

With the approval of the graduate adviser, equivalent courses taken elsewhere may be used to fulfill individual course requirements, although a minimum of 30 units including the dissertation units must be taken at Polytechnic. General knowledge of more than one area of physics is expected of all Ph.D. candidates. There is no foreign language requirement for the Ph.D. in physics. Registration for PH 901-902 Physics Colloquium is required each semester for all full-time graduate students. Registration for PH 999 Research in Physics, once begun, is required each semester consecutively until the completion of the thesis unless leave is formally granted. Until the appointment of the guidance committee, the choice of physics courses, minor courses, and elective courses should be made with the approval of the graduate adviser.

Approximately three months before completion of the dissertation, a precis of the proposed work is circulated to the physics faculty and a precis examination held. Upon completion of the dissertation, an oral thesis defense is held.

CHEMICAL PHYSICS PROGRAM

Chemical physics is an interdisciplinary program designed to train students for careers in those areas common to chemistry and physics. Jointly administered by the Departments of Chemistry and Physics, it provides, within the scope of a normal graduate program, an unusual overlap of

studies, emphasizing those aspects which are closely related to both fields.

UNDERGRADUATE COURSES

PH 091-092   Concepts of Contemporary Physics I, II   each 3:3:4
Topics in both classical and modern physics. Development of physics as a dynamic cumulative process through the interplay of experiment and theory. Co/Prerequisites: MA 091-091.

PH 104   Introductory Physics I   3:0:3
Development of the dynamics of particles and systems of particles within the general principles of symmetry and the conservation laws of physics. *This class meets six hours per week for lectures, recitation, tutorials, and examinations.* Prerequisites: MA101 (or100). Corequisite MA102 (or110). [In addition, EE's must have a grade of C- or better in MA101 (or 100)].

PH 105   Introductory Physics II   3½:0:3½
Continuation of PH 104. Electromagnetic fields and forces, and their interactions with particles. Thermodynamics and kinetic theory of gases. *This class meets five hours per week for lectures, recitations, tutorials, and examination.* Prerequisites: PH104 (or 101) and MA102 (or 110).
Corequisite: Students who register for PH105 must coregister for PH115, unless excused in writing by the Director of the Introductory Physics Program; if they withdraw from one, they must also withdraw from the other. [In addition, EE's must have grades of C- or better in MA101 (or 100), MA102 (or 110), and Ph104 (or 101). MA104 is a preferable corequisite.]

PH 106   Introductory Physics III   2½:0:2½
Continuation of PH 105. Propagation of waves, particularly as illustrated through studies of physical and geometric optics. Sound. *This class meets three hours per week for lectures, tutoreials, and examination.* Prerequisites: PH105 and PH115, (or PH102); MA102 (or 110). Corequisite: Students who register for PH106 must coregister for PH116 unless excused in writing by the Director of the Introductory Physics Program; if they withdraw from one, they must also withdraw from the other. [In addition, EE's must have grades of C- or better in MA101 (or 100), MA102 (or 110), PH104 (or 101), and PH105 (or 102). MA104 is a preferable prerequisite, and MA103 a preferable corequisite.]

PH 115   Physics Laboratory I   0:1½:½
Principles of physical measurements in electric, magnetic, and thermodynamic experiments. Lab fee required. Prerequisite: PH 104. Corequisite: Students who register for PH115 must coregister for PH105 unless excused in writing by the Director of the Introductory Physics Program; if they withdraw from one, they must withdraw from the other.

PH 116   Physics Laboratory II   0:1½:½
Continuation of PH 115. Experiments in optics and sound. Lab fee required. Prerequisite: PH105 and PH115. Corequisite: Students who register for PH116 must coregister for PH106 unless excused in writing by the Director of the Introductory Physics Program; if they withdraw from one, they must also withdraw from the other.

PH 113   Seminar in Current Physics   2:0:2
Analyses, lectures, readings and discussions of selected topics of current interest in physics emphasizing concepts and the underlying framework of physical understanding. Topics include astrophysics, atomic and nuclear physics, the solid state and biophysics. Visiting scientists.

PH 210   Analytical Mechanics   3:0:3
Statistics by virtual work and potential energy methods. Stability of equilibrium. Particle dynamics, harmonic oscillator and planetary motion. Plane rigid body dynamics, Prerequisites: MA 103 and PH 104 (or 101).

PH 230   Introduction to Atomic and Nuclear Physics   2:0:2
Properties of atoms, nuclei and electrons, photoelectrical effect, quantization, Bohr atoms and spectra, wave nature of particles, electron spin and periodic table, radioactivity, structure of nucleus, nuclear reactions. Prerequisite: PH 106 (or 103).

PH 234   Introduction to Modern Physics   2:0:2
Relativity; quantization of electricity, light, and energy; the nuclear atom and electron spin; electron waves; the Schroedinger equation; some properties of solids; atomic physics; nuclear physics and elementary particles. Lectures and discussion sessions. Prerequisites: PH105 and PH115. Corequisite or prerequisite: PH106 and 116; if students withdraw from PH106 while coregistered in PH234, they must also withdraw from PH234. [In addition, EE's must have grades of C- or better in MA101 (or100), MA102 (or110), PH104 (or101), and PH105 (or102). MA104 is a preferable prerequisite, and MA103 a preferable corequisite.]

PH 236   Physics Laboratory III   ½:1½:1
Basic experiments in modern physics. Lab fee required. Prerequisite: PH 116. Corequisite or prerequisite: PH230 or PH234. [Experiments have included such topics as (1) Measurement of e/m for the electron; (2) Spectrometer and atomic spectra; (3) Franck-Hertz Experiment; (4) Geiger-Muller tube and statistics; (5) Gamma-ray spectroscopy; (6) X-ray emission, absorption, Moseley's law, and Planck's constant.]

ƒ PH 250   Electronics for Physical Scientists   3:3:4
Lectures and laboratory on electrical measurements as currently applied in scientific research. Behavior and applications of discrete and integrated solid-state devices in electronic instrumentation. Introduction to measurements of small signals, noise and shielding problems, synchronous detection, and counting techniques. Outlines of digital electronics and descriptions and applications of several interface standards commonly employed for minicomputers in laboratory settings. Prerequisites: PH 106 (or 103) and MA 103.

PH 281   Astronomy and Astrophysics*   3:0:3
Historical development. Traditional and modern observational techniques. Theories of planets, starts, galaxies. Current advances in astrophysics and cosmology. Given on demand. Prerequisite: PH 106 (or 103).

PH 302-303   Advanced Lab I, II*   1:3:2
Precision measurements in mechanics, heat, electricity, optics, modern physics. Lab fee required. Given alternate years. PH 302 co/prerequisite: PH 334, 335. PH 303 co/prerequisite: PH 302, 336.

PH 311   Thermodynamics   3:0:3
Experimental bases of fundamental laws of macroscopic thermodynamics. Operational definitions of heat, internal energy, entropy, absolute temperature and other thermodynamic functions. Techniques of deriving and using thermodynamic relations. Prerequisite: PH 234.

PH 323-324   Electricity and Magnetism   2:0:2 each
Properties of the electrostatic, magnetostatic and electromagnetic field in vacuum and in material media. Maxwell's equations with applications to elementary problems. Prerequisite: MA 104.

PH 335   Quantum Physics II   3:0:3
Electronic and nuclear structures of the atom. Relativity, wave mechanics, natural and artificial radioactivity, fission, cosmic rays. Fundamental experiments and postulates of wave and particle physics. Prerequisite: PH 230, PH 234, or PH 334

PH 336   Quantum Mechanics   3:0:3
Introduction to the calculatical methods of quantum mechanics — with examples and applications. Prerequisite: PH 335.

PHYSICS

PH 340   Computer Methods in Physics   2:2:4
Computer methods for solutions and simulations of a wide variety of
problems in physics. Numerical methods applicable to problems in
mechanics, electromagnetism, optics, statistical mechanics, ele-
mentary quantum mechanics and the interpretation of experimental
data will be discussed. Strategies to determine if computer results
are physically reasonable. Numerical simulation techniques for ex-
perimental and theoretical problems. Students have access to
microcomputers. Prerequisites: CS 111, PH 210 and PH 323.

PH 347   Modern Optics   3:3:4
The physics of contemporary optics. Reflections and refractions of
rays, matrix optics of optical instruments. Interferences and diffrac-
tions of waves and wave packets, Fourier transform optics. Coher-
ence and quantum aspects of light. The laboratory includes com-
puter simulations of optical phenomena, and emphasizes lasers,
holography, crystal optics, and nonlinear phenomena. Prerequi-
sites: PH 324, PH 336 or equivalents.

PH 360   Special Topics in Physics   3:0:3
Lectures in some specialized area, such as acoustics, biophysics, or
relativity. Topics reflect student and faculty interests, and vary from
year to year. The course may be taken for credit more than once, for
different subject offerings. Prerequisites: PH 106 (or 103), PH 334.

PH 372   X-ray Diffraction   2:3:3
Production and properties of x-rays. Elements of crystallography.
Stereographic projections. Powder and single crystal diffraction
techniques. Structures and crystal orientations. Stress analyses and
phse and quantitative chemical analyses by x-ray techniques. Pre-
requisite: MA 104 and PH 106 (or 103).
Also listed under MT 412

**PH 373-374   Introduction to Theoretical
                 Physics I, II   3:0:3**
Mathematical methods used in   classical theoretical physics.
Lagrange's equations, vibrating strings and membranes, flow of
fluids, flow of heat, electrostatics, electrodynamics, Maxwell's equa-
tions. PH 373 prerequisites: PH 210 and PH 324. PH 374 prerequisite:
PH 373.

PH 381-382   Reading Course in Physics I, II   each 2 credits
Special topics in   physics, supervised by staff member. Prerequi-
sites: Physics major, junior standing and departmental approval.

PH 390   Senior Seminar   2:0:2
Topics of general interestt prepared, reported and discussed by
students. Prerequisite: PH 336.

PH 391-394   Bachelor's Thesis in Physics   each 2 credits
An individual investigation involving theoretical, experimental and
bibliographic studies of some problem of interest to physicists.
Students may register for thesis in parts as noted. Total crdits
determined in consultation with advisers.

PH 399   Senior Honors Work in Physics*   credit to be
                                                 arranged
Independent work undertaken by qualified honor students. Course
material arranged by a faculty steering committee.

GRADUATE COURSES

PH 601-602   Physics for Chemists I, II*   each 3¾:0:4½
For doctoral candiates in chemistry with only a general physics
background, training in classical physics, electricity and magnet-
ism, geometrical and physical optics. May not be used for degree
requirements in physics. Required for Ph.D. candidates in physical
chemistry. PH 601 prerequisites: MA 104 and PH 106 (or 103). PH 602
prerequisite: PH 601.

PH 603   Graduate Laboratory*   0:4:3
Practice in experimental research techniques through setting up
and carrying out experimental projects in   classical and modern
physics. Given alternate years. Lab fee required. Prerequisite: PH
304.

PH 604†   Physics of Stars*   2½:0:3
Discussion of internal constitution of stars with emphasis on nuclear
reactions and generation of energy. Current theories of develop-
ment of stars and of giant and dwarf stars. Prerequisite: PH 336.

**PH 605-606†   Special Techniques in
                 Experimental Physics I, II   each 0:3:1½**
A range of specialized techniques and processes of modern experi-
mental physics, depending on requirements of thesis students and
recommendations of advisers. Vacuum techniques, thin-films, prep-
aration of samples for solid-state studies, crystal growing, cryogen-
ics and instrument design. Intensive training in those particular skills
required in student research endeavors. Permission of advisers and
director of the course required. May be taken no more than two
semesters. Prerequisite: concurrent thesis registration.

PH 607   Mathematical Methods of Physics I*   2½:0:3
Vector and tensor analysis. Complex variable theory. Special func-
tions of mathematical physics. Differential equations of mathemati-
cal physics. Unifying roles of mathematics in physics on physical
conepts and problems. Prerequisites: PH 321 or equivalent and Co/
Prerequisite: PH 313 or equivalent. .

PH 608   Mathematical methods of Physics II*   2½:0:3
N-dimensional vector spaces and Hilbert space. Calculus of varia-
tions and eigenvalue problem. Green's function solutions to differen-
tial equations. Integral equations. Unifying roles of mathematics in
physics and physical concepts and problems. Prerequisite: PH 607
or equivalent.

**PH 612†   Microcomputer Instrumentation
              for Scientific Research***   2½:0:3
Fundamentals of digital electronics and minicomputers; computer-
automated laboratory instrumentation; programming and interfac-
ing required for data acquisition and control in scientific research.
Experiments with minicomputers and with laboratory apparatus
interfaced directly to minicomputers. Lab fee required. Prerequisite:
instructor's permission.
Also listed under CM 760 and BE 623

PH 615   Theoretical Mechanics I   2½:0:3
Principles of particle and rigid body dynamics. Lagrange's equa-
tions. Small vibrations of coupled systems, normal modes of oscilla-
tion. Prerequisite: PH 313 or equivalent.

PH 616   Theoretical Mechanics II   2½:0:3
Hamiltonian mechanics. Transformation theories of mechanics in-
cluding the Hamilton-Jacobi and Poisson bracket formulation,
Lagrangean formulation of mechanics of continuous media. Prereq-
uisite: PH 615.

PH 624   Electromagnetic Theory I   2½:0:3
Maxwell's equations. Plane waves. Relativistic covariance of electro-
magnetic field. Motion of charges in fields. Fields of moving charges.
Hertz and Lienard-Wiechert potentials. Radiation from charges, di-
poles and quadrupoles. Prerequisite: PH 321.

PH 625   Electromagnetic Theory II   2½:0:3
Interaction of electromagnetic fields with material media from classi-
cal viewpoint. Macroscopic description of dielectric, magnetic and
conducting materials, energy relations, dispersion, and attenuation
in dielectrics and ionized media. Wave propagation in anisotopic
crystals and ferrites; waves in inhomogeneous media. Prerequisite:
PH 623.
Also listed under EL 673

**PH 633-634†   Introduction to Nuclear and Elementary
                 Particle Physics I, II***   each 2½:0:3
Fundamental properties of atomic nucleus and its constituents.
Two-body problems at low energies and the theory of nuclear forces.
Nuclear radioactivities such as alpha-, gamma- and beta-decay.
General features of nuclear reactions and of the various nuclear
models. Basic properties of elementary prarticles, their modes of
decay, interactions, classifications and invariance laws. PH 663
prerequisite: PH 336. PH 634 prerequisite: PH 633.

PH 635 Biophysics I*   2½:0:3
Physical properties of biological systems. Natural properties of biological components. Structural strength, elasticity of bones, muscle, other tissue. Flow properties through tissue, diffusion of gases and liquids, flow through vessels. Compartmental analysis, models, trace analysis. Effects of stimuli on various body organs and mechanisms. Temperature effects, electrical excitations. Prerequisite: PH 335 or equivalent.
Also listed under BE 603

PH 636 Biophysics II*   2½:0:3
Transport processes in and models of the specific organs. Application of radionuclides and dyes for static and dynamic imaging. Theoretical and practical aspects of nerve conduction with detailed discussion of the Hodgkin-Huxley and current models. Prey-predator interactions in biological systems on the cellular level, in radioimmunoassays and in population control. Prerequisite: PH 635.
Also listed under BE 604

**PH 637 Radiation Physics with Biological and
           Medical Applications***   2½:0:3
Principles of atomic and molecular physics with stress on the problems of radiation and biological effects of ionizing radiation. Radiation dosimetry including internal and external exposures and relationship between doses, biological behavior of radionuclides, radiation and thermal radiation. Prerequisite: PH 335 or equivalent.
Also listed under BE 605

PH 638 Quantum Mechanics with Applications   2½:0:3
Wave mechanics with applications to atomic and nuclear systems. Use of Schrodinger wave equation with perturbation theory for eigenvalue/eigenfunctions of harmonic oscillator and hydrogen atom. Time dependent perturbation for radiation and collisions and applications to atomic nuclei. This course can be used by medical physics students to satisfy the prerequisites of PH 667 for a master's degree in physics. Prerequisite: PH 335 and PH 336 or equivalents.

**PH 651-652† Introduction to Solid-State
               Physics I, II**   each 2½:0:3
Phenomena and theory of physics of crystalline solids. Topics from thermal, magnetic, electrical and optical properties of metals, insulators and semiconductors. PH 651 prerequisite: PH 336. PH 652 prerequisite: PH 651.

PH 663 Statistical Mechanics I   2½:0:3
Equilibrium distributions. Relationships to laws of thermodynamics. Quantum effects. Maxwell-Boltzmann, Fermi-Dirac, Bose-Einstein distributions. Applications to bulk properties of phenomena using Boltzmann transport equation. Prerequisite: graduate status.
Also listed under EL 651

PH 664 Statistical Mechanics II   2½:0:3
Micro-, macro-, and grand-canonical ensembles and principles of classical statistical mechanics. Condensation phenomena. Treatment of fluctuation and transport phenomena. Density matrix formalism of quantum statistical mechanics. Many-body problems. Prerequisites: PH 663 and PH 667, or equivalents.
Also listed under EL 652

PH 667-668 Quantum Mechanics I, II   each 2½:0:3
Quantum mechanics with applications to atomic systems. The use of Schroedinger's equations. Angular momentum and spin. Problems and approximation methods. Semiclassical theory of field-matter interaction.
Also listed under EL 655-656

PH 669-670 Quantum Mechanics III, IV*   each 2½:0:3
Theory of measurement and connection with classical dynamics. The Dirac formulation, transformation theory, scattering theory and introduction to the theory of radiation. PH 669 prerequisites: PH 616, PH 624 and PH 667-668. PH 670 prerequisite: PH 669.

