Polytechnic
UNIVERSITY

CATALOG
1986 — 1988

Long Island Campus

Brooklyn Campus

Westchester Graduate Center

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ACADEMIC CALENDAR
1986-1987

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Tuesday, September 9, 1986 — CLASSES BEGIN
Monday, October 13, 1986 — No classes (Yom Kippur)
Thursday, Friday, November 27, 28, 1986 — Thanksgiving Recess
Tuesday, December 9, 1986 — Monday classes meet
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Thursday, December 11, 1986 — CLASSES END
Friday, December 12, 1986 — Reading day
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RECESS
Wednesday, December 24, 1986 — Thursday, January 1, 1987

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Commencement — Monday, June 1, 1987

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Wednesday, Thursday, May 27, 28, Tuesday, June 2, 1987 - Registration
Thursday, June 4, 1987 — CLASSES BEGIN
Monday, July 6, 1987 — No classes
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1987-1988

FALL
Tuesday, Wednesday, Thursday, Sept. 1, 2, 3, 1987 — Registration
Monday, Sept. 7, 1987 — Labor Day
Tuesday, Sept. 8, 1987 — CLASSES BEGIN
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Thursday, Sept. 24, 1987 — No classes (Rosh Hashanah)
Tuesday, Nov. 24, 1987 — Thursday classes meet
Thursday, Friday, Nov. 26, 27 — Thanksgiving Recess
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Monday, Dec. 14, 1987 — Reading Day
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RECESS
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SPRING
Wednesday, Thursday, Friday, Jan. 20, 21, 22, 1988 — Registration
Wednesday, Jan. 27, 1988 — CLASSES BEGIN
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Tuesday, May 3, 1988 — CLASSES END
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Friday, May 6 — Monday, May 16, 1988 — Final Exams
Commencement — Date to be announced.

INTERSESSION
Tuesday, May 17 — Friday, May 27, 1988

SUMMER
Wednesday, Thursday, May 25, 26, 1988 — Registration
Tuesday, May 31, 1988 — CLASSES BEGIN
Monday, July 4, 1988 — No classes
Tuesday, July 12, 1988 — Monday classes meet
Tuesday, Aug. 23, 1988 — CLASSES END

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
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RECESS
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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

POLYTECHNIC UNIVERSITY

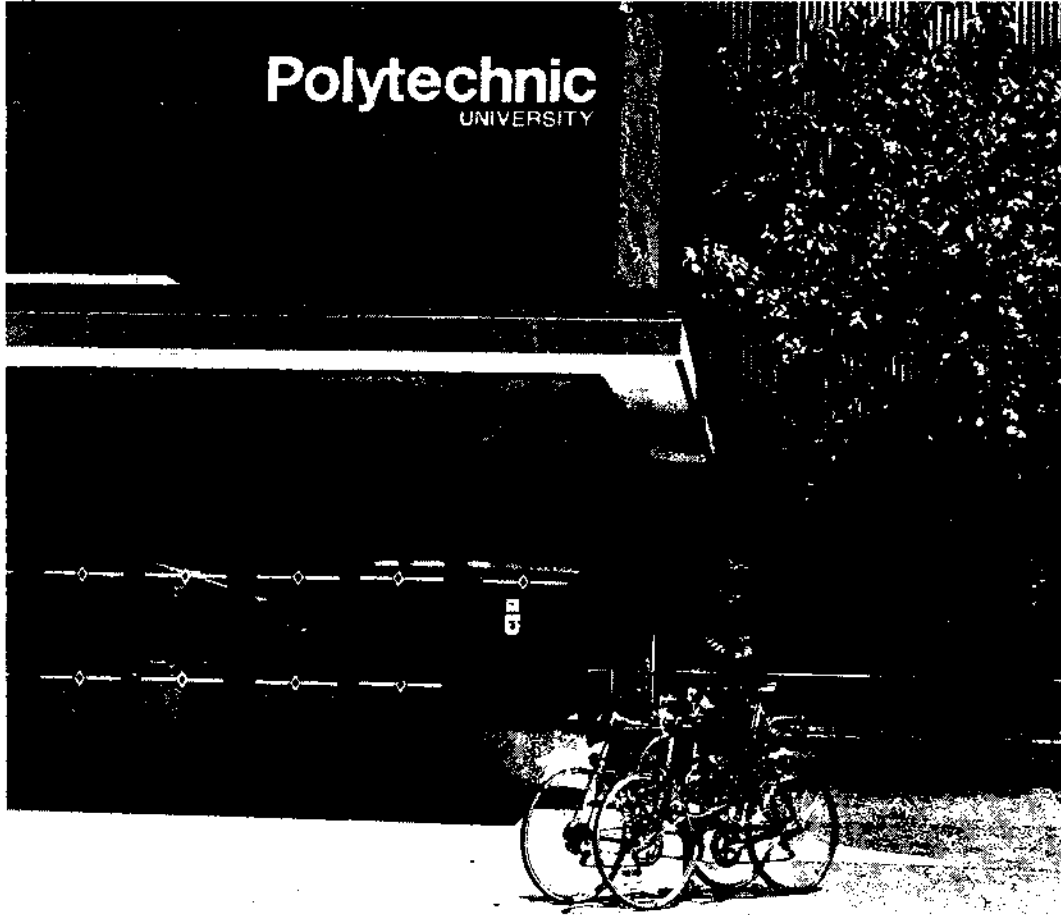Polytechnic University is the leading technological institution in the New York metropolitan region. Its mission is to address basic scientific theory and applications of technology, management of technology, and relationships between social institutions and technology through undergraduate, graduate, and continuing professional education and through an active and varied research program.

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

The student body includes over 2,200 undergraduate students and 2,200 graduate students. Engineering enrollment is one of 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 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 the commercial and governmental center of Brooklyn, across the Brooklyn Bridge from Manhattan's financial district, Wall Street. 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 graduate programs particularly relevant to the aeronautical, computer, and engineering industries clustered in Long Island. The University's Weber Research Institute, and many of the aeronautical research activities, are located here. A Graduate Center in White Plains, Westchester County, provides graduate programs to people living and working in that high technology area. In addition, Polytechnic works with major corporations to provide graduate programs for employees at their places of work.

History

Polytechnic University's distinguished tradition dates 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. Both schools began instruction in 1855.

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. The first Engineer degree — between the master's and the Ph.D. on the academic scale — was awarded in 1970.

In 1961 the Long Island Campus was opened in Farmingdale as a graduate and research center.

In 1973, Polytechnic Institute of Brooklyn merged with New York University's School of Engineering and Science to become Polytechnic Institute of New York.

Since 1973, Polytechnic has continued to develop under the leadership of its president, Dr. George Bugliarello. A graduate of the University of Padua who holds a doctorate from the Massachusetts Institute of Technology, Dr. Bugliarello has brought not only his broad engineering and research background in such areas as biomedical engineering, computer languages, and fluid mechanics, but also his vision and concern for the broader role of technology in society and for Polytechnic's role as a great technological institution in the greater metropolitan area, serving the needs of the region and of the world, for which New York is the crossroads.

Under Dr. Bugliarello's leadership, the Long Island campus opened its undergraduate division in 1974 and the Westchester Graduate Center opened in 1975. New relationships, encompassing research and education, have been developed with major technological corporations throughout the region.

New research centers have been established in transportation, imaging sciences, fire safety, advanced telecommunications, and philosophy of technology.

Curricula have been revised to integrate computer applications in all fields. New courses in computer-aided design and computer-aided manufacturing have been developed, and a contemporary liberal arts core curriculum has been created for students majoring in humanities, communications, and social sciences. New degree programs have been instituted in specialized journalism, imaging sciences, telecommunications management and other areas.

In 1985, by action of the New York State Board of Regents, the Institute was renamed Polytechnic University, a new name which more accurateley describes the range and quality of undergraduate and graduate programs as well as faculty research in engineering, the arts and sciences, and management.

Education Programs

Flexibility, 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, providing unusually great latitude for students to structure their studies to suit their needs. New programs of study are developed and traditional ones are revamped to keep pace with technological change and to broaden areas of inquiry related to science and technology.

Undergraduate

At the undergraduate level, all students receive thorough training in chemistry, physics, and mathematics, as the basis for more advanced specialized work. All 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 16 different fields of science and engineering. All students have extensive opportunities to work closely with senior research and teaching faculty during their undergraduate years.

Of particular note are undergraduate degree programs in humanities, journalism and technical writing, and the social sciences. These programs provide students with the unique opportunity to combine a major in the liberal arts tradition and course work in a vast range of science and technology-related courses — 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 35 fields; engineering degrees are available in 10 fields; Ph.D. degrees are available in 20 fields. The graduate programs have two focuses — one oriented toward professional career development, the other toward research. Specialized graduate certificate programs are also available for professional advancement.

Many of the MS programs are quite specialized within the general framework of technology. In addition to the major engineering and science disciplines, MS degrees are offered in transportation management, specialized journalism, polymer science and engineering, telecommunications management, industrial chemistry, history of science, environmental health science, and imaging sciences. Some of these programs have been recently developed to meet emerging needs: telecommunications management and imaging sciences are examples of pioneering education at Polytechnic. Some programs are particularly suited to our location: Polytechnic offers the most significant transportation management and transportation planning and engineering programs in the transportation capital of the world. Other masters programs, such as management or organizational behavior, take traditional areas of study and look at them 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.

Research Programs

Although students at all levels benefit from the advanced research taking place at Polytechnic, the Ph.D. programs are most closely intertwined with research efforts. The Polytechnic electrical engineering graduate program is ranked among the top in the country, and its faculty undertakes $2 million in sponsored research annually. The chemistry department has national prominence in the field of polymers and polymer synthesis, with a research volume of nearly $1 million a year.

Specialized research centers and clusters which draw on expertise in many disciplines address many of the fundamental technological challenges of today, and provide a research focus for Ph.D. candidates in many fields. The oldest such centers are the Weber Research Institute (formerly the Microwave Research Institute) and the Polymer Research Institute. Others have been created more recently: the Digital Systems Center, with a focus on complex computer control systems; The Institute of Imaging Sciences, which spans chemical and computer aspects of imaging problems; and the New York State Center for Advanced Technology in Telecommunications, with a broad range of topics from telecommunications networks to office automation to software engineering.

Yet another new center, the Philosophy and Technolgy Study Center, is pioneering the development of a new area of scholarly pursuit, which affirms the University's broad perspective in its role as a technological institution.

Faculty

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

Faculty work with advanced graduate students to develop teaching and research skills as teaching assistants and research fellows.

Many faculty members have written undergraduate and graduate textbooks used throughout the United States. Several have received wide recognition for professional and research activities. In 1984, Professor Athanasios Papoulis, Professor of Electrical Engineering, was awarded the IEEE Education Medal in national recognition for his contributions to education and teaching.

Other awards to faculty members in recent years have included the National Medal of Science to Herman F. Mark, who is considered the father of modern plastics; the IEEE Microwave Career Award to Professor Nathan Marcuvitz; and the Halliburton Excellence in Research Award to Professor Erich Kunhardt. 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 promotes the welfare of Polytechnic and the individual alumna and alumnus. As the need and interests of the alumni change, the responsibilities and objectives of the Alumni Association also change. It is primarily a service organization for all alumni, particularly in the area of continuing education and professional job placement and new student recruitment. While fellowship is a very important aspect of the Association's activities, it is a by-product of the service programs for alumni.

The Alumni Association helps sponsor various social activities for students including the annual Freshman Orientation. In addition, career symposiums featuring

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prominent alumni speakers are held for all interested students. These symposiums illustrate the breadth of career opportunities open to Polytechnic graduates.

The Alumni Association has established a Student Alumni Association within its structure. This all-student committee works closely and meets regularly with the Association's Board of Directors to promote liaison 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. 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.

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.

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 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 Placement 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 student-run radio station, 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 700 undergraduates with a wide range of student clubs and activities; there are also approximately 700 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 situated 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 electromagnetics; wave propagation; space-science radiophysics; quantum electronics; modern optics; laser techniques; high-frequency solid-state phenomena and devices; microwaves; 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 and 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.

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 Master's degree programs and courses of continuing education.

Classes at the Center in White Plains 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.

The Westchester Graduate Center is located at 456 North Sreet in White Plains. It is near major highways and particularly convenient for students not only from Westchester County but also from Southern Connecticut, Rockland county, and Northeastern New Jersey.

The Academic Building 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) 643-5000

Long Island Campus
Route 110, Farmingdale, NY 11735
(516) 454-5111

Westchester Center
456 North Street
White Plains, New York 10603
(914) 949-2339

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, on 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. 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.

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

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

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

Other Campuses and Programs

Westchester Graduate Center — Faculty and students can get toll-free library service by using the available hot line telephone in the Richard Laster Library Lounge or by calling the Brooklyn Library and having materials mailed upon request. Faculty and students at other approved extension programs are entitled to the same services and can obtain it by calling the Brooklyn Library.

NEW LIBRARY PLANS — Polytechnic University plans to break ground during the next fiscal year for a new 12 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 remotely and to retrieve information, books, journal articles, or documents when ever they are needed.

COMPUTER CENTER

Polytechnic maintains a Computer Center responsive to educational and administrative needs. It is available to faculty and students for use in course work and research.

On the Brooklyn campus, Rogers Hall contains the University's main computer facility, which houses an IBM 4341 and a DEC PDP 11/70 which can be accessed through terminals throughout the Institute, including the Long Island and Westchester campuses. The Center also contains an IBM 4341 mainframe, dedicated to computer-aided design and manufacturing. This computer supports similar activities via high-speed terminal links at the Long Island and Westchester campuses. The Brooklyn campus also has a personal computer laboratory.

The Long Island Center is equipped with its own DEC 1160, Harris 800, and Gould 32/6750 computers, as well as an APOLLO 4-node computer network. In addition, the Long Island Center has access to all the computer facilities, including the computer-aided design and manufacturing system housed at the Brooklyn campus, and is equipped with a Personal computer laboratory.

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.

Six research areas are active in the Center.

They are as follows:
  Networks and Systems
  Devices and Propagation
  Office Automation
  Image Communications
  Government Systems
  Network Design

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

To this end, the Center has developed a curriculum combining special courses in telecommunications practices with electrical engineering, computer science, and management offerings. (Details of the Graduate program in Telecommunications Management are listed under the Division of Management).

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.

Technological innovation is the sustaining force behind deveopment 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.

CENTER FOR DIGITAL SYSTEMS

The Center for Digital Systems was established on the Long Island Campus in 1982, with a founding grant from the Fairchild Republic Corporation. The goal of the Center is to promote close cooperation in educational and research programs between Polytechnic and industry in areas relating to the development of digital systems technology.

Specific topics for study within the scope of the Center include: fault system architectures to achieve enhanced system reliabiltiy; high speed data base technology and fiber optic communications, with special emphasis on the use of these media in avionic systems; computer-aided design of VLSI and VHSIC components; advanced techniques for the integration and automatic testing of complex digital systems; software engineering and simulation tools for the development and evaulation of digital system software.

The Center's activities are carried out by faculty, staff and graduate students from the Electrical Engineering and Computer Science Department. Projects are supported by government and industry with a major commitment to cooperate with industry on both short-and long-term projects, using capabilities maintained within the Center for Digital Systems.

INSTITUTE OF IMAGING SCIENCES

Imaging Sciences concerns all aspects of information presented in visual form. The Institute of Imaging Sciences (IIS), founded with a private gift of one million dollars, involves 15 faculty 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 imaging research projects and courses, IIS publishes a newsletter, *Imaging Quarterly*, and holds an annual research review.

POLYMER RESEARCH INSTITUTE

The Polymer Research Institute, a division of the Chemistry Department, is the oldest academic center of polymer investigations in the United States and enjoys a world-wide reputation. It was founded in 1940 by Dr. Herman F. Mark, who continues as dean emeritus of Polytechnic.

At present, six members of the Chemistry Department are engaged in teaching courses that deal with macromolecules and supervising research in that field. In addition, the "Polymer Science and Engineering" program conducted in cooperation with three members of the Chemical Engineering Department specializing in polymer technology.

As a consequence of the long tradition in the teaching of polymer science at Polytechnic, we count among our graduates a large proportion of both academic and industrial scientists active in that field.

Otto Vogl was appointed in January, 1983 as the Herman F. Mark Professor of Polymer Science. The appointment of Professor Vogl to this distinguished post reaffirms a continuing commitment by Polytechnic to the Polymer Research Institute, which serves as a focal point for unifying interdisciplinary activities in chemistry, physics and technology associated with polymer science and engineering.

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 and 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, and Mechanical/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. It promotes interdisciplinary research into the inner structure of technology; its relationships to science and art; ethical responsibilities and political problems arising from technological design, production, and evolution; aesthetic analyses of engineering and 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.

METROTECH

Polytechnic is the sponsor/developer of a $500,000,000 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 a 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.

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 prinicpal investigators have come from transportation, industrial engineering, mechanical and aerospace engineering, electrical engineering, civil engineering, metallurgy, and social sciences.

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.

FIRE RESEARCH CENTER

The Fire Research Center was established in recognition of the national need to direct the efforts of the scientific and technological communities to the complex issues of unwanted fire. The Center is located in the former Brooklyn Fire Headquarters, a landmark building on Jay Street, just south of Rogers Hall.

The Center draws on the expertise of civil engineering staff experienced in building design and construction and urban and fire protection engineering, as well as research faculty from other relevant disciplines, including low velocity aerodynamics, the behavior of polymeric materials and the behavioral sciences.

Principal focus of research is on the study of the performance of structures exposed to fire and to those aspects of fire phenomena dealing with ignition, growth and extension, and the control of products of combustion. Much of this work is directed toward the establishment of criteria and standards for use in building and fire codes.

Over the past decade, research assignments have included conducting full-scale fire tests; writing new fire safety codes for high-rise buildings under sponsorship of the New York City Fire and Building Departments; the study of fire in high-risk residential buildings and the design of low-cost fire protection measures for these structures, for the Fire Department and the Department of Housing Preservation and Development; fire prevention in urban communities for the U.S. Fire Administration; and a wide range of fire-related projects for the design professions.

Current activities of the Center include the development of a state-of-the-art laboratory for the investigation of fire and the design of a computer-based fire simulation and training system.

The Center sponsors and conducts seminars, conference and short courses of interest to the various components of the fire safety community, including the fire services, fire protection engineers, the design professions and insurance industry. Both undergraduate and graduate students are encouraged to participate in the Center's projects and programs.
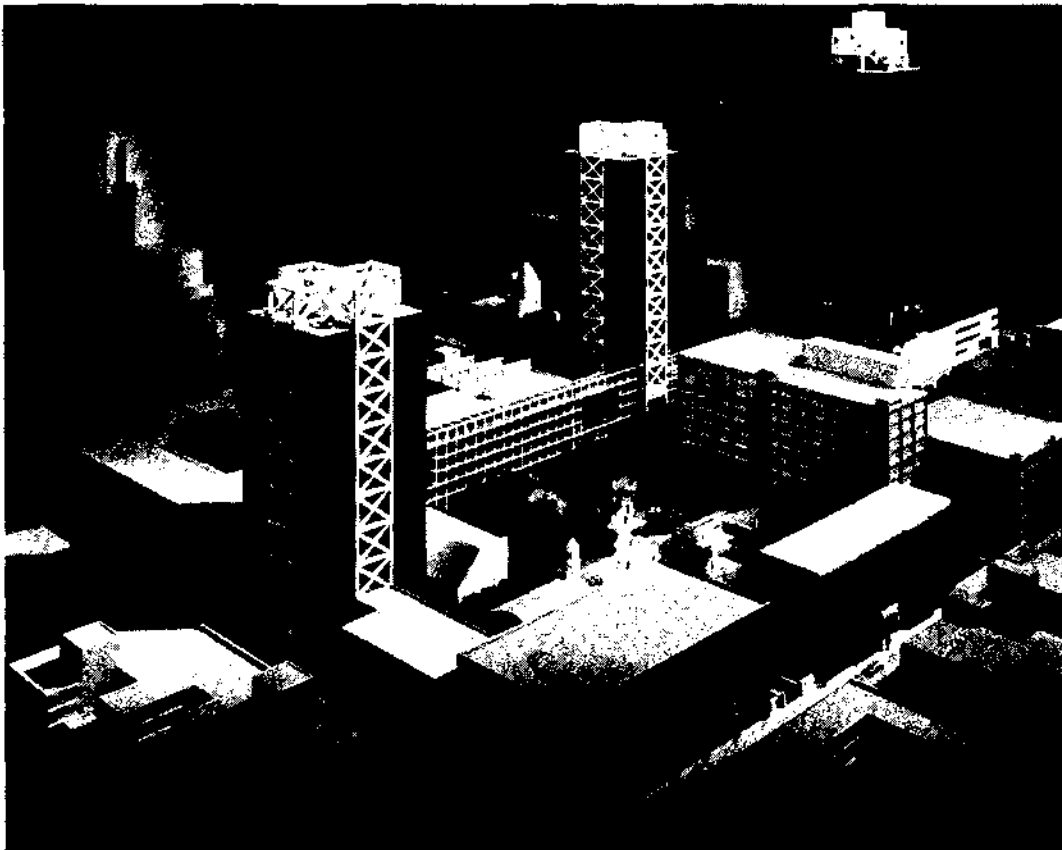
Metrotech model

CURRICULA

UNDERGRADUATE PROGRAMS

Students may work toward bachelor's degrees either in four years of full-time study in the day session 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 or February. Full-time students entering in September follow normal curricula outlined for fall and spring semesters. Those entering in January or February 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 curricula guide and program descriptions under the various departments and to the Schedule of Classes available at the Office of the Registrar

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 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.

The Cooperative Education Program is available to undergraduate students who have:
1. Completed at least 30 credits of academic work with no course deficiencies
2. Maintained at least a 2.5 cumulative average
3. Successfully completed Cooperative Education Seminars CP 101-102

Freshmen, therefore, would be eligible for their first work experience during the summer following the completion of their first academic year. Graduate students and transfer students are eligible usually after completion of one semester.

Students who apply and are accepted to the program will start interviewing with participating co-op companies during the semester prior to their first work experience. The Cooperative Education Office will be responsible for setting up the interviews. In most cases the company interview will determine whether or not the student is hired as a co-op employee. Once "on the job" the co-op student employee will be paid a salary and usually receives company benefits. In all cases the students will be given the opportunity to work at tasks directly related to their career goals.

Certificate Programs

Name of Program	Hegis Code	Name of Program	Hegis Code
Management and Business Administration	(0506)	Mathematical Programming	(0704)
Applied Statistics	(1702)	Mathematical Statistics	(1702)
Computer Applications	(1701)	Operations Management	(0506)
Computer Mathematics	(1703)	Operations Research	(0507)
Construction Management	(0599)	Organizational Behavior	(0515)
Econometrics and Forecasting	(2204)	Polymeric Materials	(0906)
Economics	(2204)	Production and Inventory Control	(0913)
Economic Systems	(2204)	Public Policy	(2102)
Energy Management	(0599)	Public Transportation	(0908)
Engineering Statistics	(1702)	Quality Control and Reliability	(0913)
Energy Policy and Engineering	(0999)	Technology Management	(0599)
Engineering Statistics	(1702)	Traffic Engineering	(0908)
Finance	(0504)	Transportation Facility Design: Operation	(0908)
Human Resources	(0515)	Transporation Management and Economics	(0908)
Industrial Engineering	(0913)	Transportation Planning	(0908)

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 Health Science (0922)		■		
History of Science (2205)		■		
Humanities (4903)	■			
Imaging Sciences and Engineering (4904)		■		
Industrial & Applied Mathematics (1703)		■		
Industrial Chemistry (0906)		■		
Industrial Engineering (0913)	■	■	■	■
Information Systems (0702)		■		
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)		■		■
Journalism and Technical Writing (0602)	■			
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

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) 643-2150	(516) 454-5150

Undergraduate applicants should complete the admissions application form and forward it to the Admissions Office with either a $20 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).

Personal essays and teacher recommendations are welcome, but not required.

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 International Applicants, page 16.)

If accepted for admission, the student 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.

Students who are admitted 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 ACTION PLAN

Under the Early Action Plan, students may request an admissions decision by December 1, provided that their applications and supporting documents are submitted on November 1. Students admitted under this program are under no obligation to make a commitment to enroll at Polytechnic.

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

In as much as the course of studies at Polytechnic is academically rigorous and intellectually challenging, 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—2 years
Electives—3 years (technical courses such as precalculus, 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.

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 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 Aptitute 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 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. Substandard performance in a course at Polytechnic will result in a reevaluation of transfer credit.

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 AN INTERNATIONAL STUDENT

Proficiency in English is a prerequisite for admission. The Test of English as a Foreign Language (TOEFL) is required of all students whose native language is not English. In addition, international applicatns must submit a statement of financial capability before being permitted to enroll.

Students holding F-1 or J-1 visas must enroll as full-time students.

International students transferring from other United States institutions are required to submit the I-20 or IAP-66 obtained from Polytechnic to their present institutions in order to begin U.S. Immigration Service Transfer Procedures.

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 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) 643-5995.

ADMISSION AS A PART-TIME STUDENT

Students seeking a bachelor's degree may enroll on a part-time basis at the Brooklyn campus taking day or evening courses, and at the Farmingdale campus taking day courses. At the present time, however, only degrees in civil, electrical, and mechanical engineering can be completed during the evening session at the Brooklyn campus. In other disciplines students will be required to take some courses during the day session in order to complete their degrees.

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.

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.

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.

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. This interview is not required as a condition for admission, but is a useful process for the applicant and the admissions staff.

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.

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 Research and Graduate Studies, 333 Jay Street, Brooklyn, New York 11201, (212) 643-3693.

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 Research and Graduate Studies. 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.

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 Research and Graduate Studies.

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 upon recommendation by a faculty member and approval of the graduate Dean. The applicant must provide all required admission documents to the Office of Research and Graduate Studies 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 Research and Graduate Studies. 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 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.

Graduate Probation. 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

Repeated courses will count only once in the grade-point average, with the higher grade being used.

After the posting of spring grades, any graduate student 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.

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 ia 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.

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 (e.g., student income; family income; the 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 required 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 percent of Polytechnic's undergraduate students receive aid in combinations of scholarships, grants, campus jobs, National Direct Student Loans, and Guaranteed Student Loans.

To Apply

1. Incoming freshmen should file the complete Financial Aid Form (FAF) with the College Scholarship Service, Princeton, New Jersey, by February 1. (Later applications are considered on a rolling basis as funds are available.)
2. Transfer students should file the FAF by May 1, and request a financial aid transcript from the transferring institution to be sent to the Financial Aid Office at Polytechnic University by May 15.

To Renew

1. Students should request the Financial Aid Form from the Director of Financial Aid in February - March.

2. Students should file the FAF with the College Scholarship Service, Princeton, New Jersey, by March 15.

3. Students should file the Polytechnic Financial Aid Application with the Office of Financial Aid by March 15. A copy of the parents' 1040 or 1040A and/or the student's 1040 or 1040A tax forms for the previous calendar year must accompany this application.

FEDERAL-BASED PROGRAMS

Supplemental Educational Opportunity Grants (SEOG)

Application procedures. Awards are determined by Polytechnic's Financial Aid Office. Students must be accepted and have filed the FAF with the College Scholarship Service.

Selection and allocation. Applicants must show need and be enrolled at least half-time as an undergraduate student.

Award schedule. Awards range from $200 to $2,000. Normally an award may be paid for up to four years, or up to five years for certain courses of study.

Responsibilities. Students must continue to make satisfactory academic progress.

National Direct Student Loan Program (NDSL)

Selection and allocation. Loans are available to needy students enrolled at least half-time.