PH 671 X-ray Diffraction I*   2½:0:3
Theory of x-ray scattering, crystallography and crystal optics, diffraction by crystalline materials, space group theory, theory of x-ray diffraction methods, including Laue techniques, rotating crystal and moving film methods, single crystal diffractometry. Introduction to powder methods.

PH 672† X-ray Diffraction II*   2½:0:3
Interpretations of x-ray powder data. Theories and methods of crystal structure analysis, crystallite size determination scattering by amorphous substances, crystal perfection, small angle scattering. Prerequisite: PH 671.

PH 673-674† X-ray Diffraction Techniques I,* II*   0:4:3
Laboratory course. The generation, detection and properties of x-rays. Orientation of single crystals powder methods, interpretation of patterns and applications to solid state problems. Determination of space groups. Intensity measurements. Stress-strain analysis, small-angle scattering and scattering by amorphous materials. Lab fee required. PH 673 co/prerequisite: PH 671. PH 674 prerequisite: PH 673 and co/prerequisite: PH 672.

**PH 676 Methods of Crystal Structure
           Determination***   2½:0:3
Theory of crystal structure analysis. Trial and error methods. Patterson function and electron density maps Direct methods. Least squares refinement procedures. Computing methods. Prerequisite: PH 672.

PH 751-752 Theory of Solids I, II*   each 2½:0:3
Quantum and statistical mechanics of the band theory of solids as applied to electrical, thermal and optical properties of metals, semiconductors and insulators. PH 751 prerequisites: PH 664 and PH 668. PH 752 prerequisite: PH 751.

PH 753-754 Crystal Dynamics I, II*   each 2½:0:3
Particular physical properties of crystals arising from anisotropy of matter constants. Thermal, electrical, optical, and elastic properties and effects arising from coupling of these properties. Interpretations of these material constants according to modern atomistic theory and principles of crystal symmetry. PH 753 prerequisites: PH 616 and PH 624. PH 754 prerequisites: PH 668 and PH 753.

**PH 761-762 Relativistic Quantum Mechanics
               and Field Theory I, II***   each 2½:0:3
Dirac theory of the electron and positron, application of Dirac equation for discussion of electron spin and fine structure of hydrogen atom spectrum. Feynman's positron theory in comparison with Dirac's hole theory. Scattering of relativistic particles Brief review of Langrangian formalism of classical fields. Quantization of fields, scattering and the S-matrix theory. Feynman diagrams and re-normalization theory. Applications of dispersion relations to strong interactions. PH 761 prerequisite: PH 670. PH 762 prerequisite: PH 761.

PH 763-764 Nuclear Theory I, II*   each 2½:0:3
Fundamental properties of nuclei. Advanced quantum mechanical treatment of nuclear forces, nuclear reactions. nuclear structures, nuclear radiation and the theory of beta-decay. Models of nuclear structure and nuclear reactions. Prerequisite: PH 670 or equivalent.

**PH 765-766 High-energy Physics and
               Elementary Particle Theory I, II*** each 2½:0:3
Basic properties of particles, their interactions and invariance laws of particle physics. Fundamental properties and quantum numbers of the elementary particles, classification of interactions. invariance under space reflections, time reversal, charge conjugation, isotopic spin. Calculation of cross-sections, branching ratios. lifetimes. Higher symmetry schemes of SU (3), SU (6), etc. Field theory and second quantization. PH 765 prerequisite: PH 670 PH 766 prerequisite: PH 765.

**PH 780   Special and General Theory
                    of Relativity***   2½:0:3
Einstein's theory of relativity, Minkowski geometry, relativistic mechanics and electrodynamics, applications of theory with special reference to high-energy physics; gravitationand principle of equivalence, Riemannian geometry, curvature tensor; equations of Einstein's theory of gravitation, approximate and rigorous solutions, observational tests of the theory, theory of pondermotive equations. Prerequisites: PH 616 and PH 624 or equivalents.

**PH 801-802   Selected Topics in
                        Advanced Physics I, II***   each 2½:0:3
Current or advanced toppcs of particular interest to graduate students. Subject matter determined each year by students and faculty. May be given in more than one section. Consult department office for current offerings.

PH 901-902   Physics Colloquium I, II   each 2:0:0
Topical subjects of experimental and theoretical physics by the staff and outside lecturers. Fee required. Required of all master's and doctoral candidates.

PH 953-954   Graduate Seminar I, II   each 1½ units
Presentations by participating students and discussion of topics in physics of current interest and from the literature.

PH 955-956   Reading in Physics I, II   each 2½:0:3
Selected papers and current literature in a specialized field of physics guided by a faculty member. Prerequisite: graduate adviser's and supervising faculty member's permission.

PH 999   Research in Physics   each 3 units
An original investigation in some branch of physics or chemical physics, which may serve as basis for the degree of master of science or doctor of philosophy, to be performed under the direction of a member of the department. Chemical physics majors should register for appropriate CM courses. The number of research credits registered for each semester should reflect realistically the time devoted to research. Prerequisites: degree status and graduate adviser's and research director's consent.

FACULTY

Edward L. Wolf, Professor of Physics and Head of Department B.A., Swarthmore College; Ph. D., Cornell University
Solid state physics, scanning tunnel microscopy, and electron tunneling specroscopy.

Stephen Arnold, Thomas Potts Professor of Physics
B.S., University of Toledo; M.A., Ph.D., CCNY
Organic solid-state and microparticle photo-physics

Raphael Aronson, Professor of Physics
B.S., University of Minnesota; M.A., Ph.D., Harvard University
Transport theory

Patrick T. Cahill, Professor of Physics
B.S., M.S., University of New Hampshire; Ph.D., Harvard University
Medical physics magnetic resonance imaging, atomic physics

Deo C. Choudhury, Professor of Physics
B.Sc., M.Sc., University of Calcutta (India); Ph.D., University of California
Theoretical nuclear physics

Hellmut J. Juretschke, Professor of Physics
B.S., M.A., Ph.D., Harvard University
Surface and condensed matter physics

Terje Kjeldaas, Jr., Professor of Physics
B.S., Polytechnic Institute of Brooklyn; M.A., Columbia University; Ph.D., University of Pittsburgh
Theoretical solid state and atomic physics

Erich E. Kunhardt, Professor of Electrophysics (Electrical Engineering), Professor of Physics, and Director of the Weber Research Institute
B.S. and M.S., New York University, Ph.D. Polytechnic Institute of New York
Plasma Physics, Non-equilibrium properties

Peter S. Riseborough, Professor of Physics
B.S. and Ph.D., Imperial College, London
Theoretical condensed matter

Gerhard Schaefer, Professor of Electrophysics (Electrical Engineering) and Professor of Physics
B.S. and Ph.D. in Physics, Technical University of Berlin
Laser physics, laser chemistry, gaseous electronics

Nathan Wainfan, Professor of Physics
B.E.E., M.S., New York University, Ph.D., University of Southern California
X-ray physics; gas discharges

Hilda Bass, Associate Professor of Physics
B.A., Hunter College; M.A., Smith College
Atomic and nuclear physics; physics education

Meir Menes, Associate Professor of Physics
B.S., Cooper Union; Ph.D., New York University
Experimental solid-state physics; gaseous electronics

Donald B. Scarl, Associate Professor of Physics
B.A., Leigh University; Ph.D., Princeton University
Quantum optics; atomic physics

Lorcan Folan, Assistant Professor of Physics
B.Sc. Trinity College, Dublin; Ph.D. Polytechnic University
Energy transfer in condensed matter, aerosols

K. Ming Leung, Assistant Professor of Physics
B.S., University of Missouri, Ph.D., University of Wisconsin
Theoretical condensed matter and surface physics

ADJUNCT FACULTY

Benjamin Bloch, Adjunct Associate Professor of Physics
B.A. Columbia University, Ph.D., Polytechnic Institute of Brooklyn

Walter Kiszenick, Adjunct Professor of Physics
B.S. Brooklyn College; M.S., Ph.D., Polytechnic Institute of Brooklyn

Rajiv S. Ravi, Adjunct Assistant Professor of Physics
B.Sc. and M.Sc., University of Mysore

EMERITUS FACULTY

John J. Dropkin, Professor Emeritus
B.A., Columbia University; M.S., Ph.D., Polytechnic Institute of Brooklyn
Solid-state physics

PHYSICS

Benjamin Post, Professor Emeritus, Research Professor
B.S., CCNY; M.S., Ph.D., Polytechnic Institute of Brooklyn
X-ray physics, crystallography, solid-state chemisry

H. William Schleuning, Professor Emeritus
M.A. New York University
Vacuum and thin films

RESEARCH FACULTY

Marten L. denBoer, Research Adjunct Professor of
Physics
B.A., Calvin College; M.S., Ph.D., University of Maryland
Surface and condensed matter physics

Peter Hanggi, Research Professor of Physics
B.S., College of Mathematics and Natural Sciences, Basel;
M.S., Ph.D., University of Basel (Switzerland)
Statistical mechanics, quantum tunneling

Sarath C. Meepagala, Research Assistant Professor of
Physics
B. Sc., University of Colombo; M.S., Ph.D., Wayne State.
Scanning Tunneling Microscopy, Superconducting Devices

POLYMER SCIENCE AND ENGINEERING

For many years, Polytechnic University has had a traditional commitment to strong polymer programs of worldwide renown. At the present time, the Departments of Chemical Engineering and Chemistry jointly offer graduate programs leading to the degrees of master of science and doctor of philosophy in polymer science and engineering.

GRADUATE STUDY

An undergraduate degree in either chemical engineering or chemistry with a mathematics background which includes at least one course in differential equations is usually required for admission to the graduate program. Applicants who have earned bachelor's degrees from foreign institutions are required to submit Graduate Record Examinations and TOEFL scores. Applicants with degrees in other fields or from other colleges may be admitted with undergraduate or graduate deficiencies after the consent of a graduate adviser is given.

The program leading to the degree of master of science is designed to meet the needs of engineers and chemists well versed in the fundamental principles of polymer science and engineering.

REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN POLYMER SCIENCE AND ENGINEERING

Candidates for the degree of master of science in polymer science and engineering are to plan their programs in accordance with the following required courses:

No.	Subjects	Units
CH 921	Polymer Processing	3
CH 922	Polymer Processing Laboratory	3
CH 926	Engineering Properties of Polymers	3
CM 771	Introductory Polymer Chemistry	3
CM 783	Laboratory Methods in Polymer Chemistry	3
CH 991-992	Seminar	0

Chosen Electives* from such courses as: CH 862, CH 917, CH 924, CH 928, CH 933, CH 940-941, CM 760, CM 772, CM 781, CM 782, CM 785, CM 801, CM 905, AM 603-604, AM 606, AM 625, MT 412, MT-603, MT 620, PH 673-674, PH 676
Project/Thesis Option
Either

CH 930	Guided Studies in Polymer Science and Engineering	6
	Electives — from above listing	3
or		
CH 987	Master's Thesis	9
	Total	36

REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN POLYMER SCIENCE AND ENGINEERING

The program for the degree of doctor of philosophy in polymer science and engineering includes advanced graduate work for qualified students interested in research and development. Students enrolled in the program may select elective courses either from polymer chemistry or from polymer engineering offerings. Polymer science and engineering may also be chosen as a minor by students in the chemistry department or the chemical engineering department.

Programs of study are planned individually with each candidate by members of the Departments of Chemical Engineering and Chemistry. Systematic study toward the Ph.D. is carried out under the direction of a guidance committee appointed by the vice president for research and graduate affairs for each candidate. The program is planned to give students a thorough polymer science and engineering background accompanied by study in a minor field chosen by the candidate. Students must pass a comprehensive qualifying examination in polymer science and engineering and present a doctoral dissertation.

Each candidate for the doctorate must complete a minimum of 90 units of academic work beyond the bachelor's degree, including a minimum of 30 units of dissertation research. Although the student may elect to take more than 30 units of Ph.D. thesis, only 30 units of Ph.D. thesis can be counted in the required 90 unit minimum, and these must be taken at Polytechnic. Once the student has started the dissertation, registration must be continuous (excluding summer sessions) until it is completed and accepted. Of the 90 units, a minimum of 30 units must be taken at Polytechnic. A minimum of 48 graduate units beyond the bachelor's degree (not including Ph.D. thesis) in polymer science and engineering subjects are required, of which at least 18 units must be taken at Polytechnic. A minor is required within a science or engineering department and should consist of at least 12 units.

Attendance is required at the chemical engineering or polymer science and engineering seminars for at least four semesters. Each student must maintain an overall B average in those courses submitted for doctoral degree.

*All electives are to be chosen in conference with the graduate adviser.

POLYMER SCIENCE AND ENGINEERING

For a Ph.D. degree in polymer science and engineering, the following courses are required and may be used to complete the 48 graduate units required:

No.	Required Subject	Units
CM 772	Synthesis of High Polymers	3
CM 781	Solution Properties of High Polymers	3
CM 782	Macromolecules in the Solid State	3
CM 783	Laboratory Methods in Polymer Chemistry	3
CH 921	Polymer Processing	3
CH 922	Polymer Processing Laboratory	3
CH 926	Engineering Properties of Polymers	3
	Total	21

Students interested in the Ph.D. program should obtain brochures outlining procedures and requirements, available from the office of the polymer science and engineering program director.

GRADUATE COURSES

CH 862   Rheology of Non-Newtonian Fluids*   2½:0:3
Classifications of non-Newtonian viscoelastic fluids. Derivation of rheological equations of state from continuum mechanics points of view. Molecular viscoelastic theories will be discussed. Experimental characterizations of non-Newtonian fluids; steady and dynamic experiments, measurements of normal stress differences in shear flow. Engineering applications to polymer processing operations. Prerequisites: CH 631, MA 531 and MA 532 or equivalent.

CH 917   Introduction to Polymeric Materials   2½:0:3
Principles of technological aspects of polymerization, compounding and processing of polymeric materials, their properties and applications. Thermoplastic materials such as polyethylene, polypropylene, poly (vinyl chloride), polystyrene, acrylics and engineering plastics are discussed. Thermosetting materials covered include phenolics, epoxies, unsaturated polyesters, aminoplastics, polyurethanes and silicones. Prerequisite: CM 123 or equivalent.

CH 921   Polymer Processing   2½:0:3
Applications of engineering principles of polymer processing. Non-Newtonian polymeric systems. Extrusion theory and applications. Discussions and problem-solving in injection molding, fiber spinning, film blowing, and co-extrusion, as well as other polymer engineering processes. Prerequisite: CH 220 and CH 221 or instructor's permission

CH 922   Polymer Processing Laboratory   0:4:3
Engineering principles and processes involved in polymer processing and analysis. Experiments include injection molding, extrusion, thermoforming, mixing and compounding, melt rheology, flat- and blown-film extrusion, blow molding. Prerequisite: CH 921.

CH 924   Polymerization Reaction Engineering   2½:0:3
Principles of polymerization reactions, such as chain polymerization and heterogeneous polymerization reactions, from engineering points of view, including mixing and thermal effects. Mathematical modeling techniques for describing molecular weight moments. Copolymer composition and sequence distribution. Principles of polymer reactor design. Model parameter estimation and reactor control. Prerequisite: CH 781 or equivalent.

CH 926   Engineering Properties of Polymers   2½:0:3
Mechanical properties and structures of solid polymers. Viscoelastic theory and response of amorphous, crystalline and composite materials in stress-strain, creep, stress relaxation and dynamic tests. Effects of orientation and previous history of mechanical behavior. Prerequisites: CH 917, CM 771.

CH 928   Polymer Composites   2½:0:3
Production, properties and durability of polymer composites. Emphasis on fiber-reinforced thermosets. Chemical compositions, cure kinetics, processing, viscoelasticity and fracture mechanics. Behavior of composites in service analyzed in terms of their structures. Prerequisites: CH 921, CH 926.

CH 933   Coatings Technology   2½:0:3
Chemistry, manufacture and applications of organic film formers; solvents and solubility principles; mechanisms and methods of film application, formation, conversion. Chemistry, manufacture and applications of pigments. Principles and methods of pigment dispersion and coatings preparation, including influence of rheology and surface chemistry. Principles of formulation of important paints and clear coatings. Specifications and test methods for coatings. Prerequisite: CM 123 or equivalent.

CH 940-941   Selected Topics in Polymer
Science and Engineering I, II*   each 2½:0:3
Topics of special interest in polymer science and engineering are announced in advance of each semester offering. Prerequisite: adviser's approval.

CM 771   Introductory Polymer Chemistry   2½:0:3
Synthesis of polymers by step reaction and addition polymerization, formation of three-dimensional networks, block and graft polymers, polymer degradation, characterization of polymers in solution, rubber elasticity, polymer crystallization, spectroscopic techniques for polymer study, properties of commercial polymers. Prerequisites: CM 123, CM 125 and CM 162.