Award schedule. Amounts which may be borrowed are $3,000 by students who have completed less than two years of a program leading to a bachelor's degree; and $6,000 by students who have completed two years toward a bachelor's degree, to include any amount borrowed through a NDSL for the first two years of study.

Responsibilities. The current interest rate, payable during the repayment period, is 5 percent on the unpaid principal. Repayment begins six months after graduation or after leaving Polytechnic and may extend up to ten years. The minimum monthly payment is $30. Payment is not required for up to 3 years of active U.S. military service, or service in the Peace Corps, VISTA, or similar national programs.

College Work-Study Program (CWSP)

Application procedures. Awards are determined by the Financial Aid Office. Students must have filed a Financial Aid Form (FAF). After eligibility is determined, work arrangements are made through the Personnel Office.

Selection and allocation. Applicants must be enrolled at least half-time. Polytechnic provides employment to eligible students who demonstrate financial need. If more students are eligible for the CWSP than there are funds available, preference is given to students with greater need who must earn a part of their educational expenses. Generally, the CWSP is not available to freshmen.

Award schedule. Polytechnic arranges jobs on or off campus with public or private nonprofit agencies. Most assignments average 15 hours per week.

Responsibilities. Satisfactory academic progress must be maintained.

Pell Grants (formerly Basic Educational Opportunity Grants)

Application procedures. Applications and other materials are available through the Financial Aid Office. Applications should be completed according to directions or students should apply for the Pell Grant by checking the appropriate box on the FAF. Student Aid reports will be sent to applicants from the Department of Education. Based on an eligibility index, the amounts of Pell Grants are determined by the Financial Aid Office. Upon enrollment, funds are paid directly to Polytechnic in the student's name.

Selection and allocation. The Pell Grant program is an entitlement program. Scholastic accomplishment has no bearing on eligibility. Applicants must be enrolled as undergraduates at least half-time. Financial need is determined by a formula developed by the U.S. Department of Education and reviewed annually by Congress. The formula is applied to all applicants, and the *student eligibility index* is calculated by this formula.

Award schedule. Currently, awards range from $250 to $2100, but not more than one-half the total cost of attendance. Awards are determined by costs of attendance and full- or part-time enrollment status. Pell Grants do not duplicate state awards.

Rights and responsibilities. Students must make satisfactory academic progress, must repay Pell Grants and other awards, or be in default of any student loans. Before receiving payment, students must sign an affidavit that all money will be used only for the costs of education. Most Pell Grant payments are credited directly to the student's University accounts.

Veterans Administration (VA) Educational Benefits

Application procedures. Applications are available at all VA offices, active duty stations and American embassies as well as the Office of Student Records. Completed forms should be submitted to the nearest VA office.

Veterans' Information. All veterans enrolled at Polytechnic should notify the Veteran Affairs clerk in the Office of Student Records 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.

Selection and allocation. 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 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.

Award schedule. 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.

Responsibilities. Interrupted attendance or termination of study by students receiving VA benefits must be reported. Details of Polytechnic's requirements are given to all applicants. Eligible students must apply for certification each semester at the Office of Student Records.

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 $1,000 for each year the scholarship is in effect.

NEW YORK STATE-BASED PROGRAMS

Tuition Assistance Program (TAP)

Application procedures. Applicants must apply annually to the New York State Higher Education Services Corporation (HESC), 99 Washington Avenue, Albany, NY 12255. The application deadline for the 1986-87 academic year is March 31, 1987. The HESC determines the applicant's eligibility with an award certificate indicating the amount of the grant. Applicants present a copy of the certificate when tuition is paid. Polytechnic will defer payment upon receipt of the certificate.

Selection and allocation. TAP is an entitlement program. Applicants must (1) be New York State residents and U.S. citizens or permanent residents; (2) be enrolled full-time at an approved New York State post-secondary institution; (3) have, if dependent, a family net taxable income below $29,000 or if independent and single with no tax dependents, a net taxable income below $5,667; an (4) be charged tuition of at least $200 per year.

Undergraduate students generally receive TAP awards for four years of study. Students enrolled in approved five-year programs may receive undergraduate awards for five years.

Award schedule. 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.) For the 1986-87 academic year, full-time dependent students can receive awards ranging from $300 to $2,700.

Responsibilities. Students must meet satisfactory academic requirements after each increment of 12 semester hours is completed. Additionally, students must satisfy program requirements stipulating that students earn passing grades in the minimum course load in each term an award is received.

AID FOR PART-TIME STUDY (APTS)

Application procedures. Applications and other materials are available at the Financial Aid Office. Applications should be completed and returned to the Financial Aid Office as soon as possible. Students must apply annually. Applications should be filed no later than the second week of classes for the following semester.

Selection and allocation. To be considered for an award, students must: (1) be working toward an undergraduate degree as part-time students enrolled for at least 6 and not more than 11 credits per semester; (2) have earned at least 6 credits or the equivalent; (3) retain good academic standing; (4) be residents of New York State; (5) be either American 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; (8) have tuition charges of at least $100 per year; (9) have, if dependent, a family net taxable income below $22,000, or if independent, or independent and not eligible to be a tax dependent, a single student's (or, if married, combined) net taxable income cannot exceed $15,000.

Award schedule. The program provides up to $2,000, but may not exceed tuition charges.

VIETNAM VETERANS TUITION AWARDS SUPPLEMENT (VVTA)

Application procedures. Applications and other materials are 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 March 31, 1987 by part-time students. Full-time students must apply by submitting both Vietnam Veterans Tuition Award Supplements *and* the Student Payment Applications (TAP Application) by March 31, 1987.

Selection and allocation. 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 entry into service and resumption of residency by September 1, 1987; (2) have served in the U.S. Armed Forces in Indochina between January 1, 1963 and May 1, 1975; (3) be honorable 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 Tuition Assistance Program (TAP) and Pell Grant awards. There are no income restrictions connected with this program.

Award schedule. 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 are specifically requiring 5 years for full-time study and double the amount of time for part-time study.

Responsibilities. Students must meet satisfactory academic requirements after each increment of 12 semester hours is completed. Additionally students must satisfy program requirements stipulating that students must earn passing grades in the minimum course load in each term an award is received.

Regents College Scholarship

Application procedures. Applicants may obtain application forms from their high schools.

Selection and allocation. Regents College Scholarships · are awarded on a competitive basis. Applicants must (1) be legal residents of New York State for at least one year immediately preceding the first term for which application of an award is made; (2) have been in attendance at a high school no more than six years before the examination was taken; and (3) not previously have competed for a Regents Scholarship.

Award schedule. The Award is $250 per year for up to five years, depending on the length of the program in which the recipient is enrolled.

Polytechnic Matching Grants have automatically been awarded to freshmen and transfer students entering on or after September 1980, even if the student is ineligible for other financial aid. The matching grant is equal to $250.

Guaranteed Student Loan Program

Application procedure. Students should obtain a loan application from participating state lending institions (banks, credit unions, etc.) in the state or permanent residence along with the GSL Needs Test Form. Completed applications should be presented to the Polytechnic Financial Aid Office for certification. Applications are then forwarded to the lending institutions and the appropriate state agencies.

Selection and allocation. To be eligible for a guaranteed state loan, students must (1) be American citizens or permanent resident aliens, (2) be enrolled in or admitted at least half-time at an approved post-secondary institution; and (3) prove need in that taxable family income is over $30,000.

Loan schedule. An undergraduate may borrow up to $2,500 per academic year, up to a total of $12,500.

Responsibilities. Students may borrow at a relatively low interest rate (currently 8 percent) with no repayment as long as the student remains enrolled at least half-time. Payment of the principal may be further deferred during graduate study or service in the Armed Forces, Peace Corps or Domestic Service.

If students apply for an additional loan, application must be made at the original lending institution. Four months after ceasing to be at least a half-time student, the borrower must make formal arrangements with the lending institution to begin repayment.

Responsibilities. Satsifactory academic progress must be maintained.

Parents Loan For Undergraduate Students (PLUS)

Application procedures. Students should obtain loan applications from participating state lending institutions (banks, credit unions, etc.) in the state of permanent residence. Completed applications should be presented to the Polytechnic Financial Aid Office for certification. Applications are then forwarded to the lending institutions and the appropriate state agencies.

Loan schedule. Parents of undergraduates may borrow up to $3,000 per year not to exceed $15,000 for total undergraduae study.

Responsibilities. When *dependent* students need even further assistance, the PLUS loan is available to their parents. No criteria of need are connected to PLUS. The loan is unsubsidized (currently carrying a 12 percent interest rate); payments begin within two months of receiving the check. *Parents, not* students, are responsible for repayment.

Auxiliary Loans to Assist Students (ALAS)

Application procedures. Students should obtain loan applications from participating state institutions (banks, credit unions, etc.) in the state of permanent residence. Completed applications should be presented at the Polytechnic Financial Aid Office for certification. Applications are then forwarded to the lending institutions and the appropriate state agencies.

Selection and allocation. Eligibility criteria for the ALAS loan are the same as the Guaranteed Student Loan except the borrowers cannot receive more than $2,500 in any single academic year (including whatever may have been borrowed under the GSL program).

Loan schedule. Combined borrowings from the Guaranteed Student Loan and Auxiliary Loan to Assist Students cannot exceed $12,500 for undergraduate studies.

Responsibilities. Independent undergraduate students, who are not eligible for the ordinary GSL, may seek help from this program. The loan is unsubsidized (currently carrying a 12 percent interest rate); payment begins immediately upon completion of studies or after full-time enrollment.

INSTITUTIONAL LOANS (Limited resource - dependent on available funds)

Application procedures. Students can apply directly to the Financial Aid Office using the Financial Aid Forms (FAF). After eligibility is determined, students are notified via award notifications.

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

Responsibilities. Students are generally allowed to borrow up to $2,000 per academic year. Interest rates are

variable. Repayment begins after graduation or after leaving school.

ALTERNATE FINANCING

While Polytechnic has no deferred payment plans, alternate financing options are available through banks and lending institutions. These programs generally provide installment payment opportunities.

SCHOLARSHIPS AND GRANTS

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

- 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 $4,500. Continuance of the awards demands maintenance of a 2.5 cumulative grade point average and application to the Pell and TAP programs.

  Board of Trustee Scholarships are awarded to academically superior freshmen. Applications are made directly to the Admissions Office. Amounts of the scholarships are equal to tutition, less any outside aids 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.

- Contemporary Liberal Arts Scholarships are awarded to academically superior freshmen majoring in Humanities or Social Sciences. Applicatons are made directly to the Admissions Office. The amounts of the scholarships are equal to tuition, less any outside aids 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.

- Geiger/Fialkov Scholarships are 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.

- Division of Arts and Sciences Scholarships 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 Head and application to the Pell and TAP programs.

- Metallurgy and Materials Science Scholarships 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 $1,000. Maintenance is dependent upon high academic performance.

- Outstanding Achievement Scholarships are awarded to full-time, continuing students (sophomore, junior, and senior) with a cumulative grade point average of 3.5 or higher who are not receiving any other Polytechinc scholarships. 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 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 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 being classes and range up to $2,500. Maintenance is based upon a 2.5 cumulative grade point average.

- Polytechnic National Society of Professional Engineers Scholarships (NSPE) 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 are awarded to recipients of a Mayor's Scholarship. Scholarship amounts range between $100 - $650. The application deadline for Mayor's Scholarships is October 1. Applications are available at high schools or the Financial Aid Office.

IMPORTANT FINANCIAL AID POLICIES

- To be eligible to recieve 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 are expected to apply for a Pell Grant and, in the case of New York residents, for the Tuition Assistance Program.

- 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 evaulations of a student's qualifications are made without 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.

- 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, National Direct Student Loan and the 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 student's; (or parents') IRS Form 1040 or 1040 A/EZ, if requested; (4) signed affidavits acknowledging Selective Service Registration; and (5) proof of permanent residency status.

Students receiving financial aid from federal or state sources, must be studying toward a degree according to the standards set forth in the Academic Policies of this catalog.

Terms of eligibility for financial aid are calculated by the total time of students enrollment at Polytechnic. Students, therefore, can be making satisfactory progress toward their degree, but potentially exhaust their eligibility for financial aid from New York State by not completing their degree requirements within the stipulated eight-semester terms of eligibility.

Students may request waivers of the standard of minimum satisfactory progress during one term. Such a request should be made to the Dean of Students.

GRADUATE

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 during the academic year is remitted.

Teaching Fellowships

Fellows are full-time graduate students who participate half-time throughout the academic year in teaching assignments. Tuition during the academic year 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.

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, leading to an advanced degree on a part-time basis. This tuition reduction offer is not available to students with "special" status.

The applicant must be accepted into a graduate program through the formal Polytechnic admissions procedure.

Written verification of employment as a full-time high school or college teacher, signed by the applicant's department head and an officer of the 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 an 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.

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 an American citizen. More information can be obtained from the Schedule of Classes or the Office of Research and Graduate Studies.

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 1986, full-time tuition for undergraduate students (12 to 20 credits) is $4,600 per semester. Students enrolled for fewer than 12 undergraduate credits pay $300.00 per credit. Full-time tuition for graduate students is $4,700 per semester, and for part-time graduate courses $330 per credit.

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

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, ranging from $20 to $80 per semester, 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 and acceptance fees, transcript charges, 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 1986-87
FOR UNDERGRADUATE STUDENTS

	Commuter	Dormitory	Off-Campus (Self-Supporting)
Tuition and Fees	$ 9,200	$ 9,200	$ 9,200
Room and Board	1,532	3,000	4,923
Books and Supplies	350	350	350
Transportation	578	Variable (Minimum 160)	578
Personal Expenses	945	945	1,965
Total:	$12,605	$13,655	$17,016

ESTIMATED EDUCATIONAL COSTS—
ACADEMIC YEAR 1986-87
FOR INTERNATIONAL STUDENTS*

	Undergraduate	Graduate
Tuition and Fees	$ 9,200	$ 9,400
Room and Board	4,300	4,300
Personal Expenses	2,300	2,300
Insurance**	60	60
Books and Supplies	475	475
Total:	$16,335	$16,535

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.