CM 772   Syntheses of High Polymers   2½:0:3
Organic aspects. Chemistry of monomer and polymer formation. Modern mechanistic analyses of reactions. Stereochemistry of polymer structures and forces of stereoregulation. Condensation, free radical (bulk, suspension, emulsion, solution), ionic, ring-opening and nonclassical polymerization reactions.

CM 781   Solution Properties of High Polymers   2½:0:3
Applications of osmometry, light scattering, equilibrium ultracentrifugation, electrophoresis, viscosity, diffusion, ultracentrifuge sedimentation, flow birefringence, polarimetry, spectroscopy and other techniques to the characterization of dissolved macromolecules. Properties of polyelectrolytes, association in solutions containing macromolecules and reaction kinetics in macromolecular solutions. Synthetic and biological macromolecules are covered. Prerequisites: CM 161, MC 162, and CM 771 or CM 783.

CM 782   Macromolecules in the Solid State   2½:0:3
Crystalline-amorphous systems, thermodynamics of crystallization, defect structures, morphology of polymer crystals. Characterization of polymeric solids by x-ray and electron diffraction, potential energy calculations, electron microscopy, absorption spectroscopy and nuclear magnetic resonance. Electrical and optical properties of polymer solids. Prerequisite: CM 771.

CM 783   Laboratory Methods of Polymer Chemistry   0:5:3
Experiments on free radical, condensation, ionic and copolymerization, absorption, and NMR spectroscopy, intrinsic viscosity, light scattering, gel permeation chromatography, x-ray diffraction, thermogravimetric analysis, differential scanning calorimetry, dilatometry, concentrated solution viscosity, and other aspects of polymer synthesis and characterization. Lab fee required. Prerequisite: CM 771.

CM 785   Special Topics in Polymer Chemistry   2½:0:3
Presentation at intervals of various advanced or specialized topics in polymer chemistry.

PROJECTS, THESES AND SEMINARS

**CH 930   Guided Studies in Polymer Science
              and Engineering   6 units, each 2 units**
Presentations of a comprehensive report of some problems involving polymer science and engineering, such as polymer synthesis, processing, evaluation, or equipment design is required. Candidates for master's degree are required to submit three unbound copies of typewritten project report to advisers one week before last day of classes. Prerequisite: degree status.

**CH 987   Thesis for Degree of Master of Science
              in Polymer Science
              and Engineering   9 units, each 3 units**
Thesis for master's degree in polymer science and engineering should give results of original investigations of problems in polymer science and engineering. Theses may involve experimental research, theoretical analyses, or process designs, and possibly a combination thereof. Candidates for master's degree are required to submit four typewritten unbound thesis copies to advisers before or on seventh Wednesday prior to commencement. Prerequisite: degree status.

**CH 989   Dissertation for Degrees of Doctor of
              Philosophy in Polymer Science
              and Engineering   30 units, each 3 units**
Dissertation must give results of independent investigations of problems in polymer science and engineering and may involve experimental and/or theoretical work. Thesis must show original contributions to polymer science and engineering worthy of publication in recognized journals. The candidate is required to take an oral examination on subject of thesis and on related topics. Candidates for a doctor's degree are required to submit five unbound thesis copies to advisers before or on the seventh Wednesday prior to commencement. Prerequisite: degree status and a qualifying examination on quantitative aspects of polymer science and engineering.

CH 991-992   Seminar in Chemical Engineering   0:2½:0
Recent developments in the field of chemical engineering or polymer science and engineering will be presented through lectures given by engineers from industry, research, and educational institutions, by staff members, or by qualified graduate students. Required for two semesters of all graduate students seeking degrees.

FACULTY

Chang Dae Han, Professor of Chemical Engineering, Director of Polymer Science and Engineering Program

T.K. Kwei, Professor of Polymer Chemistry

Yoshiyuki Okamoto, Professor of Chemistry

Eli M. Pearce, Professor of Polymer Chemistry and of Chemical Engineering, Dean of Arts and Sciences

Arnost Reiser, Research Professor and Deputy Director of the Institute for Imaging Sciences

William H. Starnes, Professor of Polymer Chemistry

Giuliana Tesoro, Research Professor of Chemistry

Otto Vogl, Herman F. Mark Professor of Polymer Chemistry

Mary K. Cowman, Associate Professor of Biochemistry

Jovan Mijovic, Associate Professor of Chemical Engineering

William Braunlin, Assistant Professor of Chemistry

SOCIAL SCIENCES

UNDERGRADUATE PROGRAMS

Programs in social sciences consist of a core curriculum in contemporary liberal arts and course concentrations in history, history of science, economics, behavioral science, and psychology. The core curriculum was conceived to meet increasing needs for specialists in the social sciences who are familiar with computers, the physical sciences, mathematics and the humanities. Students are offered specialized training in the social sciences in settings noted for their scientific and technical excellence. Degrees are interdisciplinary, with emphasis on developing integrated historical, economic, behavioral and cultural perspectives on human society and behavior.

Social science backgrounds are useful in teaching at all levels; in applied research on problems involving race, poverty, and education; urban and national planning; management, personnel operations and market research; environmental impact evaluation; foreign policy assessment; law; and medicine. Social science degrees provide an excellent basis for further education and advanced professional training. Graduates are employed in government agencies, foundations, private industry, and independent practice.

The department is also responsible for the social science courses which provide general education and professional training for scientists and engineers at Polytechnic. Foundations in the social sciences prepare students for leadership in industry, education, and government.

HISTORY AND THE HISTORY OF SCIENCE AND TECHNOLOGY

Courses in history emphasize elements of social and economic change in various areas and periods since the Renaissance. Methods and conclusions of related work in economics and the behavioral sciences are applied. Basic sequences in the history of western civilization familiarize students with political, economic, social, cultural and intellectual developments in European history since the Middle Ages. They also introduce them to original documents and scholarly interpretations. Science and technology have been pivotal in modern historical development and social change, especially in our own epoch, and are emphasized in all introductory courses. An introductory course on the modern world stresses the conflicts of ideologies in the twentieth century and the history of non-Western societies. Students analyze and discuss the best historical scholarship in a variety of special subjects: history of science and technology, development of modern Russia, international communism, American civilization, Afro-American and non-Western history, the Renaissance, imperialism, European thought, and twentieth century thought. Methods of instruction are varied and include formal lectures, discussions, colloquia, films, and tutorials leading to independent research. Students can major in the history of science and technology and benefit from one of the most comprehensive programs available in the New York area. Career openings in history and history of science and technology include law, medicine, teaching, public relations, and all fields of media and communications.

ECONOMICS

Economics courses guide students in developing critical understanding of contemporary economic ideas and their roots, institutions and problems. These courses pose, in their theoretical and historical contexts, important questions of domestic and international public policy.

Majors in economics receive thorough grounding in the tools of economic analysis, mathematics, and statistical methods. Concentration in economics prepares students for careers in governmental service, business and graduate work, not only in economics but in any of the social sciences. Theoretical training is applied to actual economic problems and circumstances.

BEHAVIORAL SCIENCES

Introductory courses in anthropology, politics, sociology, psychology and environmental psychology broaden students' understanding of social processes and human behavior and prepare them to meet professional and administrative problems with insight and sophistication. For students majoring in behavioral sciences, advanced courses provide detailed and intensive study. These courses examine contemporary American society and its impact on the individual, the variety of social and cultural forms which have unfolded in the course of history and their implications for the contemporary world as new nations enter the historical mainstream, and language, learning, and the modification of behavior with experiments in psychophysics, learning theories and communications. Students have opportunities to become acquainted with the range of behavioral science methods, from participant observation and structured interviewing to opinion sampling, psychological testing and controlled laboratory experiments.

PSYCHOLOGY

Courses introduce students to psychology as the science of behavior and emphasize that learning is an active process which can be empirically investigated. The department offers advanced courses in social, environmental, developmental, personality, comparative, physiological, learning and abnormal psychology. The major focus is experimental, and all majors take a two-semester laboratory sequence, which offers fundamental methods and concepts in the empirical investigation of human and animal behavior. Other psychology courses allow ample opportunities for students to design and complete individual research projects under the supervision of instructors. A concentration in psychology enables students to pursue graduate training in psychology and other fields including psychotherapy, social work, marketing research, personnel management, organizational behavioral, and social impact assessment.

REQUIREMENTS FOR THE BACHELOR'S DEGREE IN SOCIAL SCIENCES

Core Curriculum	Credits
Polytechnic Requirements (HU 101 and HU 200*; SS 104)	9
Mathematics courses	8
Sciences and technology courses	12
Core courses: Liberal Arts & Social Sciences	28
	57

Concentrated Studies in the Major Electives:	33-42
Humanities electives	6
Social Science electives	6
Free Electives	24-15

Total credits for graduations 126

Core Curriculum

For a full description of courses available in the Contemporary Liberal Arts Core Curriculum see pp. 115-117. These courses may be used to fulfill requirements for Bachelor of Science degrees in social sciences.

CONCENTRATIONS FOR MAJORS IN SOCIAL SCIENCES

(Students may choose from the following courses to fulfill requirements for major concentrations.)

History[1]

SS 101	History of Western Civilization I (1500-1815)
SS 102	History of Western Civilization II (1815-1914)
SS 109	The Birth of Modern Europe
SS 110	The Renaissance and Reformation
SS 116	History of Latin America
SS 120	History of Tsarist Russia to the Revolution
SS 121	History of the Soviet Union
SS 123	History of the United States: From Settlements to Reconstruction
SS 124	History of the United States: From Reconstruction to the Cold Wars
SS 126	Afro-American History
SS 128	History of Jazz
SS 154	Russia, China, and the West
SS 161	Politics and Film
SS 179	Sociology of Human Diseases
SS 221	The Contemporary U.S.S.R.
SS 226	Problems of American Foreign Policy
SS 229	Growth of the United States Constitution
SS 345	Colloquium on 20th Century Thought
SS 347	Colloquium on Imperialism
SS 348	Colloquium on the History of Socialism and Communism

History of Science and Technology

SS 133	Archaeo- and Ethnoastronomy
SS 135	History of Science and Technology: Antiquity to Galileo
SS 136	History of Science and Technology: Galileo to Darwin
SS 137	History of Science and Technology: Faraday to the Present
SS 138	Technology, Science, and Contemporary Society
SS 330	History and the Environment
SS 332	Science and Technology in America
SS 333	Medieval and Renaissance Engineering
SS 338	Galileo Galilei: The Man, his Research, the Times
SS 354	Technological Forecasting
SS 357	Technology Transfer to Developing Countries
SS 358	Human Resource Development in Advanced Developing Countries
SS 602	Seminar in the History of Science
SS 615	Guided Reading in the History of Ideas
SS 616	Guided Reading in the History of Science
SS 625	History of Technology: Antiquity through Early Industrial Revolution
SS 626	History of Technology: Industrial Revolution to the Present
SS 635	History of Psychology

Behavioral Sciences

SS 177	Social Problems
SS 178	Minorities in the New World
SS 182	Man and the Environment
SS 203	Learning
SS 204	Physiological Psychology
SS 210	Environmental Psychology
SS 214	Social Psychology
SS 215	Abnormal Psychology
SS 216	Personality Development
SS 217	Psychology of Human Development
SS 279	The Sociology of Human Disease
SS 299	Organizational Behavior
SS 310	Genes, Gender, and Society
SS 354	Technological Forecasting

Psychology

SS 189	Introduction to Psychology
SS 203	Learning
SS 204	Physiological Psychology
SS 205	Applied Psychology
SS 206	Human Cognition
SS 208	Experimental Psychology I (required)
SS 209	Experimental Psychology II (required)
SS 210	Environmental Psychology
SS 214	Social Psychology
SS 215	Abnormal Psychology
SS 216	Personality Development
SS 217	Psychology of Human Development
SS 299	Organizational Behavior
SS 310	Genes, Gender, and Society
SS 635	History of Psychology

Economics

SS 250	Basic Economics
SS 251	Micro Economics
SS 252	Macro Economics
SS 254	Economic Issues
SS 255	The Contemporary American Economy: Boom and Bust
SS 257	History of Economic Thought
SS 262	Collective Bargaining
SS 263	Labor Economics
SS 264	Urban Economics
SS 265	Money and Banking
SS 267	The Market for Engineers and Scientists
SS 354	Technological Forecasting

*IS 140-141 may be taken in place of HU 200 and SS 104.

GRADUATE STUDY

The Department of Social Sciences offers courses leading to the master of science degree in the history of science and technology and in environment behavior studies. Courses in these programs are intended for students with a B.A. in a social science field, or for graduate students in science and engineering interested in pursuing the interdisciplinary links between their own specialties and the social sciences. Students are encouraged to apply for research fellowships, teaching fellowships, or partial tuition remission.

History of Science and Technology— The master's program in the History of Science and Technology was the first of its kind to be offered in the New York City area. The need for advanced study of the growth of science and technology and their interactions with human society and values has become increasingly evident. Intense specialization has further heightened the need for understanding among the various branches of science and the humanities. In considering ideas, time, process, transfer and social changes in the history of science, students are able to explore the elusive connections which exist between science and engineering and the social sciences and humanities. Prospective teachers of science and engineering subjects are able to increase their effectiveness through knowledge of the history of their own and related disciplines. Polytechnic's libraries contain many important and rare works on the history of science which may be used for original research.

A total of 36 units is required for the master's degree. Normally students start by taking introductory courses, SS 600 and SS 601, and then proceed to more advanced courses and seminars. In all cases programs are constructed in consultation with advisers, taking into consideration individual backgrounds and interests. The student will be encouraged to take nine units of work in related fields outside the program; for example, in philosophy, mathematical logic, Renaissance history or one of the sciences or engineering.

To qualify for degrees, students may elect to write either a comprehensive examination or a thesis embodying appropriate and substantive research. If students choose the former, examinations may be taken in the term in which courses are completed. A student choosing the thesis may apply up to 12 units of thesis course work toward requirements for the degree. Acceptance of a thesis involves an oral presentation and defense. In addition to these requirements, students must demonstrate reading knowledge of one foreign language—either French, German, Russian or Spanish.

Environment-Behavior Studies— The Department of Social Sciences offers the master of science degree in **Environment-Behavior Studies,** an area which combines expertise in the behavioral sciences and design professions.

The program is designed for students with a variety of backgrounds who can combine their abilities and past experiences with programs available at Polytechnic to develop skills to deal with environmental problems.

Students plan individualized programs in consultation with faculty advisers consisting of a series of basic courses and a number of electives to develop expertise in behavioral science research methods and areas of specialization which reflect their own backgrounds and interests.

In addition to courses in Environment-Behavior studies, these electives may include courses given in other programs offered at Polytechnic such as transportation planning, solar energy, or environmental impact assessment. Program requirements also include a master's thesis.

These programs enable students to become environmental professionals capable of addressing socio/technical problems in a variety of research and applied settings. Students with design, technical, or scientific expertise are especially encouraged to apply.

Full- and part-time programs are offered at the Brooklyn campus of Polytechnic.

Types of Programs

Behavioral Approaches to Architectural Programming and Evaluation.
Students interested in this area of specialization will learn to use behavioral research and analysis techniques to evaluate the successes and failures of a setting (interior or exterior spaces) in meeting designer goals and user needs.

Human Factors in Large Scale Engineering Systems
Applications of principles of psychological research and evaluation techniques to large scale enviornmental design projects.

Behavioral aspects of transportation planning, and behavioral analysis of energy use.
Electives for programs within these areas may be chosen from the courses listed here as well as courses in the Departments of Transportation Planning, Social Sciences, and Operations Research.

Social Impact Assessment (with a minor in environmental engineering).
Theoretical basis and practical applications of social research for the analysis and appraisal of planned changes in areas such as transportation, energy, natural resources, housing and community development, education and health.

Psychology and the Uses of New Technologies in the Workplace
Students focus upon physical and behavioral factors affecting the utilization of new technologies in the workplace, including the impacts of new computer and telecommunications technologies on the office.

Laboratory Research in Environmental Effects.
Students who choose this specialty are trained to use laboratory techniques and facilities to study the effects of various environmental stresses on behavior under controlled conditions.

Certificate Program

Students may take a five courses sequence for a certificate in Environment-Behavior Studies. The program is available

as a minor for students in other programs, or for students applying directly for the certificate.

Degree Requirements

Core Courses in Environment-Behavior Studies (18 units)
SS 908—Experimental Psychology I
SS 909—Experimental Psychology II
SS 920—Seminar in Psychology
SS 926—Environmental Psychology
MA 552—Applied Statistics I

Thesis (6 units)
SS 997—Master's Thesis — 6 units. In addition to writing a thesis, students are encouraged to do practicum work in their areas of specialization.

Electives (5 units). Students may take up to 5 units of electives from a variety of departments, three of which must be chosen from advanced courses in Environment-Behavior studies.