*Subject to change. Does not include expenses for dependents.
**For single students. Family coverage is available at additional cost.

Refund Schedule:

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

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 should 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 the 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 reprocessing fees of $40. To receive academic credit, registration is required each semester for every course, including thesis. Attendance in class does not constitute registration. Registration becomes valid only after payment of appropriate tuition and fees to the Bursar and certification by the Office of the Registrar.

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 or summer semesters. 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.

All students have responsibility of registering for conflict-free schedules. In instances of student-scheduled conflicts which necessitate course changes after registration, the add-drop fee will not be waived.

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 program 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. If, however, they are deficient in only one such prerequisite course, they may apply to their advisers for admission to the advanced courses. If these applications are approved by the advisers and by the teachers of the advanced and prerequisite courses, students may be admitted to the advanced courses.

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 making changes in registration or requesting transcripts. IDs must be presented and/or surrendered to any officials 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 permanent throughout students' careers at Polytechnic and will not be changed, even if social security numbers are obtained later.

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 are one continuous year of full-time study or the equivalent part-time. See page 15 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 considered to be transfer units, subject to the nine unit limitation for the master's degree, since the student was not in residence as a graduate student when the courses were taken.

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 degrees 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 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.

Undergraduates enrolled in an engineering degree program must take a minimum of 18 credits in the humanities and social sciences as defined by 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 the above criteria are met. (These credits also fulfill part of the University requirements for these subject areas.)

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 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 together with a copy of the transcript; this is usually done in March 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 commencement 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 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 is 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.

n 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 systmatic program leading to the doctorate will confer with an adviser in the department of major interest regarding selection of courses, major and minor fields of interest, formulation of guidance committees, and qualifying and language examinations. 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 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 engineering 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, 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 offical acceptance on or before the Monday seven weeks before commencement. Draft copies of research manuscripts toward advanced degrees in chemisry 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 an 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 dissertation.

PRIZES AND AWARDS GIVEN AT GRADUATION

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
DOW JONES WALL STREET JOURNAL STUDENT ACHIEVEMENT AWARD
SIMEON GANG AWARD
MARGARET GOLDSTONE MEMORIAL FUND AWARD
GRUMMAN AEROSPACE CORPORATION AWARD
GRUMMAN AEROSPACE CORPORATION SCHOLASTIC ACHIEVEMENT AWARD
HAROLD HERTZBERG AWARD
JAMES H. J. HUGHES, JR. AWARD
INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS AWARD
INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS STUDENT 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
ROBERT RIDGEWAY STUDENT CHAPTER PRIZE
ALFRED RAYMOND PRIZE
JULIAN R. REASENBERG MEMORIAL AWARD
MYRON M. ROSENTHAL ACADEMIC ACHIEVEMENT AWARD (C.S.)
MYRON M. ROSENTHAL ACADEMIC ACHIEVEMENT AWARD (E.E.)
MYRON M. ROSENTHAL PRIZE
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.

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.

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 Student Life 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 AU 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 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 then 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 in or attends the course at Polytechnic forfeits his 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 below)

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 grade 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 lower 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 AU notation is used for audited courses. Notations AU, 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 and usually do not extend beyond the end of intersession.

An I grades 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.

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LEAVE OF ABSENCE

Undergraduates

A student wishing a leave of absence must discuss this with the Dean of Student Life. 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. However, in order to receive registration material, they should notify the Office of the Registrar. 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. 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 unit. 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 2.0 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 sessions. "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 2.0 or above, or perfomance approaching 2.0 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.	1.3	1.4	1.5	1.67	1.78	1.88	1.95	2.0	2.0	2.0

ACADEMIC MONITORING

Undergraduate academic performance is monitored at the end of each semester by the Dean of Students in consultation with the heads of departments.

DEAN'S LIST

Undergraduate students who achieve grade point averages of 3.4 or better, with no failures or incompletes, are commended by the Dean of Students and placed on the honors 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 student's permanent records.

PROBATION

Students whose grade-point average approaches 2.0 are warned of potential problems and urged to take whatever measures are necessary to maintain good standing.

Students are placed on *probation* when semester and/or cumulative grade-point averages falls below 2.00. The status of *continued probation* is assigned when the grade-point averages remain below 2.00 for longer than one term. When the grade-point average and the number of credits successfully completed approaches the minimum level of satisfactory progress, students are required to seek the permission of the Dean of Student Life in order to register.

Students on probation should limit their co-curricular activity. They may participate in advance registration, but are limited to fifteen (15) credits. If their semester performance returns them to good standing, they may add credits during on-site registration, with the approval of their academic advisers and the Dean of Students. Students who are on continued probation must have permission to register. They may not be allowed to participate in advance registration. They will not be assessed a late fee at on-site registration. Students in this situation should limit their program to no more than fifteen (15) credits.

DISQUALIFICATION

The Committee of Standing, comprised of the Dean of Students and representatives of the student's major department, shall jointly disqualify from the Institute 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 Institute 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 Student Life.

CAMPUS LIFE

OFFICE OF STUDENT LIFE

The Office of Student Life is responsible for the operation and maintenance of student-oriented and student supporting programs and services. The office helps students obtain the maximal benefits from their training — academically, culturally and socially — and supplements and reinforces the educational programs by:
- Providing Freshmen Services, including orientation, 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

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 1985 study was the group of first-time, full-time students who entered as freshmen in the fall of 1979.

Of that entering class, 56.2% received their Bachelor of Science degrees within four years; 64.9% graduated within five years; and 70% 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 strongly encouraged 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 a planning 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. 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 workshops in 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 of 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.

TUTORING PROGRAMS
(Freshmen Learning Center)

Freshmen showing failures or low grades at midterm are notified that tutoring is needed. All students can arrange for tutoring on a one-to-one basis if they have failed a course, or if there is a drop in grades during the semester. There are prearranged schedules for students and tutors

which stand for the entire semester, which generally lasts one hour a week per course. Students missing three sessions are dropped from the program. Improvement is monitored by evaluating the grades of students when entering the program versus the grades while being tutored. The tutors are seniors and juniors on the dean's list who have been carefully screened by the faculty and the counseling staff. There is no charge for this service.

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.

The Polytechnic University has enrolled international students in both graduate and undergraduate studies for many years. Students holding visas make up approximately 12% 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.

CAREER SERVICES

The placement service for students functions as part of the educational offering at Polytechnic. It is a student-oriented service committed to the principles of individual responsibility, free choice and human development. Specifically, Career Services believes that individuals must assume responsibility for deciding what, how, when and where they will provide for their future needs.

The primary function of Career Services is to help students learn how to locate suitable positions, decide whether to work or pursue graduate studies, and to make other decisions concerning post-graduate plans. This service continues after graduation, and all alumni are encouraged to contact Career Services whenever they need assistance in planning or making career or job changes.

Each year, Career Services hosts several hundred recruiters from industry, business and government for the purpose of interviewing students for employment opportunities. Additional functions, such as Career Days and Career Seminars, are also held. All students are encouraged to become acquainted with the staff of Career Services early and to utilize its services fully.

Placement of Graduates

The Career Services office assumes those responsibilities connected with career orientation and the full-time and part-time employment needs of Polytechnic students and alumni. It serves as the focal point for the continuing and expanding relationship between Polytechnic, business, government and industry. Demand for graduating students and alumni is constant. Over 250 major companies come to campus to recruit students, and over five thousand interviews are conducted annually. During the past five years, the placement rate for Polytechnic graduates has averaged over 90%.

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 the 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 video game room, ping pong tables, student organization offices, lounge space, a six-foot TV screen, and 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 tables, 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 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 the administering of student fees, social and cultural programming, and other co-curricular events. There is a separate governing board 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.

RADIO STATION

WPIV is the student-operated radio station located in the Brooklyn Student Center. The station offers a cross section of musical interests with student disc jockeys presenting shows.

ATHLETICS

For students who seek intercollegiate competition, Polytechnic maintains the following varisty 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 organization of blood donation drives, dances, and annual charity drive and handball, basketball and bowling tournaments.

On the Long Island campus, one national fraternity exists. 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.

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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 honoary 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 Electronic 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
Astronomical Society
Bohican (newspaper)
Celtic Society
Chess Club
Chinese Student Association
Christian Fellowship
Conflict Simulation Society
Demokritos (Greek 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
Photography Club (Focus)
Polywog (yearbook)
Programmable Calculator Club
Radio Club
Resident Student Organization
Reporter (newspaper)
Robotics
Scabbard and Blade
Society of Arabic Students
Student Alumni Association
Student Information Center
Vietnamese Student Association
WPIV (radio station)

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 on two floors of 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.

Each dormitory student is required by the Institute to have a full physical and health form filled out before moving into the residence hall or within the first week of residence.

Inquiries about housing should be made to the Office of Dean of Students on respectives campuses.

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
   A verbal warning is made 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 action of the suspension or removal is discussed. The length of time of suspension or permanent removal is determined by the Committee.

CODE OF CONDUCT

The Polytechnic University of New York 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 statues 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 or receiving unauthorized assistance from notes or from other students during examination, are in violation of academic regulations and are subject to academic discipline, including failure of 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 inlcude 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 appropriate 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 Student Life.

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 to the Provost.

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 applies.

    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 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 of New York 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 or 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 563† 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 563" 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 563). 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.

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 Neurophysiology* 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 995   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

William B. Blesser, Professor and Director 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

Jesse F. Crump, Associate Professor of Bioengineering
B.S., M.D., University of Nebraska
Physiology, bioengineering

ADJUNCT FACULTY

Gabor B. Levy, Adjunct Professor in 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

BIOENGINEERING

Seymour Furman (Montefiore Hospital and Medical Center)
M.D., SUNY (Downstate Medical Center)
Pacemakers; cardiovascular studies

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

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 241, CH 251; 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
PH	101	Introductory Physics I	3	0	3
CM	101	General Chemistry I	2½	0	2½
CM	111	General Cehmistry Lab I	0	1½	½
HU	101	Writing and the Humanities I[1]	3	0	3
SS	104	Main Themes in Contemporary World History[1]	3	0	3
PE	101	Physical Education I	0	2	0
					16

Second Semester				Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
MA	102	Calculus II	4	0	4
PH	102	Introductory Physics II	3½	1½	4
CM	102	General Chemistry II	2½	0	2½
CM	112	General Chemistry Lab II	0	1½	½
CS	100	Intro. to Computer Progr.	2	0	2
HU	200	Writing and the Humanities II	3	0	3
PE	102	Physical Education II	0	2	0
					16

Sophomore Year

MA	103	Calculus III	3	0	3
PH	103	Physics III	2½	1½	3
CH	123	Chem. Proc. Anal. I[3]	2	0	2
CM	122	Organic Chem. I	3	0	3
CM	124	Organic Chem. Lab I	1/3	5	2
		Hum./Soc. Sci. elective[1]			3
PE	103	Physical Education III	0	2	0
					16

MA	104	Applied Diff. Eq.	3	0	3
AM	115	Engineering Mechanics	4	0	4
CH	124	Chem. Proc. Anal. II[3]	2	0	2
CM	161	Physical Chemistry I	3	0	3
CM	123	Organic Chem. II	3	0	3
		Hum./Soc. Sci. elective[1]			3
PE	104	Physical Education IV	0	2	0
					18

Junior Year

CH	220	Trans. Opns. I	4	0	4
CH	251	Chem. Eng. Thermo.	4	0	4
CM	162	Physical Chemistry II	3	0	3
		Technical elective[2]			3
		Free elective			3
					17

CH	221	Trans. Opns. II	4	0	4
CH	241	Mult. Sep. Proc.	3	0	3
EE	370	Princ. Elect. Eng.	3	0	3
EE	374	Instrument. Lab	0	3	1
		Hum./Soc. Sci. elective[1]			3
		Technical elective[2]			3
					17

Senior Year

CH	301	Ch. E. Lab I	0	6	2
CH	322	Chem. Reac. Eng.	3	0	3
CH	351	Proc. Dyn. & Control	3	0	3
CH	361	Proc. Design I	3	0	3
		Hum./Soc. Sci. elective[1]			3
		Technical elective[2]			4
					18

CH	302	Ch. E. Lab II	0	6	2
CH	271	Eng. Materials	3	0	3
CH	362	Proc. Design II	3	0	3
		Technical elective[2]			7
					18

Total credits required for graduation: 136

See item a under "Electives" on page 52.
[1] See item b under "Electives" on page 53.
[3] See item c under "Electives" on page 53.

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 to elect a number of 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 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 36.)

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 master's degrees.

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 the 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, exhibit a reading knowledge in one foreign language 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 gaduate 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 241   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 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 271   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 301-302   Chemical Engineering
                      Laboratory I, II   each 0:6:2**
Experimental studies of operations in chemical engineering. Laboratory projects on 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 241 and CH 221. CH 302 prerequisites: CH 301, CH322 and CH351.

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 designs. Analog computer simulations. Prerequisites: CH 221, CH 241, 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 241 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 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: instructors 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.

CHEMICAL ENGINEERING

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 Electrochemical Engineering*   2½:0:3
Theories and measurements of reversible and irreversible electrochemical processes at metal-electrolyte interfaces. Thermodynamics, kinetics, mass transport, mixed potential theories, passivation. Modern experimental techniques. Electrochemical energy conversion devices (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 view-point of system 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 ass 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.

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CH 928 Polymer 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 designs. 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** 6 units, each 2 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 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 seventh Wednesday prior to commencement. Prerequisite: degree status.