Typical Programs:

For "Behavioral Approaches to Architectural Programming and Evaluation" Program

- 5 Core Courses
- Advanced Courses:

  Post Occupancy Evaluation (SS 928)
  Social Impact Assessment (SS 924)
  Stress and the Environment (SS 928)
  Human Factors in Engineering (1E 765)

- Master's Thesis

For "Social Impact Assessment" Program

- 5 Core Courses
- Advanced Courses:

  Social Impact Assessment (SS 924)
  Behavioral and Special Aspects of Transportation Planning (SS 916)
  Environmental Impact Evaluation (CE 767)
  Environmental Health Engineering (CE 751)

- Master's Thesis

UNDERGRADUATE COURSES

HISTORY AND
HISTORY OF SCIENCE AND TECHNOLOGY

SS 101   History of Western Civilization 1500-1815   3:0:3

SS 102   History of Western Civilization 1815-1914   3:0:3
SS 101-102 provide an introduction to the political institutions, theories and practices, economic organizations and techniques, scientific and technological accomplishments, religious and ethical beliefs, and the intellectual and artistic heritages of Western society from approximately 1500 to 1914. May be taken independently.

**SS 104   Main Themes in Contemporary
                  World History   3:0:3**
Major sources of change, transformations and tensions in this century. Discussions, readings, lectures, films on war, racism, scientific-technical revolutions, socialism, communism, imperialism, the United States and revolutionary movements, modernization of underdeveloped societies, cold wars and current crises.

**SS 109   The Birth of Modern Europe,
                  The Early Phase, 800-1500   3:0:3**
From the time of the first stirrings of a specifically Western European Civilization, through its initial expansion and consolidation in the High Middle Ages, to the beginnings of the next great expansion during the Renaissance. From the start the West has always been marked by a peculiar dynamism probably linked to the nature of its material, human, institutional and spiritual resources. The course will examine the history of the period at two levels: first, those resources, how they evolved over the years, and how Europeans used them to create the foundations for the institutions and patterns of functioning that still characterize the West today; and second, the nature of the historical processes behind the several cycles of growth, stasis and decay in given periods and places.

SS 110   The Renaissance and Reformation   3:0:3
Dynamic changes in intellectual and artistic values, political and economic approaches, social and religious institutions from late Middle Ages to counter-Reformation. Guided readings and research. Discussions of selected topics.

SS 116   History of Latin America   3:0:3
Early Mexico and Andean areas; Spanish conquests and establishment of hacienda systems throughout Latin America. Wars of independence. Social, cultural and political developments of last century. Latin America and United States.

SS 120   History of Tsarist Russia to the Revolution   3:0:3
Russian state and society from earliest times; structure and practice of Tsarism; Russia as "underdeveloped" society; special problems of modernization. Russia and West. Culture and literature with special emphasis on 19th century fiction. Political, social, economic causes of Revolution in 1905.

SS 121   History of Soviet Union   3:0:3
Revolutions of 1917. Leninism in power, industrialization, collectivization, ascendancy of Stalin; Soviet Union and West—from alliance to Cold War; Khrushchev and de-Stalinization; Soviet impact on underdeveloped world; contemporary trends in Soviet society.

**SS 123   History of the United States
                  From Settlements through Reconstruction   3:0:3**
Culture, politics and society from early European and Afro-American settlements through post-Civil War era. Interpretation of accessible "primary sources," which illuminate convictions, ideologies and activities of leaders as well as ordinary Americans from the 17th through the mid-19th century.

**SS 124   History of the United States:
                  From Reconstruction through
                  the Cold Wars   3:0:3**
The emergence of provincial America to global authority, interweaving of domestic struggles and foreign policies as United States moves from "Gilded Age", through Progessive Era; World Wars of the 20th century, the New Deal period through revolutionary upheavals in the post-World War II epoch.

SS 126   Afro-American History   3:0:3
Roles of black people in history: African cultural background, slavery as an institution, abolitionist movement; Civil War; reconstruction; segregation, migrations, politics; African independence. Black Americans now and their future.

SOCIAL SCIENCES

SS 128   A History of Jazz   3:0:3
History, appreciation and analyses of jazz as unique Afro-American
art form. Social and historical roots and interactions with other
musical traditions. Contemporary trends as expressions of 20th
century society and culture.

SS 133   Archaeo- and Ethnoastronomy   3:0:3
Early astronomical knowledge and its place and uses in all cultures
(excluding only the astronomies of Graeco-Alexandrian antiquity
forward; see SS 135) to keep track of the motions of celestial bodies.
The two major emphases will be: one, the astronomical knowledge
per se of several quite different cultures, along with the distinct
observational instruments and techniques and the recording and
calculating methods of each; and two, the ways in which these
astronomies both reflected and reinforced the economic and social
organization and the cosmological and religious beliefs of the cul-
tures in which they were embedded. There will be instruction in
elementary, naked-eye astronomy, exercises in designing simple
instruments and, weather permitting, actual observation. Student
work will include a term project. Course limited to 20 students.

SS 135   History of Science and Technology:
              Antiquity through Galileo   3:0:3
Science and technology from earliest time to Renaissance: neolithic
and medieval technologies; achievements of ancient Greeks from
pre-Socratics to Euclid; Copernican revolution; science and technol-
ogy in expansion of Europe; influences of science on development of
European thought.

SS 136   History of Science and Technology
              Galileo through Darwin   3:0:3
Science and technology from the scientific revolution through Lavoi-
sier to the origins of the Theory of Evolution. Galileo and Newton; the
beginnings of evolutionary thought; the organization of scientific
inquiry; the impact of scientific thought on society in the 17th, 18th
and early 19th centuries; connections between technology and
science.

SS 137   History of Science and Technology:
              Faraday through the Present   3:0:3
Science and technology from early 19th century forward: the matura-
tion of evolutionary thought and its consequences; the rise of the
sciences of electricity and heat, relativity, quantum mechanics; the
development of cell theory, genetics and biochemistry.

SS 138   Technology, Science, and
              Contemporary Society   3:0:3
Mutual relationships between technology, science and society;
emergence of "big science;" national styles in science and technol-
ogy; social effects of recent technological and scientific develop-
ments; policy issues posed by restricted and unrestricted uses of
technology and science.

SS 151   Introduction to Politics   3:0:3
Major issues in history of political philosophy: the state; nature of
political obligation; scope of dissent. Origins and functions of Ameri-
can political system. Clashing ideologies of democratic society

SS 154   Russia, China, and the West   3:0:3
Impact of modernization on traditional societies of Russia and China.
Attraction of Western ideologies—liberalism, socialism, commu-
nism and interaction with existing political cultures. Russian and
Chinese revolutions compared. Differing visions and practices of
Russian and Chinese communism. Sources of Sino-Soviet conflict.
Russia and China as great powers; new relationships to West.
Emerging diplomatic triangle-Moscow, Peking, Washington.

SS 161   Politics and Film   3:0:3
Film viewed as document and instrument of social structures and
relations. Film as facet of mass culture and mass communication
and means of shaping and reflecting attitudes and values. Each of
the following historically framed subjects constitutes a separate
course for credit: Depression America: Fantasy & Reality; War: A
Cross-Cultural Comparison; Weimar Germany in the Shadow of
Fascism; the Fall of France, 1930-1940; Great Britain - the End of
Empire; Russia in Revolution and Civil War; the Reconstruction of
Europe, 1947-1962. Film screenings, readings, lectures and discus-
sions Lab free required. May be repeated for credit.

SS 178   Minorities in the New World   3:0:3
Historical, political, social and economic background to ethnic and
race relations in United States and Latin America. Assimilationist,
segregationist, pluralist policies, related attitudes. Spanish-speak-
ing minorities of Puerto Rican and Mexican descent in United States
compared with ethnic and racial counterparts in Puerto Rico, Cuba,
and Brazil.

SS 221   The Contemporary U.S.S.R.   3:0:3
The U.S.S.R. is a global power undergoing a crisis of modernization.
The historical background: from Khrushchev's de-Stalinization to
Brezhnev's stability and stagnation. Gorbachev's "glasnost" and
"perestroika" as reform strategies out of the crisis. Culture, politics,
and economy in the U.S.S.R. today. Films, lectures, readings. Pre-
requisite: SS 121 or SS 161 (if appropriate) (or instructor's consent).

SS 226   Problems of American Foreign Policy   3:0:3
Formulations and applications of foreign policy from 18th-century
through post-Cold War; continental and overseas expansions, inter-
national rivalries; impacts of domestic influences; diplomacy of in-
fant republic; Monroe Doctrine; "manifest Destiny;" "white man's
burden;" open-door policy; "dollar diplomacy;" World Wars and
their settlements; Cold War and aftermath. Prerequisite: SS 104 and
one 100-level history course.

SS 229   Growth of the United States Constitution   3:0:3
Growth and unfolding of American constitutional system stressing
political and economic factors shaping the law. Students handle
leading court decisions and related legal texts. Prerequisite: SS 104.

SS 330   History and Environment   3:0:3
Changing human evironmental support systems and societal and
technological responses at three critical historical junctures: the
ancient world; the early modern period; and the twentieth century.
Discussions focus on current environmental issues. Prerequisite: SS
175 or 177 or 182 or 135-138.

SS 332   Science and Technology in America   3:0:3
Colonial science. Indifference to basic science during 19th century.
Technology and industrialization. Recent accomplishments of
American science and technology. Emergence to superpower sta-
tus. Prerequisite: SS 104 and one 100-level history of science course
(or consent of instructor).

SS 333   Medieval and Renaissance Engineering   3:0:3
Engineering and technological enterprise in the European High
Middle Ages and Renaissance, roughly 1000 to 1600. The period
was characterized by a growing capacity to handle complex engi-
neering tasks such as the building of the Gothic cathedral, the
mining of ores, the extraction of metals, the industrial production
chemicals (e.g., gunpowder), the building of bridges and digging of
canals, the construction of ships and the design of complex machin-
ery, both light and heavy duty, to cite a few examples. The course will
consider examples from each of several categories, both analysing
the technical procedures and looking closely at the larger contexts:
the logistical organization of a given project or task, the means of
financing, the political and institutional involvement, and the training
of the artisan-engineer and his position in society. Prerequisite: at
least one of the following: SS 101, 102, 109, 110 or one 100-level
history of science & technology course.

SS 338 Galileo Galilei: the Man, his Research, the Times   3:0:3

The life and career of one of the pivotal founders of modern science, Galileo Galilei (1564-1642). The course will concentrate on Galileo's experimental/observational researches and the genesis and development of his mature conclusions in physics and cosmology. It will also touch on his role in establishing new attitudes towards the investigation of natural phenomena, his conflict with the Church, the work of his predecessors and contemporaries and the setting: Italy in the late 16th and early 17th centuries. Students will have the opportunity of empirically investigating some of Galileo's experiments. Much of the reading will be from Galileo's writings in translation, but students who might enjoy the opportunity of exercising their reading knowledge of Italian will be encouraged to work from original primary and secondary sources. Prerequisite: At least one of the following: SS-101, 102, 109, 110 or one of the 100-level History of Science/Technology offerings.

SS 345 Colloquium in Twentieth-Century Thought   3:0:3

Contemporary ideas of Europe and America. Reading and evaluation of selected works in political theory, economic theory, philosophy of science, historiography, ethics, aesthetics, and mass cultures. Prerequisite: SS 104 and one 100-level history course (or instructor's consent).

SS 347 Colloquium in Imperialism   3:0:3

Principal theories of imperialism establishing their premises, their internal consistency, and their historical validity since dissolution of world empires after World War II. Students establish their own criteria and judgements. Prerequisites: SS 104 and one 100-level history course (or instructor's consent).

SS 348 Colloquium in The History of Socialism and Communism   3:0:3

Socialist movements from founding of Second International to collapse in 1914 and revival in interwar years. Communist movements from theoretical controversies within social democracy before World War I to Eurocommunism. Examinations of socialist theories and ideologies, national parties, international organizations. Interpretive materials and sources in translation. Prerequisite: SS 104 and one 100-level history course (or instructor's consent).

SS 354 Technological Forecasting   3:0:3

Introduction to problems associated with technology forecasting. Short range, intermediate, and long-range forecasting methodologies. Forecasting social and economic consequences of adopted innovations. Students will prepare a forecast on a topic of their choice. Prerequisite: SS 104 and one 100-level history of science course (or consent of instructor).

SS 357 Technology Transfer to Developing Countries   3:0:3

Mechanisms of technology transfer. Ecological, social and economic factors in technology selection and utilization. Local efforts to adapt technology to local needs. National and international means to stimulate or block technology transfer. Technology and political influence. Case studies of technology transfer to newly industrialized countries. Prerequisite: SS 104 and one 100-level history of science course (or instructor's consent).
Also listed under IE 357.

SS 358 Human Resource Development in Advanced Developing Countries   3:0:3

Spectrum of technology-related human resource needs in emerging technology nations. Education of engineers, technicians and technically skilled workers. Uses of foreign personnel and foreign schools. "Brain drain" problems and their consequences. Designs of educational systems and curricula to suit national needs. Roles of technical assistance programs. Forecasting of human resource needs. May include field trip. Prerequisite: SS 104 and one 100-level history of science course (or instructor's consent).
Also listed under IE 358.

BEHAVIORAL SCIENCES AND PSYCHOLOGY

SS 175 Introduction to Sociology   3:0:3

Influences of culture and social structures on human behavior. Concepts of sociological analysis; types of human societies; social stratification; urban ecology; the social context of the environmental crises; and the human impact of technology.

SS 177 Social Problems   3:0:3

Social disorganization and deviant behavior in contemporary society: crime and juvenile delinquency; mental disorder; drug addiction; alcoholism; suicide; family disorganization; poverty; and unemployment. Comparisons with cultures of other peoples and/or simpler societies. Discussions of conflicting theories of causes for deviance and social disorganization.

SS 182 Man and the Environment   3:0:3

Ecological understanding of interactions of humans with non-human environments through relevant topics: ecosystem, human interaction with ecosystem, human societies as self-regulating systems, attitudes toward nature, case studies in ecological history, present environmental crises and attempts at resolutions.

SS 185 Anthropology: Physical   3:0:3

Biosocial bases of human conduct seen in evolutionary perspectives; elementary genetic, demographic and ecological models necessary for understanding of human behavior; biology as an evolutionary complex extending from the prosimian revolution through the neolithic revolution.

SS 186 Anthropology: Cultural   3:0:3

Social evolution from the hunting and gathering band through state society. Considerations of variation and developmental trends in several human institutions: kinship; economic organization; warfare; politics; religion; and technology. Demographic and ecological variables receive primary stress.

SS 189 Introduction to Psychology   3:0:3

Scientific study of behavior, learning, phsyiological psychology, sensory systems, developmental, educational, abnormal and social psychology. Lectures, class discussion, films, demonstrations of experiments.

SS 203 Psychology of Learning   3:0:3

Response acquisition and maintenance in human beings and other animals. Concepts of reinforcement, extinction, schedules of reinforcement, generalization, discrimination training. Relationship of learning to emotion and motivation, transfer of training, retention and forgetting, concept learning, acquisition of skills. Theories of learning and application of learning to other areas of psychology. Prerequisite: SS 189.

SS 204 Physiological Psychology   3:0:3

Relationships between physiology, anatomy, and behavior. Physiological, anatomical, and biochemical bases for memory, learning, motivation, sleep, arousal, and stress. Prerequisite: SS 189.

SS 205 Applied Psychology   3:0:3

This course will show how various problems, particularly in work, can be solved through the judicious use of psychological principles. Phenomena addressed will include human being-machine interaction and other engineering-behavior interactions, smoking, study habits, memory, creative thinking, group inter-action, raising children, influencing people, self-control, and specific problems brought up in class by students. Students will learn how to employ the method of behavioral analysis in gaining an understanding of various problems. They will select a problem, do a behavioral analysis and finally modify it as a class project. Prerequisite: SS 189.

SS 206　Human Cognition and Information Processing　3:0:3
Human cognitive capabilities and information processing. Structures of memory and internal representations of knowledge, concept formation, symbol manipulation, mental operations and schema, consciousness and strategies for problem-solving. Cognitive development and roles of language in thinking. Prerequisite: SS 189.

SS 208　Experimental Psychology I　2:3:3
Theory and methods of measurement of sensory functions in human and animal subjects. Examination of the concept of the threshold and problems of its measurement. Investigation of learning, both motor and verbal, and both simple and complex, including problem solving and creative thinking. Students will perform a series of experiments with human and animal subjects. Prerequisite: SS 189.

SS 209　Experimental Psychology II　2:3:3
Experimental and descriptive methods including quasi-experimental design and large scale survey techniques used by social, environmental, and developmental psychologists to assess human behaviors in laboratory and naturalistic settings. The course focuses upon laboratory and observational methods used to assess environmental effects, attitude measurement, social impact assessment, and theory and psychometric bases of normal personality development and assessment. Prerequisite: SS 189.

SS 210　Environmental Psychology　3:0:3
Ways people use and are affected by their physical environments. Research in natural environments as well as built urban areas. Research on personal space, privacy, territoriality, crowding and design-behavior relationships. Field research to assess suitability of environments to human needs, using interview techniques, behavioral observations and unobtrusive measures. Prerequisite: SS 189 or equivalent.