**CH 998 Chemical Engineering
Design Projects** 9 units, each 3 units
Engineering analyses, syntheses, optimizations and designs of processes or novel equipment. Projects require original individual work. Evaluations of results, uses 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, Associate 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

CHEMICAL ENGINEERING

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*

Mohammad M. Ataai, Assistant Professor of Chemical
Engineering
B.S., M.S., Tufts University; Ph.D., Cornell University
Biotechnology; Biochemical Engineering

John R. Battler, Assistant Professor of Chemical
Engineering
B.S., M.S., Georgia Institute of Technology; Ph.D., Rice
University
Thermodynamics, Process Control

ADJUNCT FACULTY

Joseph W. Prane, Adjunct Professor of Chemical
Engineering
B.Ch.E., CCNY; M.S., Columbia University

Irven H. Rinard, Adjunct Professor of Chemical
Engineering
B.Ch.E., University of Delaware; S.M., Sc.D. (Ch.E.),
Massachusetts Institute of Technology

Chee-Gen Wan, Adjunct Professor of Chemical
Engineering
B.S., National Taiwan University; M.S., Kansas State
University; Ph.D., Polytechnic Institute of New York

Israel Wilenitz, Adjunct Professor of Chemical
Engineering
B.S., University of London; M.S., Ph.D., Polytechnic
Institute of New York

EMERITUS FACULTY

Paul F. Bruin, 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 Brook-
lyn, 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
- 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.	Subjects	Units
CM 703	Chemical Physics I	4½
CM 704	Chemical Physics II	4½
MA 630	Complex Variables	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 313-314	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 (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

* 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

*Terje Kjeldaas, Jr., 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

PARTICIPATING FACULTY

Stephen Arnold, Professor of Physics

Ephraim Banks, Professor of Chemistry

Patrick T. Cahill, Professor of Physics

Hellmut J. Juretschke, Professor of Physics

Norman C. Peterson, Professor of Chemistry

Arnost Reiser, Research Professor of Chemistry and Deputy Director of the Institute of Imaging Sciences

Peter Hanggi, Assistant Profesor of Physics

Donald M. Schleich, Associate Professor of Chemistry

*Ex officio

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 chemisry. 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 stimulus 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 101-103	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.

To graduate, students must demonstrate knowledge of French, German or Russian equivalent to fourth semester courses. This may be done by passing appropriate courses or special examinations administered by the humanities department.

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*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
		Hum./Soc. Sci. electives	6	0	6			Hum./Soc. Sci. elective	3	0	3
MA	101	Calculus I	4	0	4	MA	102	Calculus II	4	0	4
PH	101	Introductory Physics I	3	0	3	PH	102	Introductory Physics II	3½	2½	4
PE	101	Physical Education	0	2	0	CS	100	Intro. to Computing	2	0	2
					16	PE	102	Physical Education	0	2	0
											16

Sophomore Year

			Cl.	Lab.	Cr.				Cl.	Lab.	Cr.
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	6	0	6
MA	103	Calculus III	3	0	3	CM	161	Physical Chemistry I	3	0	3
PH	103	Introductory Physics III	2	1½	3	MA	104	Applied Diff. Equations	3	0	3
PE	103	Physical Education	0	2	0	PE	104	Physical Education	0	2	0
					17						17

Junior Year

			Cl.	Lab.	Cr.				Cl.	Lab.	Cr.
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	3
		Elective			3			Elective			3
					17						17

Senior Year

			Cl.	Lab.	Cr.				Cl.	Lab.	Cr.
CM	109	Inorganic Chemistry Lab	0	3	1	CM	392-	Advanced Chemistry	3	0	3
CM	175	Adv. Physical Chemistry	4	0	4		394	Thesis			6
CM	390-	Bachelor's Thesis			4			Electives			4
	391										13
		Hum./Soc. Sci. elective	3	0	3						
		Elective			3						
					15						

Total credits required for graduation: 128

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

		Cl.	Lab.	Cr.
CM	109 Inorganic Chemistry Lab.	0	3	1
	Hum./Soc. Sci. electives			3
CM	390- Bachelor's Thesis			4
	391			
	Electives			3
				14

		Cl.	Lab.	Cr.
CM	119 Analytical Chemistry	3	0	3
CM	120 Analytical Chemistry Lab	0	6	2
CM	392- Thesis			6
	394			
	Hum./Soc. Sci. electives			3
	Electives			2
				16

Total credits required for graduation: 128

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*To graduate, students must demonstrate a knowledge of French, German or Russian equivalent to a fourth semester course. This may be done by passing appropriate courses or special examinations administered by the humanities department.

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 and comparative religion 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.

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.

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. Requirement 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 degrees 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*	6	0	6			Hum./Soc. Sci. elective*	3	0	3
MA	101	Calculus I	4	0	4	MA	102	Calculus II	4	0	4
PH	101	Introductory Physics I	3	0	3	PH	102	Introductory Physics II	3½	2½	4
PE	101	Physical Education	0	2	0			Technical elective	3	0	3
CS	100	Introduction to Computer				PE	102	Physical Education	0	2	0
		Programming	2	0	2						17
					18						

Sophomore Year

CM	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*	6	0	6	CM	125	Organic Chemistry Lab II	3/10	5	2
MA	103	Calculus III	3	0	3			Hum./Soc. Sci. electives*	6	0	6
PH	103	Introductory Physics III	2	1½	3	CM	161	Physical Chemistry I	3	0	3
PE	103	Physical Education	0	2	0	PE	104	Physical Education	0	2	0
					19						· 19

Junior Year

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	129	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
					18			elective***			3
											18

Senior Year

CM	175	Physical Chemistry III	4	0	4	CH	241	Multistage Separation	3	0	3
		Bachelor's Thesis			4			Processes			
CM	108	Inorganic Chemistry	3	0	3			Engineering elective			3
		Hum./Soc. Sci. electives	4	0	4			Bachelor's Thesis			6
		elective***			3						12
					18						

Total credits required for graduation: 138
(CH Total credits for graduation 136)
(CM Total credits for graduation 128)

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*Two semesters of a foreign language (German, or French or Russian are strongly recommended. The corresponding courses should be chosen in consultation with advisers.
***Engineering option courses should at least total 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 Teaching or Research Assistants continue 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 101	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 selectd 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 102	Introductory Physics II	3½	2½	4
MA 102	Calculus II	4	0	4
PE 101	Physical Education	0	2	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
PH 103	Introductory Physics III	2	1½	3
MA 103	Calculus III	3	0	3
CS 100	Introductory Computing	2	0	2
PE 102	Physical Education	0	2	2
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

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

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
	Total credits: 46	

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Third Year

No		Subject	Cl.	Lab.	Cr.
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	0	4½
					16

During this semester, the student shall make formal application to the Graduate Program in Chemistry.

Summer Session (either first, second or both)
Electives (two) 6

Total credits: 40

No		Subject	Cl.	Lab.	Cr.
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	TBA
		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

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

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

			Cr.
CM	971	Colloquium in Chemistry	0
CM	999	Research in Chemistry	15
		Advanced Chemistry Course	3
			18

			Cr.
CM	972	Colloquium in Chemistry	0
CM	999	Research in Chemistry	18
			18

Year's Total credits: 36

Sixth Year

			Cr.
CM	971	Colloquium in Chemistry	0
CM	999	Research in Chemistry	18
			18

			Cr.
CM	972	Colloquium in Chemistry	0
CM	999	Research in Chemistry	18
			18

Year's Total credits: 36

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 712 Research Instrumentation
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

At least six units of advanced topics in Inorganic Chemistry, and either CM 802 or CM 905

ORGANIC CHEMISTRY

CM 905 and CM 920.

PHYSICAL CHEMISTRY

CM 802 or CM 907; PH 313-314, CM 721, CM 722 and CM 995 (Seminar in Chemical Physics).

POLYMER CHEMISTRY

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 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 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.

In the fourth year, the student selects a research adviser after interviewing a minimum of five faculty members. The student will also take during this year the Written Preliminary Examination, for which two attempts are allowed. (After a second failure the student is dropped from the program). The student then selects a dissertation

committee, including the research adviser (major advisers), a minor adviser, and at least two additional faculty members, who monitor 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 the 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 judgement is made by the dissertation committee on awarding a Ph.D. degree.

Academic policy for the graduate program in chemistry requires that a B average be maintained. Similarly a B average 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. Chemistry graduate students cannot take CM 500 level courses for graduate credit, except for MS 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) 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.

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 895	Management of Innovation, Technological Changes, Research and Developments	3
	either	
CM 760	Minicomputer Instrumentation for Scientific Research	
	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

Admission to doctoral programs requires passing a set of qualifying examinations at the level of the bachelor's degree in chemistry.

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	4 ½
CM 703	Chemical Physics I	
	or	4 ½
CM 704	Chemical Physics II	
CM 802	Applied Spectroscopy	
	or	4 ½
CM 907	Organic Spectroscopy	
CM 903	Organic Chemistry I	
	or	4 ½
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 703, CM 704, CM 802 or 907, CM 903 or 904, PH 313-314, CM 721, CM 722 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 areas 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. Students whose native language is not English must demonstrate competence in English.

7. By the end of the second year, students are required to pass preliminary examinations, administered by the Guidance Committee, which consist of written and oral portions.

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 conservation laws; states of matter; acid-base and oxidation-reduction theories; introducions to chemical thermodynamics and chemical equilibria, electrochemistry, kinetics.

CM 102   General Chemistry II   2½:0:2½
Atomic and molecular structure; periodic table; descriptive inorganic chemistry; introduction to organic chemistry including polymer and biochemistry; and photochemistry. Prerequisites: CM 101, CM 111.

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 experiements in qualitative analyses are taken in conjunction with CM 102. Lab fee required. Prerequisites: CM 101, CM 111.

CM 118   Chemical Equilibria   2½:5:4
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 (ultraviolet, 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   ⅓:5:23
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
Surveys of modern biochemistry with emphasis on current areas of research. Structure-function relationships in proteins and nucleic acids. 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. Important principles of intermediary metabolism, energetics, membrane structure and transport; replication of DNA and RNA, protein synthesis, 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 conference and seminars scheduled as work progresses. Students required to give oral resumes of work before at least two members of chemistry faculty. Full-time students are expected to register for 10 credits of thesis during senior year. Reregistration beyond CM 394, each semester: 2-credit charge for evening students; 4-credit charge for day students. 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 reactions important in maintaining the ecosystem and in pollution of the environment. Chemical properties of pollutants in air, water, soil. 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 712   Research Instrumentation*   2½:5:6
Laboratory course in electronics for students planning to use electronic instrumentation in research. Malmstadt/Enke Instrumentation Laboratory used. Power supplies, vacuum tube and solid state amplifiers; oscillators; servo systems; operational amplifiers; digital instrumentation. Prerequisite: adviser's approval.
Also listed under CH 841, BE 622 and SA 605

**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 Reaction, Valence and Molecular Structure, Electrochemistry.

CM 721   Quantum Mechanics for Chemists*   3¾:0:4½
Principles of quantum mechanics quantitatively developed. Comparison of various approaches. Most important approximatation 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 an H 602.

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.

**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.

**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.
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; fre 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, 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 also discussed. The course 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 condensation; ionic and copolymerization; absorption; 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.

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.

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.

**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 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 Industial 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 chemisty. 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, advance laboratory skills in X-ray diffractions, solid state synthesis, measurements of magnetic moments and susceptibilities, spectroscopic techniques, chromatographic techniques, thermal analyses, relaxation kinetics, electrochemistry, etc. Emphases 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.

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 chemisty and 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 140 Environmental Biology*   **2½:1½:3**
Studies of interrelationships of organisms and their environments. Structures and dynamics within the ecosystem including biogeochemical cycles, energy, populations and food supply. Effects of pollution and technology as they influence alternatives. Economics, law and policy decisions in environmental management are considered. Knowledge of FORTRAN or similar languages desirable. Lab fee required. Co/Prerequisite: MA 104 or instructor's consent.

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 Senior 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 provides 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 Electron Microscopy, 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

William H. Starnes, Professor and Head, Department of Chemistry
B.S., Virginia Polytechnic Institute; Ph.D., Georgia Institute of Technology
Polymer Degradation, stabilization, and Microstructure; mechanisms of organic reactions.

Ephraim Banks, Professor of Inorganic Chemistry
B.S., CCNY; Ph.D., Polytechnic Institute of Brooklyn
Chemistry and physics of crystals; solid state reactions and phase transitions

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.

CHEMISTRY

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, Associate Professor of Organic Chemistry
B.S., CCNY; Ph.D., Princeton University
Stereochemistry of reactive intermediates; macromolecular stereochemistry; isolation of bio-active plant substances

Sybilla Kennedy, Academic Associate and Director of Laboratories (Farmingdale)
B.A., Smith College; M.A., SUNY (Stony Brook)

T.K. Kwei, Research 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

Herbert Morawetz, Institute Professor, Professor 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

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 New York
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

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.

Donald M. Schleich, Associate Professor of Inorganic Chemistry
B.S., SUNY (Fredonia); Ph.D., Brown University
Photoelectrochemistry, intercalation andd materials studies

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 from electronics applications

Nancy M. Tooney, Associate Professor of Biochemistry
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

Otto Vogl, Herman F. Mark Professor of Polymer Chemistry
Ph.D., University of Vienna
Polymer synthesis polymer stabilizers; polymer drugs

William T. Winter, Associate Professor of Polymer Chemistry
B.S., Ph.D., SUNY (College of Environmental Science & Forestry), Syracuse University
Polymer morphology and crystallography; polysaccharides and other biopolymers; CP-MAS NMR

EMERITUS FACULTY

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

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 mechanics, environmental engineering, geotechnical engineering, highways, hydraulics, irrigation and drainage, pipeline, structural, surveying and mapping, 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 to corporations, governmental agencies, architects and others that require their expertise. Others own construction companies and 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 do not practice as licensed professionals but 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 advanced studies in management, planning, and medicine.

The undergraduate program is accredited by the Accreditation Board for Engineering and Technology.

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 application—such as highways, environmental engineering and detailed design of structure—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 selected graduate courses (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
AM 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 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 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.

Students should select an area of concentration (such as literature, communications, the arts, or philosophy and comparative religions in the Department of Humanities and Communication, or economics, history, anthropology, or psychology in the Department of Social Sciences) and elect a number of 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.

Management courses and ROTC courses may not be used.