SS 214　Social Psychology　3:0:3
Behavior as function of social stimulation. Nature of sociopsychological inquiry, with particular emphasis on experimental methods. Biological bases of social behavior, socialization processes, effects of social stimuli on perception and communication, group processes, attitude change, interpersonal bargaining. Student participation in experiments. Prerequisite: SS 189.

SS 215　Abnormal Psychology　3:0:3
Types of abnormal behavior: neurosis, psychosis, psychosomatic reactions, character disorders. Developmental and social learning theories, biological, etiological models. Relations of methods of treatment of abnormal behavior to models of etiology. Prerequisite: SS 189.

SS 216　Personality Development　3:0:3
Methods of inquiry relevant to study of personality. Personality development in terms of social learning variables. Dynamics and structure of personality, personality change. Examples of personality research on variables: authoritarianism, need for achievement, self-concept. Prerequisite: SS 189.

SS 217　Psychology of Human Development*　3:0:3
Human development from birth to old age. Effects of age on thinking, learning, social behavior. Implications for teaching and educational programs. Prerequisite: SS 189.

SS 279　The Sociology of Human Disease　3:0:3
Human disease in contexts of social and biological adaptation. Disease profiles of the three major levels of man's social evolution — hunters and gatherers, low-energy agriculturalists, and states-considered from broadly conceived human ecological viewpoints. Recommendation: some background in biology and anthropology. Prerequisite: SS 175 or 177 or 185 or 186.

SS 299　Organizational Behavior
Behavior in industrial settings.
Informal and formal group dynamics: interpersonal relationships, supervision, leadership, communication theories, attitude measurement, creativity. Analyses of administration problems through case studies and simulated situations. Prerequisite: SS 189.

SS 310　Genes, Gender, and Society　3:0:3
Psychology, anthropology, sociology of women and women's movements. Biological bases of sex role differentiation, sex role acquisition in cross-cultural perspectives, societal allocation of roles. Women's movements—history and potential for change in current attitudes, lifestyles, the political and economic systems. Prerequisite: SS 189 or 185/186 or 175/177.

ECONOMICS*

SS 250　Basic Economics　3:0:3
Basic micro and macroeconomics. Supply and demand. Markets and market structure. Income distribution. Market failures. National output. Aggregate supply and aggregate demand. Unemployment and inflation. Fiscal and monetary policy.
Students who take SS 250 cannot receive credit for SS 251 or SS 252.

SS 251　Microeconomics　3:0:3
Supply and demand analyses. Allocations of resources and distribution of income. Various market structures: perfect competition, imperfect competition, oligopoly and monopoly.

SS 252　Macroeconomics　3:0:3
National income analysis. Employment and unemployment, inflation and growth. The federal government and fiscal policy, the Federal Reserve Board and monetary policy.

SS 254　Economic Issues　3:0:3
Unemployment and inflation, urban fiscal crises, racial and sexual discrimination, pollution, poverty, imperialism and military spending. Role of state in economy. Prerequisite: SS 250.

SS 255　The Contemporary American
Economy: Boom and Bust　3:0:3
The current economy: inflation, unemployment, growth and recession. Interest rates, money, the stock market, wages, productivity, profit rates and the balance of payments. Role of military expenditures. Legacies of the Vietnam War. Evaluations of the Federal Reserve and government regulation of the economy: spending, taxation, deficits and monetary policy. Supply side economics. Wage-price controls, unions and the future of economic planning. Prerequisite: SS 250 or SS 252.

SS 257　History of Economic Thought　3:0:3
Development of economic thought. Various schools of thought which anticipated and prefigured modern economic analysis. Prerequisite: SS 250, SS 252 or SS 251 or equivalent.

SS 262　Collective Bargaining　3:0:3
Labor-management collective bargaining. Historical background, bases of power, day-to-day administration and bargaining. Intra-union bargaining, major substantive issues and problems, legislation, public policy implications, effects of technological progress, the strike and its alternatives, comparison with other bargaining settings (e.g. international negotiations). Prerequisite: SS 250 or SS 251.

SS 263　Labor Economics　3:0:3
Theoretical and empirical analyses of labor market phenomena. Trends in the size and composition of the labor force. Supply. Demand and marginal productivity theory. Influence of market and other institutional forces on wages. Unemployment. Allocation by relative wages and job opportunities. Legislation, wage controls, labor unions, technology and skill requirements. Discrimination. Demand determinism. Prerequisite: SS 250 or SS 251.

SS 264　Urban Economics　3:0:3
Contemporary American cities and changing functions. Interrelation of population with housing, jobs, transportation. Problems of public finance and services, land use, urban decay and renewal. Analytic tools to examine economic aspects and evaluate policy alternatives. Prerequisite: SS 250 or SS 251.

SS 265   Money and Banking   3:0:3
Nature of money, gold and paper standards, commercial banks and
Federal Reserve system, financial institutions, balance of payments,
exchange rates, international monetary order. Money, prices, infla-
tion, business fluctuations. Domestic and international monetary
policy. Prerequisite: SS 250 or SS 252.

SS 267   The Market for Engineers and Scientists   3:0:3
Growth of the technological professions; social implications of tech-
nological progress; applications of conventional supply-demand
models; institutional forces beyond supply and demand; schooling
and skills; roles of government; supply models; demand models;
non-wage responses to shortages and surpluses; the method of job
evaluation; earnings and employment studies; future prospects.
Prerequisite: SS 250 or SS 252.

*The introductory courses are SS 250 (one semester), or
alternatively SS 251 and SS 252 (two semesters). Consequently,
students who take SS 250 cannot receive credit for SS 251 or SS
252. Students who take SS 251, SS 252, or both, cannot receive
credit for SS 250.

Special Topics and Guided Studies

**SS 300-301   Guided Readings in
            Social Sciences**   each 3:0:3
Selected problems in social sciences—history, economics, anthro-
pology, sociology, psychology, politics, interdisciplinary studies.
Individual or group projects under faculty supervision involving guid-
ed reading and/or research. For mature students of social sciences
wishing to undertake specialized, independent study under tutorial
guidance. Prerequisite: junior standing in social sciences or depart-
ment's permission.

**The following special topics courses are offered from time to
time by the staff of the department or visiting scholars. The
specific titles and prerequisites are announced prior to
registration. May be repeated for credit.**

SS 361   Special Topics in Social Sciences*   each 3:0:3

SS 362   Special Topics in History*

**SS 363   Special Topics in History of Science and
            Technology***

SS 364   Special Topics in Economics*

SS 365   Special Topics in Psychology*

GRADUATE COURSES

HISTORY OF SCIENCE AND TECHNOLOGY

**SS 600†   History of Science and Technology:
            Antiquity to the Scientific Revolution**   2½:0:3
Biological and physical sciences from antiquity to Renaissance.
Issues, aims and tools of historians of science working in these
periods.

**SS 601†   History of Science and Technology:
            Scientific Revolution to Darwin**   2½:0:3
Biological and physical sciences form scientific revolution to Darwin.
Issues, aims and tools of historians of science working in these
periods.

SS 602†   Seminar in History of Science   2½:0:3
Advanced problems in history of science: development of quantifi-
cation, historiography of science, history of ecology, science and
social thought. Main topic chosen by students and instructor. Train-
ing in methods of archival research. Required regular reports leading
to a major paper. Course may be taken twice for credit with different
topical emphasis and instructor's consent.

SS 616†   Guided Reading in History of Science   2½:0:3
Independent studies of leading interpretive works and sources in
history of science. Regular tutorial sessions and periodic student-
faculty colloquia. Course may be taken twice for credit with different
topical emphases and instructor's consent Comprehensive written
examination.

**SS 625†   History of Technology: Antiquity through
            Early Industrial Revolution**   2½:0:3

**SS 626†   History of Technology: Industrial
            Revolution to the Present**   2½:0:3
These two courses involve the evolutions of techniques and tools
used in man's attempts to master the environment Reciprocal
relationships between technology and other facets of society's
economic and social structures, political policies; general cultural
manifestations. Technological bases of historical changes and inter-
actions of science and technology. SS 625 prerequisite: SS 600 or
equivalent. SS 626 prerequisite: SS 601 or equivalent.

SS 635†   History of Psychology*   2½:0:3
Survey of psychology against background of periods in which princi-
pal modern schools and issues emerged. Early psychology as spec-
ulative discipline, essentially part of philosophy. Differentiation of
psychology into various fields. Prerequisite: SS 189-190 or
equivalent or SS 135-136 or equivalent.

SS 640-641†   Environmental Studies Seminar*   3:0:3
This seminar provides an opportunity to investigate environmental
issues by focusing on a specific topic each year. The aim is to
cultivate a more holistic understanding of human societies in their
ecological settings. Attention is given to such factors as weather,
technology, population, social organization and political structure.
All students are responsible for a seminar paper. Guest participants
on special topics. Prerequisite: SS 182 or other appropriate environ-
ment studies course or instructor's consent.

SS 672   Technological Forecasting   2½:0:3
Introduction to   gy forecasting.
                                               ing methodolo-
                                               ces of adopted
                                               t topic of their
                                               tory of science/

                                                         2½:0:3
                                               n, transfer and
                                               and criteria of
                                               sful technolo-
                                               ory history of

                                                         2½:0:3
                                               s developed
                                               ed mechan-
                                               brain-drain"
                                               educational
                                        ing countries. Designs of
national needs. Roles of technical assistance pro-
grams. Forecasting of human resource needs.
Also listed under IE 758

**SS 678†   Human Resource
                Information Systems   2½:0:3**
Design, selection, implementation, enhancement and operation of Human Resources Information Systems (HRIS) in organizations. Organizational, legal and political issues as well as hardware, software, applications and communications in HRIS. The uses of time-sharing, personal and minicomputers and mainframes. Focus on design and use of HRIS to facilitate objectives of human resource functions, as well as to support entire organizations.
Also listed under MG 626.

PSYCHOLOGY

SS 905   Psychology: Applied   2½:0:3
This course will show how various problems, particularly in work, can be solved through the judicious use of psychological principles. Phenomena addressed will include human being-machine interaction and other engineering-behavior interactions, smoking, study habits, memory, creative thinking, group inter-action, raising children, influencing people, self-control, and specific problems brought up in class by students. Students will learn how to employ the method of behavioral analysis in gaining an understanding of various problems. They will select a problem, do a behavioral analysis and finally modify it as a class project. Prerequisite: SS 189.

**SS 906   Human Cognition and Information
                Processing   2½:0:3**
Human cognitive capabilities including natural language and information processing. Memory, internal representation of knowledge, concept information, symbol manipulation, language acquisition, reasoning and problem solving. Artificial intelligence approaches to natural language learning and acquisition of cognitive skills. Prerequisite: SS 189.

SS 907   Human Computer Interaction   2½:0:3
This course will introduce students to human behavioral issues in the design and use of interfaces for information systems. Basic issues of behavioral research and evaluation methods will be discussed. Sensory systems, memory and learning theory relevant to systems human factors will be reviewed and related to specific interface issues, such as interaction devices, dialogue design, and reference material. The focus will be on understanding the issues involved in creating systems amenable to human use. Prerequisite: SS 189 or equivalent course.

SS 908†   Experimental Psychology I   2½:3:3
Theory and methods of measurement of sensory functions in human and animal subjects. Examination of the concept of the threshold and problems of its measurement. Investigation of learning, both motor and verbal, and both simple and complex, including problem solving and creative thinking. Students will perform a series of experiments with human and animal subjects. Prerequisite: SS 189.

SS 909†   Experimental Psychology II   2½:3:3
Experimental and descriptive methods including quasi-experimental design and large scale survey techniques used by social, environmental, and developmental psychologists to assess human behaviors in laboratory and naturalistic settings. The course focuses upon laboratory and observational methods used to asses environmental effects, attitude measurement, social impact assessment, and theory and psychometric bases of normal personality development and assessment. Prerequisite: SS 189.

SS 910†   Theories of Learning   2½:0:3
Programmed learning, behavior therapy, attitude function, and social interaction. All students are required to perform one experiment on learning under guidance of instructor. Available to undergraduate majors in social science. Prerequisite: SS 189 or equivalent.

**SS 911†   Psychology of Language
                and Communication   2½:0:3**
Methodological problems in analysis of language, verbal behavior in animals, anatomical and physiological aspects of speech apparatus, operant and respondent conditioning of verbal behavior, semantics, statistical approaches and mathematical models, contextual factors, pathology of speech. All students are required to perform one experiment under guidance of instructor. Available to undergraduate majors in social science. Prerequisite: SS 189 or equivalent.

SS 912   Sensation and Perception   2½:0:3
Review of different sensory systems: vision, audition, taste, smell, touch, temperature sensitivity, vestibular and kinesthetic senses and their relations to nonsensory controlling stimuli such as states of the organism, learning, social psychological variables. Techniques for obtaining psychophysical data on each sensory system and relations of these techniques to theories of discrimination. Available to undergraduate majors in social science. Prerequisite: SS 189 or equivalent or instructor's permission.
Also listed under BE 675

SS 913   Physiological Psychology   2½:0:3
Physiological and anatomical bases of behavior. Memory, motivation, emotion, sleep reward mechanisms, psychosurgery and higher cortical functions. Prerequisite: SS 189.
Also listed under BE 695

**SS 915   Behavioral and Societal Aspects of
                Transportation   2½:0:3**
Behavioral analyses of transportation decision-making and travel characteristics. User needs in design of transporation systems: crowding, social isolation, crime, comfor and convenience. Social impacts of transport systems on communities. Prerequisite: under graduate introductory psychology or MG 601 or equivalent.
Also listed under MG 856 and TR 756

SS 920   Proseminar in Psychology   2½:0:3
Major areas of psychology required of all master's candidates. History and systems, sensation and perception, learning, developmental and abnormal

SS 925   Social Impact Assessment   2½:0:3
How physical changes urban or rural settings affect social systems and group and individual behavior. Measuring quality of life and social responses to technology; uses of alternative futures paradigms. Students do an analysis of a problem in social impact and report finding to the class.

SS 926   Environmental Psychology   2½:0:3
Critical issues in person-environment relations, including privacy, crowding and environmental design. Work includes a term paper and a major research project, emphasizing applications of psychological research methods to practical design problems or specific environmental issues.

**SS 928   Advanced Topics in
                Environmental Psychology   2½:0:3**
This course varies from year to year depending on the needs and interests of students and instructors. Potential subjects include: social impacts of transportation systems; stress and the environment; adversive environmental factors; laboratory assessment of environmental effects on animal learning; effects of pollution; human factors of software design; assessing the built environment including the office; applied behavioral analysis.

SS 997   Thesis for Degree of Master of Science*each 3 units
Independent research project demonstrating scientific competence performed under guidance of advisers.

FACULTY

Pamela E. Kramer, Associate Professor of Psychology and Head of Social Sciences
B.A., Bryn Mawr College; M.Ed., M.S., Tufts University; Ph.D., Yeshiva University
Psychology of women, human cognition, psycholinguistics and developmental psychology.

Marvin E. Gettleman, Professor of History
B.A., City College of New York; M.A., Ph.D., Johns Hopkins University
History of the United States, American constitutional history, nationalism, modern radicalism

Helmut Gruber, Charles S. Baylis Professor of History
B.S., City College of New York; M.A., Ph.D., Columbia University
History of socialism and communism, intellectual social and cultural history of 19th and 20th centuries, contemporary history

Frederick C. Kreiling, Professor of History of Science
A.B., Hofstra College; A.M., Ph.D., New York University
History of science, environmental studies, music history

Louis Menashe, Professor of History and Administrative Officer of Social Sciences
B.A., City College of New York; M.A., Ph.D., New York University
Russian social history, revolutionary thought and politics, Soviet and contemporary history, Soviet cinema

David Mermelstein, Professor of Economics
B.A., Amherst College; Ph.D., Columbia University
Radical economics, current macroeconomic problems, comparative economic systems, urban fiscal problems

Kurt Salzinger, Professor of Psychology
B.A., New York University; A.M., Ph.D., Columbia University
Behavior theory and learning, abnormal psychology, language behavior

Thomas B. Settle, Professor of History of Science and Technology
B.A., M.A., Ph.D., Cornell University
Galilean Studies, the Italian Renaissance, engineering in Medieval and Renaissance Europe.