TRANSFER STUDENTS (Undergraduate)

Potential transfer students should refer to the guidelines as shown on pages 15 and 33 of 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.

EVENING SESSION

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	4	0	4
CM	101	General Chemistry IA	2½	0	2½
CM	111	General Chemistry Lab IA	0	1½	½
PH	101	Introductory Physics I	3	0	3
HU	101	Writing and the Humanities I	3	0	3
AM	101	Graphics	1	3	2
PE	101	Physical Education	0	2	0
					15

Second Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
MA	102	Calculus II	4	0	4
CM	102	General Chemistry IIA	2½	0	2½
CM	112	General Chemistry Lab IIA	0	1½	½
PH	102	Introductory Physics II	3½	1½	4
SS	104	Main Themes in Contemporary World History	3	0	3
CS	100	Introduction to Computer Programming	2	0	2
PE	102	Physical Education	0	2	0
					16

Summer camp (2-week session)
CE   150 Surveying Fieldwork   2

Sophomore Year

MA	103	Calculus III	3	0	3
PH	103	Introductory Physics III	2½	1½	3
AM	116	Engineering Mechanics I	2	0	2½
CE	151	Surveying	3	3	4
HU	110	Basic Report Writing I	3	0	3
PE	103	Physical Education	0	2	0
					15

MA	104	Applied Differential Equations	3	0	3
AM	117	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
HU	200	Writing and the Humanities II	3	0	3
PE	104	Physical Education	0	2	0
					16

Junior Year

CE	214	Computer Techniques in Engineering	3	0	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
AM	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	3	0	3
CE	340	Water Resources & Hydr. Engrg.	3	0	3
		Hum./Soc. Sci. elective	3	0	3
*		Mathematics elective (First Semester in Farmingdale)	3	0	3
					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

*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			Cl.	Lab.	Cr.
No.		Subject		Hours/Week	
MA	101	Calculus I	4	0	4
HU	101	Writing and the Humanities I	3	0	3
					7

Second Semester			Cl.	Lab.	Cr.
No.		Subject		Hours/Week	
MA	102	Calculus II	4	0	4
PH	101	Introductory Physics I	3	0	3
SS	104	Main themes in Contemporary World History	3	0	3
					10

Second Year

			Cl.	Lab.	Cr.
MA	103	Calculus III	3	0	3
PH	102	Introductory Physics II	3½	1½	4
HU	110	Basic Report Writing I	3	0	3
					10

			Cl.	Lab.	Cr.
MA	104	Applied Differential Equations	3	0	3
PH	103	Introductory Physics III.	2½	1½	3
AM	101	Graphics (1987-1988, 1989-1990) or	1	3	2
CS	100	Introduction to Computer Programming (1986-1987, 1988-1989)	2	0	2
					8

Third Year

			Cl.	Lab.	Cr.
AM	116	Engineering Mechanics I	2	0	2
CM	101	General Chemistry I	2½	0	2½
CM	111	General Chemistry Lab I	0	1½	½
***		Mathematics elective	3	0	3
					8

			Cl.	Lab.	Cr.
AM	117	Engineering Mechanics II	2	0	2
CM	102	General Chemistry II	2½	0	2½
CM	112	General Chemistry Lab II	0	1½	½
AM	101	Graphics (1987-1988, 1989-1990) or	1	3	2
CS	100	Intro. to Programming (1986-1987, 1988-1989)	2	0	2
					7
CE	150*	Surveying Fieldwork			2

Fourth Year

			Cl.	Lab.	Cr.
CE	202	Mechanics of Materials	3	0	3
EE	370	Principles of E.E.	3	0	3
					6

			Cl.	Lab.	Cr.
CE	222	Fluid Mechanics	3	3	4
CE	322	Theory of Structures I	3	0	3
HU	200	Writing and the Humanities II	3	0	3
					10

Fifth Year*†

			Cl.	Lab.	Cr.
CE	214	Computer Techniques in Engineering	3	0	3
AM	201	Thermodynamics I	3	0	3
		Hum./Soc. Sci. elective	3	0	3
					9

			Cl.	Lab.	Cr.
CE	232	Soil Mechanics	2	3	3
CE	303	Nature * Prop. Struc. Matls.	1	3	2
CE	340	Water Resources & Hydr. Engrg.	3	0	3
					8

Sixth Year**

			Cl.	Lab.	Cr.
CE	151	Surveying	3	3	4
		Hum./Soc. Sci. elective	3	0	3
					7

			Cl.	Lab.	Cr.
CE	323	Theory of Structures II	3	0	3
CE	331	Steel Structures	3	0	3
					9

Seventh Year*†

			Cl.	Lab.	Cr.
CE	341	Environmental Engineering I	2	3	3
CE	351	Highway & Transportation Engrg.	2	3	3
		Technical elective	3	0	3
					9

			Cl.	Lab.	Cr.
CE	342	Environmental Engineering II	2	3	3
		Technical elective	3	0	3
		Hum./Soc. Sci. elective	3	0	3
					9

Eighth Year**

			Cl.	Lab.	Cr.
CE	252	Reinforced Concrete Structures	3	0	3
CE	317	Foundations	2	3	3
		Technical elective	3	0	3
					9

			Cl.	Lab.	Cr.
CE	305	Eng. Contr. & Specs.	2	0	2
CE	332	Design of Struc. Systems	2	3	3
		Technical elective	3	0	3
					8

Minimum total credits required for graduation: 136

* This 2-week course is offered every May during the day.
†* Offered in alternate *odd* years, i.e., 1987-1988, 1989-1990. (The fifth and sixth years are interchangeable.)

** Offered in alternate even years, i.e. 1986-1987, 1988-1989. (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, engineer in civil engineering, doctor of philosophy in civil engineering, and the undesignated degree of doctor of philosophy in environmental health science.

The department has applied for permission to offer a program leading to the degree of master of science in environmental engineering. Details are available from the department head.

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.

REQUIREMENTS FOR THE MASTER'S DEGREE

A bachelor's degree in civil engineering is required for students pursuing a master's degree in civil engineering. Those seeking master's degrees in environmental health science are required to hold a bachelor's degree in science. Applicants with degrees in other fields may be admitted with undergraduate deficiencies as evaluated by the departmental graduate adviser. Typical programs are illustrated subsequently.

Courses in some areas of specialization are not offered on a regular basis. Students should consult with the department head to determine the expected scheduling of such courses. More detailed requirements are described in the first part of this catalog and in The Civil Engineering Graduate Manual, which is available from the department office.

M.S. PROGRAM 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, public works engineering-infrastructure, and geotechnical engineering.

Students interested in highway engineering or construction engineering and management may take the public works-infrastructure program with appropriate elective courses and a suitable project.

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 structural engineering, water resources and hydraulic engineering, water quality engineering, public works engineering-infrastructure, or geotechnical engineering — 15

Major Electives

At least 6 units of approved courses in civil and environmental engineering — 6

Other Approved Electives

At Least 9 units of approved graduate courses — 9

TOTAL 36

Major Requirements

Structural Engineering

CE 601	Theory of Structural Analysis and Design	3
CE 609	Matrix Methods of Structural Analysis I	3
CE 614	Metal Structures I	3
CE 625	Structural Dynamics	3
CE 641	Reinforced Concrete Structures I	3
		15

Water Resources and Hydraulic Engineering

CE 715	Open Channel Hydraulics	3
CE 716	Hydraulic Problems	3
CE 722	Hydrology	3
CE 781	Formulation & Analysis of Public Works Projects	3

At least one of the following -

CE 711	Hydraulic Design of Structures	
CE 725	Water Resources Mathematical Modeling	3
CE 732	Coastal Engineering	
		15

Water Quality Engineering

CE 738	Sanitary Chemistry	3
CE 740	Sanitary Microbiology	3
CE 742	Water & Wastewater Treatment I	3
CE 743	Water & Wastewater Treatment II	3
CE 747	Analysis of Stream & Estuary Pollution	3
		15

Public Works Engineering - Infrastructure

CE 781	Formulation & Analysis of Public Works Projects	3
CE 791	Infrastructure Systems Analysis	3
CE 792	Infrastructure Design & Management	3
CE 801	Flexible Pavements — Design and Evaluation	3
CE 806	Highway Capacity and Traffic Analysis	3
		15

Geotechnical Engineering

No.	Courses	Units
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 I	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

No.	Course	Units
Environmental Health Science Requirements		
CE 738	Sanitary Chemistry	3
CE 740	Sanitary Microbiology	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

	Units
At least 12 units of approved graduate courses	12
Minimum Total Units	36

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 demonstrated scholastic ability may pursue a doctorate in civil engineering. In general, an applicant 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.

Students interested in Ph.D. programs are advised to refer to the *Civil Engineering Graduate Manual* (available from the departmental office) for information on qualifying examinations and other regulations.

UNDERGRADUATE COURSES

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.

CE 151   Surveying   3:3:4
Modern methods and computations for engineering surveys. Fundamental theory of photogrammetry with laboratory exercises. Prerequisites: CE 150 and AM 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: AM 115 or AM 116.
Also listed under AM 121

CE 214   Computer Techniques in Engineering   3:0:3
Use of higher-level computer languages and techniques in engineering. Use of digital computers for numerical methods involving differentiation, integration and solution of systems of equations. Problem-oriented languages in engineering design practice. Computer graphics in 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: AM 115 or AM 116 and AM 117.

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
Analusis 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 3:0:3
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 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.

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 I 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. Co/Prerequisite: CE 601.

CE 610 Matrix Methods of Structural Analysis II 2½:0:3
Extension of matrix methods to grid frames, curved members, space structures, nonlinear analysis and optimization of structures. Prerequisite: CE 609.

**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 I 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 615 Metal Structures II 2½:0:3
Techniques for designing cable-suspended and cable-stayed structures, latticed shells, space frameworks and other complex structures. Application of nonlinear analysis utilizing electronic digital computers. Prerequisite: CE 614.

**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. Prerequisites: CE 609 and CE 610.
Also listed under AM 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 AM 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 AM 661

**CE 627 Dynamic Response of
Civil Engineering Structures** 2½:0:3
Description of dynamic loading on civil engineering systems. Effects of wind on bridges, suspension systems and tall buildings using random vibration theory. Earthquake analysis of structures responding inelastically. Applications to problems in material behavior such as fatigue in cables, hysteresis loops in concrete and steel and damping in structural systems. Prerequisite: CE 625.

CE 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. Prerequisites: AM 601 or equivalent.
Also listed under AM 632

CE 641 Reinforced Concrete Structures I 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 642 Reinforced Concrete Structures II 2½:0:3
Biaxial bending of columns. Stability of reinforced concrete columns. Design of two-way and flat slabs, arches and horizontally curved members. Shear wall design and design problems of tall structures. Prerequisite: CE 641.

WATER RESOURCES AND HYDRAULIC ENGINEERING

Prerequisite for all courses: MA 104, CE 222

CE 711 Hydraulic Design of Structures   2½:0:3
Hydraulic principles utilized in design of structures such as spillways, measuring flumes, energy dissipators, channels of linear and nonlinear alignment, gradual and sudden transitions in subcritical and supercritical flow, culverts, lateral spillway channels, Co/Prerequisite: CE 715.

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 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 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 vertification. 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 733 Forces on Marine Structures   2½:0:3
Analysis of forces on marine structures such as piers, platforms, jetties, subjected to hydrodynamic and other loads. Waves as random processes. Applications of wave forecasting and spectral analysis. Description of interactions between wave forces and structural responses.

CE 734 Design of Marine Structures   2½:0:3
Planning of port facilities and coastal protection. Problems involved in design of marine structures. Choice of design parameters affected by hydrodynamic and other loads.

CE 735-736 Special Topics in Water Resources and Hydraulic Engineering I, II   2½:0:3
Topics in water resources and hydraulic engineering including 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 ENGINEERING

CE 738 Sanitary Chemistry   1:2:3
Review and applications of principles of chemistry to waters and wastewaters. Laboratory analysis of representative waters and wastewaters for most commonly determined parameters as related to applications in water environment. Evaluations of methods and procedures.

CE 740 Sanitary Microbiology   2:1:3
Lectures and laboratory work. Microbiology of wastewater treatment processes, wastewaters, receiving waters. Microorganisms and ecological relationships. Laboratory includes identification and microbiological examination of waters and wastewaters.

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 738.

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. Prerequisite: CE 740.

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 biological 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 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.

PUBLIC WORKS ENGINEERING — INFRASTRUCTURE

**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.

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.

CE 792   Infrastructure Design and Management   2½:0:3
Design and use of geographic data base systems for inventory and planning. Algorithms for design of systems for the delivery of municipal services. Use of comprehensive, computer models for design, costing and management of infrastructure systems for fire protection, emergency health services, water supply, solid and liquid waste disposal, parks and recreation, energy delivery, and other urban services. Prerequisite: CE 214 or equivalent.

CE 793   Workshop on Infrastructure   2½:0:3
Students undertake a comprehensive project involving the design of the engineered infrastructure for an urban community. Development of a computer data base, collection and organization of all necessary information for the planning, design, costing and development of a management system for each of several selected infrastructure subsystems. Alternative designs considered and life-cycle cost methods used to optimize investments. The course is taught by a faculty team from the Department of Civil Engineering. Prerequisite: CE 214 or equivalent.

**CE 798-799   Special Topics in Infrastructure Systems and
                  Construction I, II   2½:0:3**
Current topics of interest including 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.

HIGHWAY ENGINEERING

Prerequisites for all courses: MA 104, CE 351

CE 801   Flexible Pavements: Design and Evaluation   2:1:3
Design and construction of flexible highway pavements, including road-mix, plant-mix and high-type bituminous pavements. Pavement performance and evaluation. Laboratory tests of bituminous materials and mixtures, including Marshall, Hubbard-Field and Hveem stability tests. Viscosity by capillary viscosimeter.
Also listed under TR 720

CE 802   Rigid Pavements: Design and Evaluation   2:1:3
Design and construction of rigid highway and airport pavements. Pavement performance and evaluation. Laboratory tests of plain and reinforced concrete pavements. Nondestructive testing techniques. Prerequisite: CE 252.
Also listed under TR 721

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 801

CE 805   Traffic Engineering   1:3:3
Traffic engineering and its role in person movement. Traffic demand and its generation and management. Capacity analysis concepts and basic study techniques. Substantial treatment of intersections, arterials, and arterial management. Laboratory emphasis on field procedures and on the use of analysis procedures, including personal computer applications.
Also listed under TR 701.