Felix F. Strauss, Professor Emeritus of History
B.A., Hofstra College; M.A., Ph.D., Columbia University
Renaissance and reformation, entrepreneurial history, modern Central Europe

Lester O. Bumas, Associate Professor of Economics
B.E.E., City College of New York; Ph.D., New York University
Labor economics, industrial relations, economic policy

I. Leonard Leeb, Associate Professor of History
B.A., University of Pennsylvania; Ph.D., Columbia University
History of the Netherlands, colonialism and imperialism, history of political thought

F. David Mulcahy, Associate Professor of Anthropology
B.A., M.A., Ph.D., University of Massachusetts
Marginal communities, human ecology, cultural symbolism, sociolinguistics

Romualdas Sviedrys, Associate Professor of History of Technology
B.A., Cornell University; Licenciada, Universidad Nacional (Colombia); Ph.D., Johns Hopkins University
Technology forecasting and technology assessment, history of technology and science since 1750, technology and science in America

Richard E. Wener, Assistant Professor of Psychology
B.A., University of Wisconsin; M.S., Ph.D., University of Illinois at Chicago
Environmental psychology, crowding, assessment of the built environment, software evaluation, clinical psychology

ADJUNCT FACULTY

Barbara Bienstock, Lecturer in Psychology, B.A., Ph.D., Queens College

Steven J. Freimark, Assistant Professor of Psychology
B.S., M.S., Polytechnic Institute of New York; M.A., Queens College; Ph.D., State University of New York at Stonybrook

Malcolm McCullough, Lecturer in Psychology
B.S., Polytechnic Institute of New York; Ph.D., Queens College

James Moore, Lecturer in History and Economics
B.A., M.A., University of Nebraska; Ph.D., State University of New York at Stony Brook

SYSTEM ENGINEERING

System engineering is based on the body of theoretical knowledge that underlies the engineering of modern complex systems. System engineering is the application of this body of knowledge to the design of systems, usually involving the integration of several disciplines to achieve the desired design objective. The theoretical resources of these fields include selections from among the newer branches of applied mathematics, methods of modeling and simulation, methods for the analysis of signals and systems, the theories of communication and control, the techniques of optimization and of decision-making, and many of the facets of computer science.

Faced with a diverse and complex scientific environment, the system engineer may receive assignments crossing traditional lines of engineering applications. System engineering is presently applied in areas such as transportation, urban services, bioengineering, resource management, power and energy, and environmental and pollution control.

The course in system engineering covers, in an interdisciplinary manner, the viewpoints, tools of analysis, and mathematical techniques of feedback control, instrumentation and measurement, analysis of data, optimization, communication of information, and simulation, stressing the use of analog and digital computers. The system engineering graduates' orientation and training enable them to participate in the analysis and solution of today's complex technological and societal problems.

The Department of Electrical Enginering and Computer Science administers the program leading to the degrees of master of science, engineer and doctor of philosophy in system engineering. Outstanding students should apply for financial aid in the form of research fellowships, teaching fellowships or partial tuition remission.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE

The entrance requirement for the master of science in system engineering is a bachelor's degree in engineering or science from an accredited institution, with a superior undergraduate record, including undergraduate courses in differential equations, probability, linear systems, feedback control and computer programming. Students with deficiencies in these areas may be admitted if they take appropriate introductory courses to remove these deficiencies.

To satisfy the requirements for the M.S. in system engineering degree, the student must complete a total of 36 units of courses, as described below. An overall grade average of B in all courses is required by the University. In addition, a B average is required in specific groups of courses, as indicated below.

Course Requirements | **Units**

1. Three courses from among the following:

EL 531	Probability	
EL 610	Linear Systems	
EL 611	Signals, Systems and Transforms	
EL 613	Applied Matrix Theory	
EL 621	Feedback Control I	
MA 861	Statistical Inference I	9

2. Two approved one-year sequences, which may include the above courses. At least one of these sequences must be in EL or CS courses. 6-12
3. Approved electives 21-15

Total 36

A complete course of study, including the choice of the one-year sequences, should be arranged in consultation with an adviser. A master's thesis of 9 units may be included as part of the elective courses. At least 24 of the 36 units must be in courses in engineering subjects, computer science or operations research, and at least 18 units must be in EL or CS prefixed courses.

An overall B average is required in the combination of five to seven courses offered to satisfy categories (1) and (2) in the above table.

The departmental *Graduate Student Manual* should be consulted for more detailed rules and procedures, including student status, recommended electives and one-year sequences, current areas of research and disqualification for low grades.

REQUIREMENTS FOR THE ENGINEER DEGREE

This post-master's professional degree is intended for engineers who desire to advance their professional development and training beyond the master's degree by taking additional graduate courses and carrying out a substantial design project.

A candidate for the engineer in system engineering degree must have a program of study approved by an advisory committee. This program must contain a minimum of 72 units beyond the B.S. degree, and the candidate must have satisfied the requirements for a master's degree in system engineering.

In all other respects, the procedures and rules concerning this degree are identical to those for the engineer degree described in the electrical engineering section of this catalog.

REQUIREMENTS FOR THE DOCTOR OF PHILOSOPHY DEGREE

Graduate students who have demonstrated a high degree of scholastic proficiency and have given evidence of ability for conducting independent research may consider extending their studies toward the doctorate.

Admission to Program — Admission to the program is based on qualifying examinations, which a student usually takes after having completed one year of graduate studies. Successful completion of the master's requirements in system engineering should provide adequate course preparation for the examinations.

Specific requirements for this degree parallel those for the Ph.D. in electrical engineering as described elsewhere in this catalog and in the EE *Graduate Student Manual*. These include course requirements, guidance committee formation, area examination, submission of the bound thesis, etc.

Qualifying Examinations — The format for these examinations is described in connection with the Ph.D. in electrical engineering. Principal areas of concentration for system engineering candidates are: communications, automatic control, computers and mathematical modeling and optimization. Current information about examination topics should be obtained from the Electrical Engineering Graduate Office.

GRADUATE COURSES

**SE 997   Thesis for Degree of Master of
      Science in System Engineering   each 3 units**
Independent engineering project, demonstrating professional maturity, performed under guidance of adviser. Oral thesis defense and formal, bound thesis volume required. Registration of 9 units required (continuous thesis registration required). Prerequisite: degree status.

**SE 998   Project for Degree of Engineer
      in System Engineering   each 3 units**
Comprehensive planning and design of engineering project under guidance of faculty adviser. Emphasis on up-to-date techniques. Oral examination and formal, bound report required. Scope of projects is 6-12 units by prior agreement with adviser (continuous project registration required). Prerequisite: degree status.

**SE 999   Dissertation for Degree of Doctor of
      Philosophy in System Engineering   each 3 units**
Original investigation of system engineering problem. Must demonstrate creativity and include features of originality and utility worthy of publication in recognized journal. Candidate must successfully defend dissertation orally. Registration of 24 units required (continuous dissertation registration required). Prerequisite: passing of qualifying examination. Registration beyond 12th unit requires passing of area examination.

PARTICIPATING FACULTY

Joseph J. Bongiorno, Jr., Professor of Electrical Engineering

Norbert Hauser, Professor of Industrial Engineering and Management Science

Walter Helly, Professor of Operations Research

Frank Kozin, Professor of System Engineering

Frank J. Lupo, Professor of Electrical Engineering and Computer Science

William R. McShane, Professor of Transportation and Industrial Engineering

Athanasios Papoulis, Professor of Electrical Engineering

Philip E. Sarachik, Professor of Electrical Engineering

Leonard G. Shaw, Professor of Electrical Engineering

Martin L. Shooman, Professor of Electrical Engineering and Computer Science

Joachim I. Weindling, Professor of Operations Research and System Engineering

Dante C. Youla, Institute Professor

Richard A. Haddad, Associate Professor of Electrical Engineering

Prodip Sen, Assistant Professor of Electrical Engineering

TELECOMMUNICATIONS MANAGEMENT

The Management Division of Polytechnic University supported by the Electrical Engineering and Computer Science Department offers a master of science degree program in telecommunications management.

Polytechnic started this master's degree program in 1984 with the express purpose of providing education for executives faced with these new challenges and opportunities.

The master of science in telecommunications management is a rigorous 2-year, 4-semester program. It consists of 12 individual courses and an independent research project.

The development of the curriculum was sponsored by the New York State Center for Advanced Technology in Telecommunications (CATT) at Polytechnic University which continues to coordinate the program.

The program's development was supported by a private sector advisory board. The board's current functions are as follows:
(i)   monitor the effectiveness of the program
(ii) help keep the detailed course syllabi current
(iii) propose changes in the program in light of experience.

The philosophy of the program is to provide a solid foundation in telecommunications technology and management in the intial semesters of the program followed in the final year by course work integrating technology and management skills by means of case studies, exercises, and research investigations.

All students are working professionals in telecommunications and most have one or more years of managerial experience. About half the students are employed by providers of telecommunication services and the other half by users of these services.

Classes meet every other week, all day, Friday and Saturday, at Polytechnic's new Westchester Graduate Center in Hawthorne, New York. Breakfast, lunch, and coffee breaks are provided. All classes are videotaped and made available for viewing on campus or at home.

An all-inclusive fee covers tuition and fees, text books and other educational material, special tutorials and lectures, meals on class days, and video tapes of all classes and lectures.

Admission Requirements and Application Information:

Admission to the program requires a bachelor's degree from an accredited institution with a superior undergraduate academic record and demonstrated proficiency in calculus and statistics. Furthermore, all students must be sponsored by their employer.

Applications for admission are accepted throughout the year but admission is for Fall semester only. Because enrollment is limited, early application is recommended.

Degree Requirements:

The general requirements for the master of science degree are stated elsewhere in this catalog.

Curriculum:

The curriculum consists of twelve (12) courses (36 academic units) which are offered in a structured program over a two (2) year period, plus an independent research project during the second year.

The courses in the curriculum are:

1st semester:
EL 535   Elements of Communication Networks
MG 600   Management Process
MG 609   Managerial Accounting and Finance

2nd semester:
EL 635   Principles of Communication Networks
MG 652   Telecommunications Regulation, Policy and Law
MG 820   Project Management

3rd semester:
EL 735   Communication Networks
MG 607   Marketing Management
MG 654   Economics of Information Systems

4th semester:
CS 681   Information Privacy and Security
MG 650   Management of Information Systems
MG 970   Business Policy and Strategy

The courses described below are unique to this program. Please refer to appropriate sections of this catalog for description of all other courses.

COURSES

MG 609   Managerial Accounting and Finance
Aspects of accounting and finance of practical use to the manager. Relations among accounting, economic and financial perspectives. Analysis of principles and practices of the finance function and its application in organizations.

MG 652   Telecommunications Regulation, Policy and Law
The relationships between the development of the telecommunications industry, national growth, and the development of telecommunications policy issues and policy making organizations. Analysis of the major issues which have impacted the telecommunications industry and commerce and society generally. The options and opportunities afforded by recent regulatory and policy issues.

MG 965   Independent Research Project (3 units)
During the second year of the MS in telecommunications management program, the students complete an independent, applied research project on a topic of practical importance to their work experience. The purpose of the project is to give the students an opportunity to apply and integrate the subjects taught in the program by analyzing the impact of a new technology on their organization. This course is specific for the MS in telecommunications management degree and cannot be applied to the master's in management degree. Prerequisite: advanced standing in the master's in telecommunications management program.

FACULTY

Ivan T. Frisch, Professor of Electrical Engineering and Computer Science; Director of the Center for Advanced Technology in Telecommunications
B.S. (Physics), Queens College; B.S., M.S., Ph.D. (EE), Columbia University
Computer communications, network control, information systems

Aaron Kershenbaum, Professor of Computer Science
B.S., M.S., Polytechnic Institute of Brooklyn; Ph.D., Polytechnic Institute of New York.
Computer communications, algorithms

A. George Schillinger, Professor of Management
B.E.E., City College of New York; M.S. Eng., Sc.D., Columbia University
General management, technology management, and corporate strategy

Richard Van Slyke, Professor of Electrical Engineering and Computer Science
B.S., Stanford University; Ph.D., University of California at Berkeley.
Computer communications; telecommunications

Byron David, Assistant Professor of Management
B.A., Queens College of the City University of New York;
M.S., Polytechnic Institute of New York
Operations management

INDUSTRY PROFESSOR

Nancy J. Needham, Academic Director, Telecommunications Management Program; Industry Professor, Management
B.A., Wellesley College; M.B.A., D.B.A., Harvard University
International telecommunications and financial services

ADJUNCT FACULTY

Dennis J. Dugan, Adjunct Professor of Management
B.S., Creighton University; Ph.D., Brown University

David Kreinik, Adjunct Associate Professor of Management
B.A., New York University

E. Hart Rasmussen, Adjunct Professor of Management, Director, Management Programs, Westchester.
B.S., M.S., Technical University of Denmark

Allan Rossi, Adjunct Professor of Management
B.S., M.S.E.E., Purdue University
M.Sc., University of London

TRANSPORTATION

Polytechnic offers graduate degree programs in transportation and undergraduate concentrations in transportation.

The graduate degree programs lead to the degrees of

- master of science, transportation planning and engineering
- master of science, transportation management
- engineer's degree, transportation engineering
- doctor of philosophy, transportation planning and engineering

An undergraduate degree concentration is available in the B.S. (Industrial Engineering), and electives in transportation may be chosen in other majors in consultation with the student's academic adviser.

The MS degrees are practice-oriented, with a strong foundation in underlying principles and methods. The MS (Transportation Planning and Engineering) is available to both full-time and part-time students. The MS (Transportation Management) is primarily available to part-time students.

The Transportation Program also cooperates with the Department of Civil and Environmental Engineering to provide a program in highway engineering as part of the master's degree in civil engineering.

Students and continuing professionals from a variety of disciplines undertake studies in transportation to lead to careers in transportation operations, design, planning, or management. Some may choose to pursue this in a dual degree program which can also lead to a Master of Urban Planning or a Master of Public Administration at New York University.

For those oriented to planning or engineering careers, the Polytechnic transportation programs have a strong foundation in traffic engineering, transportation planning, and public transportation. Students may structure degree programs to build on this, emphasizing transportation infrastructure, computer aided engineering, or facility design and operations.

For those oriented to management careers, Polytechnic transportation programs have strong foundations in transportation principles, economics and finance, and transportation policy and management. Students may concentrate in public or private sector management, and emphasize transit maintenance management, logistics, or productivity management.

The primary goal of the academic program is to educate transportation planners, engineers and managers who are able to plan, functionally design and control facilities and systems which satisfy the demand for both passenger and freight transportation services.

The program stresses multi-modal approaches to transportation and maintains strong course offerings in:
- highway and traffic engineering
- public transportation
- transportation planning

- transportation safety
- freight transportation
- transportation management and economics

Students are exposed to an atmosphere that provides a meaningful integration of practical and theoretical approaches. Classroom presentations, laboratory experiences, and practical problem solutions strengthen the overall education.

DEPARTMENT REQUIREMENTS

Admission Requirements

To be eligible for admission as graduate students, applicants must hold at least a baccalaureate degree from an acceptable institution. Students with undergraduate degrees in engineering, the sciences, social sciences, and the arts are admitted. Students pursuing the "transportation planning and engineering" degrees are expected to have the stronger quantitative background, usually with prior degrees in engineering, mathematics, or the physical sciences.

Students are expected to have basic skills in English adequate for the preparation of reports and papers. Such skills are evaluated in appropriate courses together with technical material. All foreign students admitted to the transportation programs are required to take an examination in English before registration. Based upon evaluation of that examination, they may be required to take one (in rare cases, two) additional courses in English as a second language for which no graduate credit is given.

Grade Requirements

To earn graduate degrees or certificates, Polytechnic requires that student have 3.0 grade point averages or better in all graduate courses and in all guided studies (readings, projects, theses, dissertations). Averages are separately computer for courses and guided studies. Transfer credits from other institutions are not included in these averages.

In addition to Polytechnic grade requirements, the transportation programs require overall averages of B or better in all required courses taken toward all degrees. Students may not repeat a course toward any of the transportation degrees more than once.

Analytic Background

All applicants for Master of Science degrees must show evidence of analytic ability, generally including two years of college mathematics and some exposure to statistics.

All applicants for certificate programs must meet the same entrance requirements as Master of Science applicants.

All applicants for the Engineer and Ph.D. degrees are expected to have a solid analytic background. They must take at least one course in graduate level statistics,

regression analysis, or design of experiments as part of their studies.

Computer Literacy

Students will be exposed to uses of computers and computer packages in transportation integrated into the curricula. Emphasis is on personal and micro-computers. Students will use packages in highway capacity, traffic signal timing and coordination, and transportation assignment (EMME/2 and QRS) in required coursework. The Department has its own computer laboratory, using IBM and IBM compatible micro-computers. Students also have access to Polytechnic's mainframe via the Department's terminals, and to Polytechnic's CAD/CAM system and its personal computer laboratories.

Advising

In all graduate programs, the relationship between the student and the academic adviser is important. The academic adviser assists students in selecting courses, and gives guidance in all academic matters. The academic adviser maintains checks on students' progress, and makes recommendations when problems arise. The department head assigns academic advisers.

Students should meet with their academic adviser *prior* to each registration, and and at any other time they need advice or consultation. The student must have a detailed Program of Study formally approved by the academic adviser prior to registration. Advisers also handle requests for waivers of certain degree requirements, such as required courses. Such waivers must be approved in writing by advisers and instructors of required courses, and must be entered into students' departmental files. When such waivers are granted, students may be required to take other specific courses in their place, or to select additional electives.

Students registering for any guided studies (readings, project, thesis, dissertation) are assigned project advisers for each such activity. These are generally not the same as academic advisers, depending upon the subjects being studied. To register for guided studies, students must submit written proposals of the topics to appropriate project advisers and have academic advisers' written approval.

Doctoral students are not permitted to register for dissertation until they have pased the Ph.D. qualifying examination.

Students studying under research fellowships are assigned research advisers, normally the principal investigators of the projects which fund the fellowships.

While academic advisers consult with and give advice to students, students must ensure that requirements are fulfilled and submit all proper forms and applications when necessary.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREES

M.S. degrees in transportation planning and engineering and transportation management each require 36 units, of which 27 must be taken in Polytechnic graduate courses.

Twelve units are in a common core shared by the two M.S. degrees. Each MS degree has an additional twelve units of required courses, suited to the orientation of the degree. The remaining twelve units is completed by electives approved by assigned academic advisers.

Full-time students, particularly those studying under research fellowships, may be required to do a project for which they receive three or more units as part of their electives.

Common Core		Units
TR 600	Characteristics of Transportation Demand and Systems	3
TR 629	Transportation Workshop	3
TR 750	Transportation Economics and Finance	3
TR 759	Transportation Policy and Decision Making	3
		12

Other M.S.(TP&E) Requirements		
TR 601	Travel Demand Forecasting	3
TR 701	Traffic Enginering I	3
TR 702	Traffic Enginering II	3
TR 710	Design of Traffic Facilities	3
		12

Other M.S.(TM) Requirements		
TR 660	Public Transportation	3
TR 757	Metropolitan Transportation Management	3
TR 620	Project Planning and Control	3
TR 645	Productivity Management	3
		12

Electives

All electives require approval of the assigned academic adviser, and are identified in two groups for each degree:

Elective Group A Students must take at least three courses from this group, based upon electives shown in Table 1.

Elective Group B Remaining electives may be taken from any courses shown in Table 1, from core courses for the "other" transportation M.S. degree, or from any other courses selected by the student and the academic adviser. These may include courses in other departments, or at other institutions suited to individual educational needs.

A total of 36 units is required for M.S. degrees in TP&E and in TM.

Depending upon transfer credits and the particular needs and backgrounds of students, Group A requirements may be modified by the concurrence of the academic adviser and the student.

Transfer Credits

The residency requirement for M.S. degrees is 27 units, of which minimum of 27 units must be taken at Polytechnic. Students may transfer up to 9 units of acceptable courses from other institutions subject to the department's approval. Students may apply for transfer credits after they complete 12 units of appropriate graduate courses at Polytechnic. To be eligible for transfer credits, the courses in question must be relevant to the transportation program, and students must have received B's or better. Courses graded pass-fail basis are not considered for transfer credits unless detailed course evaluations from the instructors are provided. All transfer requests must be accompanied by an official transcript from transferring institutions. Transfer credits are *not* included in computing grade point average. Validation credits by examination may not be used for any transportation degrees.

Table 1:
ELECTIVES FOR THE
TRANSPORTATION M.S. DEGREES

		ELECTIVE GROUP A	
		TP&E	TM
TRANSPORTATION FACILITY DESIGN AND OPERATION			
TR 660	Urban Public Transportation	X	X
TR 670	Planning and Design of Terminals	X	-
TR 665	Design of Rail Facilities	X	-
TR 671	Airport Planning and Design	X	-
TR 672	Port Planning and Design	X	-
TR 722	Highway Pavement Design	X	-
TR 723	Design and Management of High-way Structures and Materials	X	-
TRANSPORTATION PLANNING AND URBAN PLANNING			
TR 602	Urban Transportation Planning	X	-
TR 603	Computer Applications and Analytic Techniques in Transportation	X	X
TR 630	Urban Planning Principles	X	-
TR 633	Land Use and Environmental Planning	X	-
TRAFFIC SAFETY			
TR 864	Transportation Safety Engineering	-	X
TR 865	Traffic Safety Engineering	X	-
TRANSPORTATION MANAGEMENT: PRIVATE AND PUBLIC SECTORS			
TR 754	Logistics Analysis	-	X
TR 760	Management of Transit Maintenance and Operations	-	X
MG 601	Organizational Behavior	-	X
MG 613	Industrial Relations	-	X
MG 614	Collective Bargaining	-	X

Note: The "X" denotes a Group A Elective for the indicated program.

DUAL DEGREE PROGRAM WITH NYU

The transportation program at the Polytechnic has a dual degree program with the Graduate School of Public Administration at New York University. Students may pursue an M.S. (transportation planning and engineering) or an M.S. (transportation management) at Polytechnic, and a Master of Urban Planning (MUP) or a Master of Public Administration (MPA) at NYU. Because of course waivers or advanced standing where appropriate, the two degrees may be obtained with some efficiencies in total units of study and in total time for two distinct degrees.

The two institutions also have an option in which students registered in any of the cited degree programs may take one or more courses from the pool of courses offered by the two cooperating institutions. Such registration is subject to prior approval by the academic adviser for the specific degree program in which students are enrolled.

Those interested in the Dual Degree Program must apply to that program specifically, by indicating this in a letter to the Polytechnic Transportation Program or to the NYU Graduate School of Public Administration, accompanied by application forms to both institutions. To aid in program planning, students are encouraged to apply initially, rather than to convert later to the Dual Degree Programs. Those already enrolled in one of the degrees cited, and interested in the Dual Degree Program, should consult their academic advisers.

REQUIREMENTS FOR THE ENGINEER DEGREE IN TRANSPORTATION ENGINEERING

Engineer degrees in transportation engineering are intended to be terminal degrees for those students wishing advanced practical education beyond the M.S. level. It requires 36 units beyond the M.S. (Transportation Planning and Engineering).

Engineer degree programs require all of the following prerequisites for admission:

1. An undergraduate degree in an engineering discipline from an accredited institution;

2. All required courses for the master of science in transportation planning and engineering, or their equivalent;

3. A master of science in transportation planning and engineering, or equivalent.

Students lacking any of these must fulfill the prerequisites in addition to the degree requirements listed below. Studies for Engineer's Degrees must include at least one graduate-level course in statistics, regression analysis, or design of experiments.

All students must complete the following courses:

		Units
TR 602	Urban Transportation Planning	3
TR 670	Planning and Design of Terminal	3
IE 620	Project Planning and Control	3
TR 998	Engineering Project in Transportation	6
		15

In certain cases, an appropriate M.S. thesis (not project) or evidence of professional experience may be substituted for the engineering project, in which case 6 additional units of course work are required. Students must select 15 units of electives from among the following courses and choose an additional 6 units approved by the academic advisers.

TR 603	Computer Applications and Analytic Techniques in Transportation	
TR 660	Urban Public Transportation	
TR 665	Design of Rail Facilities	
TR 671	Airport Planning and Design	
TR 672	Port Planning and Design	
TR 705	Advanced Topics in Highway Capacity and Traffic Analysis	
TR 710	Design of Traffic Facilities	
TR 715	Urban Goods Movement	
TR 720	Flexible Pavements: Design and Evaluation	
TR 721	Rigid Pavements: Design and Evaluation	
TR 865	Traffic Safety Engineering	
	Central Electives	15
	Additional Electives	6
	Total beyond M.S.	36

If any courses listed above are taken as part of a prior M.S. program, additional electives are added to achieve the required total of 36 units beyond the M.S. degree. All electives are subject to the approval of the student's academic adviser.

Residency requirements for the engineer degree are 27 units of study at Polytechnic beyond the M.S. degree. No more than 9 units of transfer credits may be awarded toward this degree.

DOCTOR OF PHILOSOPHY DEGREE IN TRANSPORTATION PLANNING AND ENGINEERING

The Ph.D. in transportation planning and engineering required 90 units of graduate study beyond the bachelor's degree. The 90 units are made up of the following:

1. A 30-unit major in transportation including all courses required for the M.S. degree.

2. Two 15-unit minors in related areas, one of which is generally in quantitative methods. The second often focuses on a specific transportation area, such as transportation facility design, transportation management, or transportation infrastructure. The minors should support the dissertation topic.

3. A 30-unit dissertation, which must be an original piece of research which meaningfully advances an area of transportation study.

It must be stressed that these are minimum requirements. Many students, particularly those entering with advanced degrees in other fields, may require additional courses to support their dissertation development and to aid completion of the Ph.D. qualifying examination. Applicants to the Ph.D. program are urged to make appointments with Ph.D. program academic advisers for individual consultations and recommendations.

Before being permitted to register for dissertation units, candidates must pass a comprehensive Ph.D qualifying examination. Given twice a year, usually in January and June, it consists of written and oral portions. Copies of previous examinations are available on request from the Program Office to aid the students in preparation for this examination.

Students normally take the qualifying examination after their first year of full-time coursework (or their part-time equivalent) is completed. All students who wish to take the examination are permitted to do so once they have discussed their interest with the academic adviser. Subsequent attempts are at the discretion of the Department; in no case are more than three attempts permitted.

There is no foreign language requirement.

The residency requirement for the Ph.D. is 30 units, which must include the dissertation. Candidates are, thus, only required to complete their dissertations at Polytechnic to earn degrees here. Any and all graduate courses taken at other approved institutions which are appropriate for either majors or minors may be transferred, provided they are of graduate level and that grades of B or better were achieved.

In support of dissertation research, a doctoral committee is formed to advise each student. Because of the interdisciplinary nature of transportation research, advisory committees often include faculty members from other departments. Outside committee members with suitable backgrounds are permitted, from other universities or from industry.

Once students register for dissertation units, they must meet several requirements. Dissertation registration must be continuous (excluding summers) until work is completed. Leaves of absence must be formally requested from the Graduate Office. Student must submit and orally defend dissertation proposals before registering for a second full-time semester of dissertation work, or before going beyond 9 units of combined full-time/part-time dissertation study. At the end of each semester of registration, students must submit written progress reports to their dissertation advisers. Upon completion, dissertations must be presented and orally defended before the faculty.

CERTIFICATE PROGRAMS

The Transportation Program offers graduate certificates to students completing 15 units in concentrated subareas of transportation planning, engineering, or management. Certificate programs are geared to students who do not

wish to commit themselves to full advanced degree programs. These may be students with bachelor's degrees who wish to specialize in other aspects of transportation, or those already holding advanced degrees who wish to develop additional specialties and receive formal certification for it. Students who enroll in certificate programs may apply for transfer to degree programs without loss of credits, assuming they are admitted to degree studies and that the courses taken are appropriate to the degree.

The Transportation Program offers the following certificates:

Traffic Engineering Certificate | Units

Required: 15

TR 701	Traffic Engineering I	
TR 702	Traffic Engineering II	

Plus three of:

TR 603	Computer Applications and Analytic Techniques in Traffic and Transportation
TR 670	Planning and Design of Terminals
TR 710	Design of Traffic Facilities
TR 865	Traffic Safety Engineering

Transportation Planning Certificate | Units

Required: 15

TR 600	Characteristics of Transportation Demands and Systems
TR 601	Travel Demand Forecasting
TR 602	Urban Transportation Planning
TR 701	Traffic Engineering I

Plus one of:

TR 603	Computer Applications and Analytic Techniques in Transportation
TR 630	Urban Planning Principles

Transportation Facility Design and Operation Certificate | Units

Required: 15

TR 670	Planning and Design of Terminals
TR 701	Traffic Engineering I
TR 710	Design of Traffic Facilities

Plus two of:

TR 660	Urban Public Transportation
TR 665	Design of Rail Facilities
TR 671	Airport Planning and Design
TR 672	Port Planning and Design
TR 722	Highway Pavement Design
TR 723	Design and Management of Highway Structures and Materials

Public Transportation Certificate | Units

Required: 15

TR 660	Urban Public Transportation
TR 759	Transportation Policy
TR 760	Management of Transit Maintenance and Operations

Plus two of:

TR 600	Characteristics of Transportation Demands and Systems
TR 670	Planning and Design of Terminals
TR 750	Transportation Economics and Finance
TR 864	Transportation Safety Engineering

Transportation Management and Economics Certificate | Units

TR 750	Transportation Economics and Finance	15
TR 755	Legal and Regulatory Aspects of Transportation	
TR 757	Metropolitan Transportation Management	
TR 759	Transportation Policy	

Plus one of:

TR 660	Public Transportation
TR 760	Management of Transit Maintenance and Operations
TR 754	Logistics Analysis
MG 613	Industrial Relations
MG 614	Collective Bargaining

Units earned toward certificate programs are transferable to degree programs if applicable. No course, however, may be credited toward more than one certificate program.

Course substitutions in certificate programs are permitted with the written approval of the assigned academic advisor.

UNDERGRADUATE COURSES

The Program offers several undergraduate courses, which may be used in transportation concentrations (such as in the B.S.(I.E.) degree), as technical electives where approved by advisers, or as free electives. Students with suitable undergraduate records may also take graduate transportation courses in their senior year, if approved by their advisers. Graduate students may not take undergraduate courses for credit.

There are two courses with TR numbers, and one course with an IE number. In addition, the Transportation Program faculty staffs the undergraduate Civil Engineering course in Highway Engineering.

IE 350   Logistics   3:0:3
Analysis of logistic problems and procedures applied to inventory control, materials handling systems, packaging, warehousing, transportation, facility location, information/communications, and customer services. Cost tradeoffs between the various components in optimization of the total logistics system. Logistics system designs and productivity measures. Business and military cases and applications. Prerequisite: IE 328.

CE 351   Highway and Transportation Engineering   2:3:3
Fundamentals of highway and transportation engineering including land, urban, air, and water transporation. Geometric design, capacity intersection design, drainage, economic analysis and finance, rigid and flexible pavements, velocity profile and performance, evaluation, future developments. Prerequisite: CE 151.

TR 360   Traffic Planning and Operations   3:0:3
Development and use of traffic engineering techniques to aid in planning, functional design and control of highway and street systems. Traffic studies, accident analysis, capacity analysis, sign and coordination, etc. Practical applications. Prerequisite: junior status.

TR 362   Public Transportation   3:0:3
Public transportation systems, their design and operation. Physical and hardware considerations such as rail vehicles, station design, control systems. Service characteristics: express bus, local bus commuter rails, rail rapid transit, demand actuated transit, etc. Operational and planning aspects: scheduling, fare, structure and fare collection systems. Prerequisite: junior status.

GRADUATE COURSES

Refer to Table 1 for identification of elective courses by specialty area. These groupings are intended to aid students in course selection, subject to approval of academic advisers.

**TR 600   Characteristics of Transportation
                 Demand and Systems   2½:0:3**
An overview of transportation demand, modal characteristics, and an introduction to material needed for transportation studies. Transportation as an industry. Decisions on home-work locations. Review of census data. Introduction/review of analysis of transportation-related data. Discussion of critical issues in transportation.

TR 601   Travel Demand Forecasting   2½:0:3
Theory and application of travel forecasting methods to predict the amount and nature of travel on transportation systems. Corequisite: TR 600 or equivalent.
Also listed under CE 804.

TR 602   Urban Transportation Planning   2½:0:3
Transportation system planning from regional to local scales. Problem identification, issues and needs. Planning, design and operation of transportation systems. Evaluation of transportation system performance and impact. Prerequisite: TR 601 or equivalent.

**TR 603   Computer Applications and Analytic
                 Techniques in Traffic and Transportation   2½:0:3**
Model-building in transportation by use of analytic techniques and computer tools such as spreadsheets, statistical analysis, and existing transportation and traffic engineering packages. Emphasis in computer applications is on personal computers and existing software packages. Analytic techniques are addressed on three levels: (1) basic concepts; (2) case studies; and (3) review of literature. Modeling of trip generation, transportation safety, and other topics by deterministic analysis. Sensitivity analysis. Cost-utility analysis. Surveys and errors in surveys. Transportation packages including NETSIM, TRANSYT, TRAF, and Assignment packages. Prerequisites: TR 702 and TR 600.

TR 629   Transportation Workshop   0:5:3
Comprehensive projects designed to assure students' understanding of basic principles and their applications, drawing on knowledge from the M.S. requirements. Typically, two to four design or evaluation projects are completed, some of which are group projects. Written reports and oral presentations required. Projects or sub-assignments are based upon the degree the student is pursuing. Prerequisites for M.S. (TP&E) students: TR 601 and TR 701. Co-requisite: TR 702. Pre- or Co-requisites for M.S. (TM) students: IE 620, TR 750, TR 660.

TR 630   Urban Planning Principles   2½:0:3
A survey of the contemporary theory and methods of the planning function.
Also listed under CE 810.

TR 633   Land Use and Environmental Planning   2½:0:3
Land use planning and its interactions with transportation planning processes; relationships between land use patterns and travel demands; objectives and methods of land use planning; zoning and other implementation measures. Prerequisite: TR 630 or adviser's approval.

TR 660   Public Transportation   2½:0:3
Needs for public transportation in urban areas. Characteristics of public transportation services: commuter rail, rail rapid transit, light rail transit, express and local buses, commuter paratransit modes, taxi and other paratransit services. Planning and operations of transit routes and systems. Transit service performance measures. Functional design of transit stations, park and ride facilities, and transit rights-of-way.

TR 665   Design of Rail Facilities   2½:0:3
Design of systems for moving passengers and freight on rails. Roadbeds, tracks, alignments, yard, stations, signal communications, and protection devices. Design of light-rail transit facilities.

TR 670   Planning and Design of Terminals   2½:0:3
Passenger and freight terminals, with emphasis on system descriptions of these facilities. Land, marine, and air terminals. Methods for determining levels of service for pedestrian flow, TOFC and truck terminals are also covered.
Also listed under CE 840.