CE 806   Highway Capacity and Traffic Analysis   1:3:3
Highway capacity techniques and traffic data collection and analysis. Capacity analysis techniques of the Highway Capacity Manual. Measurement, analysis, and interpretation of traffic stream data is emphasized. Traffic safety studies. Use of personal computers in analysis, and workshop exercises. Prerequisite: CE 805.
Also listed under TR 704

CE 810 Urban Planning Principles 2½:0:3
A survey of contemporary theory and methods of the planning function.
Also listed under TR 630

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 870

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 871

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. Prerequisite: CE 825.
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. Prerequisite: CE 825.
Also listed under MG 827

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 853 Analysis and Design of Earth
and Rockfill Dams** 2½:0:3
Importance of dams, selection of type, hydrological and geological considerations, design aspects of earth and rockfill dams, stability analysis, seismic stability, displacement treatment, ecological and environmental aspects.

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
Studies of index tests by classical and statistical procedures with emphasis on particle size distribution, particle shape and packing. 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.

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, 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 I 2½:0:3
Soil sampling and exploration procedures; emphasis on standard penetration tests. Analytical procedures for determining bearing capacity as a function of stability and settlements. Plate-loading test. Analysis and design of footings, mats, piles. Modulus of subgrade reaction and realm of validity.

CE 872 Foundation Engineering II 2½:0:3
Settlement studies with attention to elastic, primary and secondary settlements. Role of soils laboratory in providing necessary soil parameters. Analysis and design of single piles and pile groups. Pile driving, load capacity and settlement. Negative skin friction. Analysis and design of cofferdams, piers and caissons. Prerequisite: CE 871.

**CE 881-882 Special Topics in Geotechnical Engineering
and Foundation Engineering I, II** 2½:0:3
Current topics of interest including 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 890 Earthquake Engineering 2½:0:3
Earthquakes, causes, distribution, intensity and magnitude, seismic zoning, measurement of ground motion, theory of vibrations, response spectrum theory, effects of earthquakes on soils and structures, design considerations.

CE 892 Soil Dynamics 2½:0:3
Treatment of single-degree of freedom systems. Wave propagation in homogeneous and layered half-spaces. Behavior of dynamically loaded soils. Theories for vibrations of foundations on elastic media. Design procedures for dynamically loaded foundations. Half-space theory and lumped parameter analogs, earth pressures due to seismic loading, design of foundations in seismic areas, the liquefaction problem. Prerequisite: CE 861.

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 Institute's "Regulations on Format, Duplication and Publication of Reports, Theses and Disertation" at the Office of Research and Graduate Studies.

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. 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 and department head's approval.

CE 997   Thesis for the Degree of Master of Science
                                          each 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. Prerequisite: degree status and thesis adviser's approval.

CE 998   Project for Degree of Engineer   each 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. Prerequisites: degree status and project adviser's approval.

**CE 999   Dissertation for Degree of
          Doctor of Philosophy   each 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 at the rate of at least three units per term. Prerequisites: degree status, completion of qualifying examinations and thesis adviser's approval.

FACULTY

Alvin S. Goodman, Professor and Head of Civil and Environmental Engineering
B.C.E., CCNY; M.S.C.E., Columbia University; Ph.D., New York University; Professional Engineer
Water resources

Paul R. DeCicco, Professor and Director of the Fire Research Center
B.C.E., M.C.E., Polytechnic Institute of Brooklyn; Professional Engineer
Urban systems; fire safety

Henry F. Soehngen, Professor of Civil Engineering
B.C.E., M.C.E., Polytechnic Institute of Brooklyn; M.S., International Training Center for Aerial Surveys, Delft (Netherlands); Professional Engineer, Land Surveyor
Computer science, surveying and photogrammetry

Carl J. Turkstra, Professor of Civil Engineering
B.Sc., Queen's University; M.S., University of Illinois; Dip. Man., McGill University; D.S.A., University of Montreal; Ph.D., University of Waterloo (Canada); Professional Engineer
Structural analysis and design; structural reliability

Ping Chun Wang, Professor of Civil Engineering
B.S.C.E., National Central University of China; M.S.C.E., Ph.D., University of Illinois; Professional Engineer
Structures

Raul R. Cardenas, Jr., Associate Professor of Environmental Engineering
B.A., University of Texas; M.S., Ph.D., New York University
Environmental health science; environmental engineering

Albert H. Griswold, Associate Professor of Civil Engineering
B.S.C.E., University of Connecticut; M.S.C.E., Columbia University; Professional Engineer
Mechanics

Bernard Grossfield, Associate Professor of Civil Engineering
B.C.E., M.C.E., Eng. Sc.D., New York University; Professional Engineer
Structures

Alan H. Molof, Associate Professor of Environmental Engineering
B.S.Ch.E., Bucknell University; M.S.E. (Ch.E.), M.S.E. (Sanitary Engineering), Ph.D., University of Michigan
Environmental engineering; water quality

Matthew W. Stewart, Associate Professor of Civil Engineering
B.C.E., M.C.E., Polytechnic Institute of Brooklyn; Professional Engineer
Hydraulic engineering

Mohammad Karamouz, Assistant Professor of Civil Engineering
B.S.C.E., Pahlavi University (Iran); M.S.C.E., George Washington University; Ph.D., Purdue University; Professional Engineer
Water resources

Chaim J. Poran, Assistant Professor of Civil Engineering
B.Sc., The Technion, Israel Institute of Technology; M.S., Ph.D., University of California at Davis; Professional Engineer
Geotechnical

Vijay K. Puri, Assistant Professor of Civil Engineering
B.S.C.E., Panjabi University (India); M.Eng., University of
Roorkee (India); Ph.D., University of Missouri-Rolla
Geotechnical

Ahmed M. Sayed, Assistant Professor of Civil Engineering
B.S., Cairo University; M.S., Ph.D., Polytechnic Institute of
New York; Professional Engineer
Structures

Andrew G. Tallin, Assistant Professor of Civil Engineering
B.S.C.E., M.S.C.E., University of Manitoba (Canada);
Ph.D., The Johns Hopkins University
Structures

EMERITUS FACULTY

Stephen T. Mikochik, Professor Emeritus of Civil
Engineering
B.C.E., Manhattan College; M.S. Rutgers—the State
University
Geotechnical engineering

James E. Miller, Professor Emeritus of Meteorology
A.B., Central Methodist College; M.S., New York
University
Meteorology and oceanography

Robert C. Veit, Professor Emeritus of Civil Engineering
C.E., M.C.E., Polytechnic Institute of Brooklyn
Structures

Chilton A. Wright, Professor Emeritus of Civil Engineering
C.E., M.C.E., Ph.D., Cornell University
Hydraulic engineering

ADJUNCT FACULTY

Joseph C. Cataldo, Adjunct Professor of Civil
Engineering
B.C.E., M.S.C.E., Ph.D., CCNY; Professional Engineer

William T. Ingram, Adjunct Professor of Environmental
Engineering
A.B., Stanford University; M.P.H., The Johns Hopkins
University

Anthony V. Rizzi, Adjunct Professor of Civil Engineering
B.S., CCNY; M.S.C.E., Columbia University; Professional
Engineer

Joseph W. Vellozzi, Adjunct Professor of Civil
Engineering
B.S., University of Miami; Ph.D., Rensselaer Polytechnic
Institute; Professional Engineer

Ing H. Wong, Adjunct Professor of Civil Engineering
B.S.C.E., London University; M.S., Ph.D., Massachusetts
Institute of Technology; Professional Engineer

Sidhartha Bagchi, Adjunct Associate Professor of Civil
Engineering
B.A., Calcutta University; B.E.C.E., Calcutta University;
M.E.C.E., Calcutta University; Professional Engineer

Mohammed M. Ettouney, Adjunct Associate Professor of
Civil Engineering
B.S.C.E., M.E., Cairo University (Egypt); Ph.D., Massa-
chusetts Institute of Technology; Professional Engineer

Vito Guido, Adjunct Associate Professor of Civil
Engineering
B.S.C.E., M.S.C.E., Ph.D., Polytechnic Institute of New
York

Edward Kavazanjian, Jr., Adjunct Associate Professor of
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S.B. (Civil), S.M., Massachusetts Institute of Technology;
Ph.D., University of California, Berkeley; Professional
Engineer

Abdul Q. Mohammad, Adjunct Associate Professor of
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B.E. (Civil), University of Gauti; M.S.C.E., University of
Missouri; Ph.D., Polytechnic Institute of New York; Profes-
sional Engineer

Constantine Yapijakis, Adjunct Associate Professor of
Civil Engineering
M.C.E., National Technical University of Athens (Greece);
M.S., New York University; Ph.D., Polytechnic Institute of
New York

Louis S. D'Amico, Lecturer
B.S.C.E., Polytechnic Institute of New York

Albert Berg, Lecturer
B.S.C.E., M.S.C.E., New Jersey Institute of Technology;
Professional Engineer

Mohamed K. El-Choum, Lecturer
B.S.C.E., M.S.C.E., Polytechnic Institute of New York;
M.S. (Computer Sc.), CUNY - Staten Island

J. Robert Elner, Esq., Lecturer
Attorney-at-law

Frank Fazio, Lecturer
B.S.C.E., New York University; Professional Engineer

Kamal A. Gadalla, Lecturer
B.S.C.E., Alexandria University; M.S., Eng., Polytechnic
Institute of New York; Professional Engineer

Clifford Gordon, Lecturer
B.S.C.E., Missouri School of Mines; Professional Engineer

William F. Graner, Lecturer
B.S.C.E., Ph.D., Polytechnic Institute of New York; M.C.E.,
New York University; Professional Engineer

Paul W. Grosser, Lecturer
B.E., M.E., Stevens Institute of Technology; Ph.D., Poly-
technic Institute of New York; Professional Engineer

King Sen Heh, Lecturer
B.S.C.E., M.S.C.E., Polytechnic Institute of New York;
E.D., Columbia University; Professional Engineer

CIVIL AND ENVIRONMENTAL ENGINEERING

Irving J. Hirshman, Lecturer
B.Arch., New York University; Registered Architect

Thomas Lindvit, Lecturer
Professional Engineer; Land Surveyor

Edward E. Lockley, Lecturer
B.S.C.E., Polytechnic Institute of New York; M.S., M.P.A.,
Long Island University; Professional Engineer

Aristodimos J. Philippacopoulos, Lecturer
B.S. (Eng.), Aristotelion University (Greece); M.S.C.E.,
Ph.D., Polytechnic Institute of New York

Kevin J. Phillips, Lecturer
B.C.E., CCNY; M.S. (Env. Eng.), Massachusetts Institute
of Technology; Ph.D., Polytechnic Institute of New York;
Professional Engineer

Satinder P.S. Puri, Lecturer
B.S.C.E., Punjab University (India); M.S.C.E., University
of Illinois; Professional Engineer

Gabriel D. Rossetti, Lecturer
B.S.C.E., New England College; M.S.C.E., M.S. (Manage-
ment), Polytechnic Institute of New York; Professional
Engineer; Professional Planner

Michael J. Sakala, Lecturer
B.S., Drexel University; M.S.C.E., Polytechnic Institute of
New York; Professional Engineer

Sri K. Sinha, Lecturer
B.S.C.E., Patna University; M.S., CCNY; Professional
Engineer

Andre Touma, Lecturer
B.S.C.E., Damascus University (Syria); M.S., Imperial
College (England); Ph.D., Duke University; Professional
Engineer

Jeffrey Vollmuth, Lecturer
B.S. (Marine Science), Southampton College (L.I.); M.S.
(Environmental Engineering), George Washington Univer-
sity; Professional Engineer

Richard R. Zavesky, Lecturer
B.S.C.E., Rensselaer Polytechnic Institute; M.S.C.E.,
Ph.D., Polytechnic Institute of New York

Jacob D. Paz, Research Assistant Professor of Civil
Engineering
B.S., Jewish Theological Seminary; M.S., C.W. Post
College; Ph.D., Polytechnic Institute of New York

John T. Tanacredi, Research Associate
B.S., Richmond College; M.S., Hunter College

COMPUTER SCIENCE

Computer science is the study of both the theory and the applications of computers. Computer scientists are interested in information processing, simulation and modeling of various systems, and in the theoretical foundations of computation. They are concerned with the development of efficient algorithms, of effective languages with which to represent algorithms and of effective means to structure and access information.

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 and, in cooperation with the electrical engineering faculty, the programs in computer engineering.

UNDERGRADUATE PROGRAM

The program in computers is designed to provide the student with broad, basic preparation in the theory, organization and application of computers and information processing systems. Foundation courses teach the basics of hardware, software, and their interrelationships. Practical courses emphasize the use of both microcomputers and large computers. The graduate is ready for immediate employment or for further graduate study.

The student may choose either one of the following two programs: (a) the computer science program leading to the bachelor of science degree in computer science described in the present section of the catalog, or (b) the computer engineering option leading to the bachelor of science degree in electrical engineering described in the electrical engineering section of the catalog. Both programs draw from the same core curriculum of computer courses, and both require that the student take a balanced selection of software (programming languages, etc.) and hardware (computer architecture, computer laboratory, etc.) courses; both programs also require essentially the same basic mathematics, physics and chemistry courses.