TR 671   Airport Planning and Design   2½:0:3
Techniques for forecasting air passenger traffic and aircraft operations at commercial and general aviation facilities. Principles and practices for planning and design of terminal facilities, ground transportation systems, parking facilities, runways and navigational aids. Airport site selections, configuration and economics.
Also listed under CE 841.

TR 672   Port Planning and Design   2½:0:3
Planning of marine terminal facilities for freight and passengers. Harbor and port capacity analysis. Functional design and control of ports. U.S port terminal needs for containers and bulk freight. Port operations.

TR 701   Traffic Engineering I   1:3:3
First course in a two-semester sequence covering the basic aspects of traffic engineering. Driver, roadway, vehicle, and traffic stream characteristics, and their influence on operations, controls, and design. Traffic studies and data analysis: volume, speed, delay, density, accidents, etc. Concepts of traffic capacity and level of service analysis. Capacity and level of service analysis of limited access facilities: freeways, freeway components, two-lane rural highways, multilane highways. Laboratories emphasize the use of spreadsheets in data analysis and the use of computer packages for capacity and level of service analysis. Co-Requisite: TR 600 or equivalent.
Also listed under CE 805.

TR 702   Traffic Engineering II   1:3:3
Second course in a two-semester sequence covering the basis of traffic engineering. Traffic control, operations, and management. Characteristics of signs, signals, and markings. The "Manual on Uniform Traffic Control Devices" and its use. Intersection control. Signal systems and coordination. Pretimed and actuated control. Design of street hardware. Traffic flow regulations and their implementation. Intersection and arterial analysis. Prerequisite: TR 701 or equivalent.
Also listed under CE 806.

TR 710   Design of Traffic Facilities   2½:0:3
Functional and preliminary design principles and analyses for freeways and arterials. Interchange design for freeway facilities and design of at-grade intersections, using principles of channelization. Design of parking garages and parking lots.
Also listed under CE 821.

TR 722   Highway Pavement Design   2½:0:3
Design, construction, maintenance, and rehabilitation of flexible and rigid pavements.
Also listed as CE 796.

**TR 723   Design and Management of Highway
                 Structures and Materials   2½:0:3**
Structures for highways, rural roads, and airports. Special problems of construction. Management of pavement systems.
Also listed under CE 797.

TRANSPORTATION

TR 750   Transportation Economics and Finance   2½:0:3
Basic principles of present worth, single payment and uniform series, sinking funds, annualized costs. Differences in the public and private sectors of transportation: profit, depreciation, return on capital. Benefit-cost analysis. Rate of return. Bond issues. Formulation and use of unit costs in highways, transit, and other modes. History of financing of road systems, transit, and trucking. Privatization. Balance sheets, financial control, cash flow. Preparing a private venture business plan.
Also listed under CE 812.

TR 754   Logistics Analysis   2½:0:3
Basic principles of logistics costs and analysis; interactions to physical distribution aspects of the shipper (packaging, plant and warehouse location) and related logistical analysis approaches.

**TR 755   Legal and Regulatory Aspects of
            Transportation   2½:0:3**
Origins, causes and effects of regulation on transportation and society in the United States economic and constitutional basis for transportation regulation. Legal basis, structure and function of federal, state and local regulatory bodies and their interaction with transportation industries. Current controversies concerning deregulation of sectors of the transportation industry.

**TR 757   Transportation Management
            and Decision Making   2½:0:3**
Current multi-dimensional problems in financial management, organizational management, labor-management relations, ridership development (marketing) and productivity which challenge top managers and political leaders in the mass transportation and commuter railroad industries. The political environment in which these organizations function is explored and analyzed. Case studies are used extensively.

TR 759   Transportation Policy   2½:0:3
Analysis of the major policies, regulations, and controls established or imposed by government at all levels — federal, state, and local — which currently impact on the transportation industry. (All modes considered). Case studies used exclusively.

**TR 760   Management of Transit Maintenance and
            Operations   2½:0:3**
Management of functional transit system aspects, including design and monitoring of maintenance functions to provide viable operating fleets and right-of-way, and management of daily operations, including scheduling, run-cutting, dispatching, and street management.

**TR 860-861   Selected Topics
            in Transportation I, II   each 2½:0:3**
Periodic presentations of topical materials of current interest. Topics presented are: site development and site impact; decision-making in transportation; computer packages in transportation; transportation systems safety. Prerequisite: academic adviser's approval.

TR 864   Transportation Safety Engineering   2½:0:3
Application of engineering principles to the operator-vehicle-environment system in all transportation modes to achieve maximum levels of human safety (both accident occurence and death/injury reduction). Proven practical engineering approaches in each mode and pan-modally are applied in the removal of hazards and harzardous conditions at every stage of transport activities, including planning, design, engineering, operation and maintenance.

TR 865   Traffic Safety Engineering   2½:0:3
Applications of system-safety engineering principles to the driver-vehicle-environment system to achieve higher levels of human safety (reduced accident occurrence and reduced severities of injuries). Proven, practical approaches are applied in the removal of hazards and hazardous conditions in every stage of the highway system activity cycle, including planning, engineering, design, operation, maintenance.

TR 901-902   Readings in Transportation I, II   2½:0:3
Special problems in transportation under the direct supervision of faculty members. Prerequisite: academic advisers' approval.

TR 951-952   Transportation Seminar I, II   nc
Relevant topics in transportation by guest speakers. Presentations and discussions of on-going research by course participants and faculty. Required of all full-time degree students in the program. Prerequisite: academic advisers' approval.

**TR 962   Master's Project in Transportation
            Planning and Engineering   each 3 units**
An independent project leading to a comprehensive report demonstrating professional competence. Reports must be orally defended and be submitted in acceptable (unbound) written form. Prerequisites: degree status and academic advisers' approval.

TR 963   Master's Internship in Transportation   each 3 units
Internships with relevant transportations organizations, leading to report demonstrating students' professional competence. Students are examined orally and must be orally defended and be ubmitted in acceptable (unbound) written form. Prerequisites: degree status and academic advisers' approval.

**TR 966   Master's Project in Transportation
            Management   each 3 units**
An independent project leading to comprehensive report demonstrating professional competence. Projects must be orally defended and be submitted in (unbound) written form. Prerequisites: degree status and academic adviser's approval.

**TR 997   Thesis for the Degree of Master
            of Science   each 3 units**
Continuation of project work, initiated in TR 962, or original research of sufficient comprehensiveness for motivated students. Bound written report required. Prerequisite: degree status and academic advisers' approval.

TR 998   Engineering Project   each 3 units
A comprehensive individual project, usually in the form of a comprehensive engineering study and analysis, a functional design project or control/operations system design. Prerequisites: degree status and academic adviser's approval.

**TR 999   Dissertation for the Degree   each 3 units
            of Doctor of Philosophy**
An original investigation embodying the results of comprehensive research in a specific area of transportation worthy of publication in recognized scientific or engineering journals. Students are required to take an oral examination of the subject of the dissertation and related topics. Prerequisites: degree status, passage of Ph.D. qualifying examination and academic adviser's approval.

TRANSPORTATION TRAINING AND RESEARCH CENTER

The Polytechnic established the Transportation Training and Research Center (TTRC) in 1975 to focus its research and non-degree training related to transportation. The Center has encouraged such research and has involved faculty from a number of the Polytechnic's departments and programs in research proposals and projects. In recent years, prospective principal investigators have come from transportation, industrial engineering, mechanical engineering, electrical engineering, civil engineering, metallurgy, and social sciences.

Acting through the TTRC, the Polytechnic is a participating member of the Regional Transportation Consortium, which consists of twelve universities in Federal Region II having a special interest in mutual interaction in transportation research, training, and technology transfer. Agencies may

contract with Polytechnic directly or through the Consortium.

Students are encouraged to become involved in the Center's research as research fellows, research associates, and project aides. In some cases, the student's education is fully funded by research.

Recent projects within the Center have included the development of the 1985 edition of the Highway Capacity Manual and the related personal computer software development; demand estimation for a high-speed ferry system; trip generation estimation; tire-pavement noise investigations; evaluation of single cable communications in rail rapid transit; and policy studies on van-pooling, express buses, and local bus-routing. Training development work has covered highway capacity, transit management for middle managers, transit management for first line supervisors, and microcomputer applications.

The Center anticipates a continuing emphasis on its strengths in traffic and highway engineering, transportation planning, and transportation management, as well as stronger emphasis in infrastructure, computer aided engineering, telecommunications related to transportation, and freight and goods movement.

FACULTY

William R. McShane, P.E., Professor of Transportation and Industrial Engineering; Head, Department of Mechanical and Industrial Engineering; Director, Transportation Training and Research Center.
B.E.E., Manhattan College; M.S., Ph.D., Polytechnic Institute of Brooklyn
Traffic engineering, highway capacity, expert systems in transportation, PC applications and models, economics and finance

Edmund J. Cantilli, P.E., Professor of Transportation and Safety Engineering
B.A., B.S.C.E., Columbia University; Certificate in Highway Traffic Engineering, Yale University; Ph.D., Polytechnic Institute of Brooklyn
Transportation safety; environmental impacts of transportation; urban planning; pedestrian, bicycle planning and human factors

John C. Falcocchio, P.E., Professor of Transportation Engineering; Academic Officer, Transportation
B.C.E., M.S., Ph.D., Polytechnic Institute of Brooklyn; Certificate in Highway Traffic Engineering, Yale University.
Transportation planning; public transportation; travel demand; traffic engineering; transportation system evaluation; transportation systems management

Walter Helly, Professor of Operations Research
B.S., Cornell University; M.S., University of Illinois; Ph.D., Massachusetts Institute of Technology
Queues and routing in networks; land use models; stochastic mode choice models

Herbert S. Levinson, P.E., Professor of Transportation
B.S.C.E., Illinois Institute of Technology; Certificate in Highway Traffic Engineering, Yale University
Transit operations, traffic engineering and capacity, highway engineering, transportation policy

Roger P. Roess, Professor of Transportation Engineering and Dean of Engineering
B.S., M.S., Ph.D., Polytechnic Institute of Brooklyn
Traffic capacity and design; traffic engineering; public transportation; transportation economics

Ravinder Nanda, Associate Professor of Industrial Engineering and Operations Research
B.S., Banaras Hindu University (India); M.S., Ph.D., University of Illinois
Operational planning of production systems; productivity measurement and evaluation; work design and performance improvement; training of management and supervisory personnel

Elena V. Shenk, Instructor in Transportation; Deputy Director of Transportation Program
B.A., State University of New York, Oneonta; M.S. Polytechnic Institute of New York
Traffic engineering; transit and economics; AI applications; software systems for transportation applications.

Jose M. Ulerio, EIT Instructor in Transportation
B.S., M.S., Polytechnic Institute of New York
Highway engineering; highway capacity; transportation assignment; transportation demand estimation; CAD and CAE applications.

ASSOCIATED FACULTY

Luiz Gomes, Visiting Professor (1985); Professor, Catholic University of Rio de Janeiro (Brazil)

ADJUNCT FACULTY

Paul Cohen, Lecturer
B.A., City College of New York; M.S., University of Illinois.

Philip A. Habib, PE, Adjunct Professor
B.E., City College of New York; M.S., Ph.D., Polytechnic Institute of Brooklyn.

Michael Horodniceanu, PE, Adjunct Professor
B.S., Technion Israel Institute of Technology; M.S., Columbia University; Ph.D., Polytechnic Institute of New York.

Seymour Kashin, Adjunct Professor
B.S., Columbia University; M.S., New York University.

Vassilis Papayanoulis, Lecturer
B.S., National Technical University of Athens, Greece; M.S., University of Birmingham, United Kingdom; M.S., Polytechnic Institute of New York.

Albert T. Rosselli, Adjunct Professor
B.C.E., City College of New York

Gennaro E. Sansone, Lecturer
B.S.E.E., Kansas State University; M.B.A., Iona College

TRANSPORTATION ADVISORY COMMITTEE

Polytechnic has a Presidental Transportation Advisory Committee which aids Polytechnic and its Transportation Programs in long-range strategic planning related to transportation. The committee is composed of distinguished transportation professionals and policymakers

The members as of January, 1988, are as follows:

S.S. Greenfield, Chairman of the Committee

Parsons Brinckerhoff, Chairman of the Board

Samuel Schwartz
First Deputy Commissioner of Transportation,
NYC Department of Transportation
New York City

Donald S. Berry,
Professor Emeritus,
Northwestern University

Louis J. Gambaccini,
Assistant Executive Director and Director of Administration
of the Port Authority of New York and New Jersey

David Gunn
President, New York City Transit Authority

Paul Soros
President, Soros Associates

THE ADMINISTRATION

ADMINISTRATIVE OFFICERS
George Bugliarello, Sc D., President
Donald M. Bolle, Ph.D., Senior Vice President, Academic Affairs
Seymour Scher, Ph.D., Senior Vice President
James J. Conti, D.Ch.E., Vice President, Educational
    Development and Director, Long Island Campus
Martha R. Leonard, M.B A , Vice President, University Relations
Vacant, Vice President for Development
Robert J. Maciag, M.S., Vice President, Academic Operations
John E. Rorer, M.P.A., Vice President, Administration
    and Finance

PRESIDENT'S OFFICE
George Bugliarello, Sc.D., President
Margaret Mastrianni, M.A., Executive Assistant to the President

ACADEMIC ADMINISTRATION
Donald M. Bolle, Ph.D., Senior Vice President, Academic Affairs
Robert J. Maciag, M.S., Vice President, Academic Operations
Eli M. Pearce, Ph.D., Dean of Arts & Science
Ernest B. Racz, Ed.D., Dean of Management
Roger P. Roess, Ph.D., Dean of Engineering
Richard S. Thorsen, Ph.D., Dean of Research
    and Graduate Studies
Samuel B. Korin, M.S., Director, Westchester Graduate Center
Helen Warren, Director of Academic Operations

Student Life
Caryl M. Stern, M.S., Dean of Students
Jeffrey A. Kessler, M.S., Associate Dean of Students
Robert E. Gardner, M.A., Assistant Dean of Students
Cheryl A. McNear, Director of Student Activities and Residence
    Coordinator
Kevin M. Banks, B.A., Director of Student Life - L.I. Campus

Student Development Programs
Ellen E. Dressner, M.S., Director

Special Services
    Haang Fung, M.S., Director
    Roseann Brogna, M.S., Associate Director
    Inyoung Lee, Ed.D., Assistant Director, Brooklyn
    Lenore Waldman, M S., Assistant Director, Long Island
        Campus
    Beverly Bayer, M.Ed., Counselor

Career Services
    Yvonne V. Harrison, B.S., Associate Director
    Katheleen Kennedy, M.S., Assistant Director, Brooklyn
    Jeanette Grill, B.A., Assistant Director, Long Island Campus

Registrar
Steven B. Berenback, M.A., Registrar
Lorraine R. Smith, M.Ed., Associate Registrar
Percess Atteloney, B.S., Assistant Registrar
Ruth Rosen, Assistant Registrar

Libraries
Richard Sweeney, M.L S., M.A., Dean of Libraries
    and Information Services
James Jarman, M.L.S., Assistant Dean of Libraries
    and Information Services

Irene Frye, M.L.S., Manager, InfoDash, InterLibrary Loan, Database
    Searching and Library Marketing Services
Svend Hoiberg, M.L.S., Librarian, InfoDash Division
Lilliana Middleton, M.L.S., Librarian, Reference Division
Paul Renzetti, B.S., Assistant Director, Electronic Library Systems
Lorraine Schein, M.L.S., M.S., Manager, Long Island Campus
    Library
Heather Walters, M.L.S., Librarian, Technical Services

Admissions
George Lynes, B.A., Director, Undergraduate Admissions
Marianne Boufall-Tynan, M.S., Director, Graduate Admissions
William N. Blades, M.Ed., Director of Admissions, Long Island
    Campus
Georgia-Lynne Lamens, M.S.Ed., Director, Youth in Engineering
    Science Program
Beverly Johnson, Admissions Office Manager

Financial Aid
Dale Herold, B.A., Director, Financial Aid
Brian Amelkin, B.A., Associate Director, Financial Aid
Mona Goldberg, Assistant Director, Financial Aid
Juan Cifuentes, B.S., Student Loan Coordinator

ADMINISTRATION AND FINANCE
John Rorer, M.P.A., Vice President, Administration and Finance
J.V. Cossaboom, B.A., Assistant Vice President, Computing and
    Administration
Robert Hawks, M.A., Assistant Vice President, Finance and
    Facilities
Ellen Bussard, M.S., Director, Planning and Budget
Richard N. Peeler, B.S., Controller
Rick R. Bacani, B.S., Assistant Director of Programming
Janet C. Koztowski, M.S., Personnel Officer
Charles Wildermuth, B.B.A., Director of Support Services

DEVELOPMENT
Vacant, Vice President, Development
Roddy A. Austin, Director, Corporation/Foundation Relations
David E. Pais, B.A., Director, Alumni Affairs
David Walker, B.A., Director, Special Events
John Watkins, B.A., Director, Annual Fund

Alumni Association
Christopher J. Witt '53, President
Anthony Palazzolo '72, Vice President
Benjamin Schneidman '71, Vice President
Charles Gozdziewski '72, Treasurer
Martin Dellato '81, Secretary

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