The computer science undergraduate program is designed to provide the student with a program in computer science as well as with a minor in a second area. The core sequence consists of 32 credits in computer science. Additionally, the curriculum provides a sound foundation in mathematics, physics, chemistry, and in the social sciences and humanities. A minor specialty consisting of a minimum of 12 credits in an integrated, well-defined area encourages the student to develop some depth of understanding in a field other than computer science. The minor specialty is chosen by the student in consultation with and approval of an academic adviser. The minor can be chosen from a broad range of areas in science,

engineering, and humanities. (Typical examples of minors are given in the Undergraduate Student Manual). Students with interest in both electrical engineering and computer science should consider the computer engineering option in electrical engineering.

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 year; however, special programs may be worked out for 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.

Curriculum for the Bachelor of Science Degree in Computer Science (for Freshmen entering 1986)

Freshman Year[3]

First Semester No.	Subject	Cl.	Lab.	Cr.
CS 112	Programming in Pascal	3	0	3
MA 101	Calculus I[6]	4	0	4
PH 101	Introductory Physics I	3	0	3
CM 101	General Chemistry I	2½	0	2½
CM 111	General Chemistry Lab I	0	1½	1
HU 101	Writing and the Humanities I[1]	3	0	3
PE 101	Physical Education[2]	0	2	0
				16

Second Semester No.	Subject	Cl.	Lab.	Cr.
CS 204	Intro. to Data Structures	3	0	3
MA 102	Calculus II[6]	4	0	4
PH 102	Introductory Physics II	3½	1½	4
CM 102	General Chemistry II	2½	0	2½
CM 112	General Chemistry Lab II	0	1½	1
HU 200	Writing and the Humanities II[1]	3	0	3
PE 102	Physical Education[2]	0	2	0
				17

Sophomore Year

No.	Subject	Cl.	Lab.	Cr.
CS 203	Computer Programming II	3	0	3
MA 104	Appl. Diff. Equations[6]	3	0	3
PH 103	Introductory Physics III	2½	1½	3
HU 110	Basic Report Writing I	3	0	3
	Hum./Soc. Sci. elective[5]	3	0	3
PE 103	Physical Education[2]	0	2	0
				15

No.	Subject	Cl.	Lab.	Cr.
CS 236	Switching Circuits & Dig. Sys.	3	0	3
MA 103	Calculus III[6]	3	0	3
EE 377	Intro. to Electronics	3	1	3
SS 104	Main Themes in Contemporary World History[4]	3	0	3
	Hum./Soc. Sci. elective[5]	3	0	3
PE 104	Physical Education[2]	0	2	0
				15

Junior Year

No.	Subject	Cl.	Lab.	Cr.
CS 205	Ass'y & Machine Lang.	3	0	3
CS 237	Intro. to Computer Architecture	3	0	3
MA 223	Intro. to Probability	3	0	3
	Minor specialty[7]			3
	Hum./Soc. Sci. elective[5]	3	0	3
				15

No.	Subject	Cl.	Lab.	Cr.
CS 206	Compilers	3	0	3
CS 298	Computer Lab I	2	3	3
MA 358	Introductory Numerical Analysis	3	0	3
	Minor specialty[7]			3
	Technical elective[8]			3
	Hum/Soc. Sci. elective[5]	3	0	3
				18

Senior Year

No.	Subject	Cl.	Lab.	Cr.
CS 238	Operating Systems	3	0	3
CS 299	Computer Lab II	1	3	2
	Minor specialty[7]			3
	Technical elective[8]			3
	Hum./Soc. Sci. elective[5]	3	0	3
	Free elective[8]	3	0	3
				17

No.	Subject	Cl.	Lab.	Cr.
CS 398	Sr. Project in CS	1	6	3
	MA or CS elective	3	0	3
	Minor specialty[7]			3
	Technical elective[8]			3
	Hum./Soc. Sci. elective[5]	3	0	3
				15

Total credits required for graduation: 128

[1] Newly admitted students take the English Composition Placement Test administered by the Department of Humanities and Communications. Most students are placed in HU 101 or HU 103. A few may be exempted from HU 101 and placed directly in HU 200, and others may first be required to take the non-credit HU 008 or HU 009.

[2] Full-time students take four semesters of Physical Education; the same PE course number may be repeated. Polytechnic ROTC courses MS 101, 102, 201, and 202 may be substituted on a zero-credit basis. Physical Education is waived for students who attend part-time for their first 64 credits, and for students who receive 64 transfer credits. The waiver is prorated when part-time attendance or transfer is less than 64 credits.

[3] CP 101 - 102 are required of full-time students in the Cooperative Education Program and must be completed before assignment to the first work period. These courses are not a BS degree requirement.

[4] IS 140 - 141 may be substituted for HU 200 plus SS 104.

[5] Take specified HU, IS, LA, ML, or SS-lettered course with adviser approval.

[6] Students with superior mathematical aptitude may replace the MA 101 - MA 104 sequence with MA 111 - MA 114. Consult the Department of Mathematics about your eligibility and course availability.

[7] The minor specialty consists of a substantial concentration in a particular subject area other than computer science, approved by the departmental adviser. Examples of acceptable minor areas are statistics, system analysis, operations research, controls, communications, psychology. Other minors may be arranged to satisfy the particular interest of the student (Typical examples of minors are given in the Undergraduate Student Manual.)

[8] Technical electives are chosen from a list of approved courses, departmental and out-of-department, published and updated each year. Students may propose alternative courses to the adviser. A free elective can be any course as long as the subject is not a duplication of material studied under another course number. A programming course in another language is not an acceptable elective.

ROTC cadets may use a maximum of six credits of junior/senior level ROTC courses to replace three credits of free electives and three credits of technical electives. The eligible courses are MS 301, 303, 401, 403.

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,* consisting of the courses in computer science plus courses in other technical subjects. This requirement for a minimum *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 technical 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 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 D+, D or I 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 *technical* 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 condition 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 departmental office in Farmingdale. Each student is responsible for keeping informed.

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.

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 information systems master's program is intended to provide graduate-level instruction for students interested in pursuing professional work in the development, specification and management of information and data-processing systems.

Both programs are specifically structured to enable the graduate to keep abreast of developments in the chosen discipline and to interact with other disciplines. Students in both programs 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 research fellowships, 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 grade in each course is a necessary condition for transfer to graduate status. No student will be admitted to full-time conditional status who lacks the equivalent of CS 530.

COMPUTER SCIENCE

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 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 accord 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 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	
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)

		UNITS
Required Courses		27
CS 603	Design and Analysis of Algorithms I	
CS 606	Software Engineering I	
CS 608	Principles of Database Systems	
CS 609	Information Analysis and System Design I	
CS 623	Operating Systems I	
IE 600	Engineering Economy	
MA 562	Statistics	
MG 601	Organizational Behavior	
MG 810	Project Planning and Control	

Electives		9

Three courses as approved by an adviser, including at least one from each of the following groups:
Group A: CS 610, 616, 624, 633, 637, 653, 661.
Group B: IE 614, 619, 627, 628; MG 606, 624, 762, 820.

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 minimum 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 non-computer 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 111 Computer Programming I 3:0:3

Types of languages, problem-solving, algorithms, flow charts. Basic PL/I instructions, simple programs, programming style, structured programs. Character and bit strings, arrays, built-in functions, function and subroutine procedures. Problems assigned from several disciplines solved on the Polytechnic computer. (Last offered fall, 1986.)

CS 112 Programming in Pascal 3:0:3

Computers and programming; use of terminals; problem solving, simple programs 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 203 Computer Programming II 3:0:3

Programming in Pascal; data types, assignments, loops, and conditional statements; arrays, records, sets, files, and pointers; functions and procedures. Methods for the design of high quality programs. (Last offered spring, 1987.) Prerequisites: CS 111 and MA 101.

CS 204 Introduction to Data Structures 3:0:3

Mathematical models and computer representations. Operations on arrays, stacks, queues. Sequential and linked representations, linear data structures, trees and graphs. Sorting and searching. Data access. Dynamic allocation of storage. Manipulation of strings. Prerequisite: CS 112.

CS 205 Assembly and Machine Language Programming 3:0:3

Assembly language, machine language programming and PDP-11 architecture. 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 112.

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. Prerequisites: CS 204 and 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.) Prerequisites: CS 100 or CS 112.

CS 236 Switching Circuits and Digital Systems 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, clock mode and pulse mode systems, state reduction, machine synthesis. Prerequisite: CS 100 or CS 112.

CS 237 Introduction to Computer Architecture 3:0:3

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. Prerequisite: CS 236.

CS 238 Operating Systems 3:0:3

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 204, CS 205 and CS 237.

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 298 Computer Laboratory I 2:3:3

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: EE 377 and CS 236; co/prerequisite: CS 237.

COMPUTER SCIENCE

CS 299   Computer Laboratory II   1:3:2
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. Prerequisites: CS 237 and CS 298.

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; top-down and bottom-up design; defensive programming; documentation using HIPO diagrams, pseudocode and flowcharts. Path testing, exhaustive test models and construction of test data. Introduction to software tools. Students' term projects involve group software development. Prerequisites: CS 203 plus junior status.

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 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 and CS 237.

CS 397   Senior Seminar and Project
in Computer Science   2:0:2
Topics of general interest prepared, reported and discussed by faculty and students. Project proposals prepared and presented by students. Prerequisites: CS 206 and CS 298 (Last offered Fall 1986).

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 397. Co/Prerequisite: CS 299.

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 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, simple programs 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.

CS 540   Elements of Data
Structures   2½:0:3
Concentrated orientation course for students entering computer science from another field. Internal representation of the stack, queue, list and their applications. Trees and graphs. Recursive programming techniques. Internal searching and sorting. Prerequisite: CS 530.

CS 550   Assembly Language
Programming   2½:0:3
Assembly language, system organization and architecture of the PDP-11. 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   Introduction to Logic and
Automata   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   Introduction to Computer
Architecture   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. 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. Consult the *Graduate Student Manual* for these scheduling cycles as well as for information about day offerings and the summer program. 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 or other degree programs administered by the Department of Electrical Engineering and Computer Science.) Prerequisite: graduate status.
Also listed under IE 601.

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: Graduate status and 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: graduate status and 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
Introduction to digital computer organization and architecture. Arithmetic operations; adders, accumulators, multipliers, dividers; organization and control of computer, mini-computer architecture; machine languages and systems principles. (Knowledge of a programming language required) Prerequisites: graduate status and CS 550, CS 580.

CS 614 Computer Architecture II 2½:0:3
Further development of topics in machine organization and architecture. Microprogramming and microprocessors, hardware-software tradeoffs, parallel computers and distributed processing, stack computers, overlap and pipeline processing, array processors, computer network. 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
Introduction to the structure of multiprogramming computer operating systems. Memory hierarchies, memory management, static and dynamic including paging and segmentation, concurrency, sharing and synchronization. Prerequisites: graduate status.

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. Introduction 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 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 635 Principles of Communication Networks 2½:0:3
Network modeling. Designs and performance analyses of networks. Data communication hardware: terminals, modems, multiplexers, concentrators, communications media. Nodal processor and host processor architecture. Software considerations and designs. Protocols. Line control, polling and random access methods. Satellite and local area networks. Prerequisite: graduate status. (After Fall 1986 listed only under EL 635.)
Also listed under EL 635.

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: graduate studies and CS 540, 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: graduate status and 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 651 Computer Graphics and Image Processing 2½:0:3
Introduction to computer graphics. Vector, curve, and character generation. Display components and algorithms, data structures. Discussion of digital image processing; digitization, enhancement, encoding and representation techniques. Prerequisite: CS 613.

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. Prerequisite: graduate status.

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 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: graduate status and 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, push-down automata, Turing machines. The halting problem, solvable and unsolvable linguistic questions. Prerequisitie: 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. Prerequisite: graduate status and mathematical maturity.

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

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

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and Computer Science
B.S., California Institute of Technology; M.A., Ph.D.,
Harvard University
Quantum electronics; computer software

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B.S., City College of New York; M.S., Ph.D., New York
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Numerical analysis, theory of computation, applied mathematics, software engineering

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B.S.E. (Math), B.S.E. (EE), Ph.D., University of Michigan;
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Software engineering, programming, circuit theory

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Software engineering, system reliability and safety

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Computer communications, telecommunications

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B.S., M.S. (EE), M.S. (Math), Ph.D., Polytechnic Institute
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Artificial intelligence, expert systems

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Computer architecture, operating systems, signal processing, computer music

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B.A. (Math), Hofstra University; Ph.D. (Math), Rutgers
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Programming and computer software

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Coding theory, operating systems, high-level architecture

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Artificial intelligence, robotics, applied mathematics

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Institute of Education (U.S.S.R.)
Logic, artificial intelligence

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Artificial intelligence, robotics

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B.S. (EE), College of English (India); M.S. (EE), Indian
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Computer graphics

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B.S., M.S., Polytechnic Institute of New York
Microprocessor architecture

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Data management, programming languages, natural language processing

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Computer Architecture

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Computer architecture, switching and automata

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Technologie Electrique (France)
Parallel processing

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B.S. (Math), Queens College; M.S. (Quantative Analysis/
Finance), New York University; M.S. (CS), Polytechnic
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Information-systems, computer networks

INDUSTRY PROFESSORS

Robert J. Flynn, Industry Professor
B.S., Manhattan College; M.S., Ph.D., Polytechnic Institute
of Brooklyn
Computer architecture; operating systems

Paul Friedland, Industry Professor
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Computer software, database systems

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COMPUTER SCIENCE

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
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Microprocessor systems, data acquisition and transmission, signal processing

ADJUNCT FACULTY

Maurice Karnaugh, Distinguished Adjunct Professor
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B.S., New York University; M.S., Polytechnic Institute of New York

Charles J. Bontempo, Lecturer
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Ximena Cardenas, Lecturer
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Daniel Gill, Lecturer
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Amine G. Kandalaft, Lecturer
B.S., 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

Semyon Shteingart, Lecturer
B.S., Ph.D., Polytechnic Institute of New York; M.S, University of Michigan

Ronald I. Sklar, Lecturer
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David C. Willen, Lecturer
B.S., M.S., Polytechnic Institute of New York

Rosalind Yu, Lecturer
B.B.A., Kent State University; M.B.A., St. John's University; M.S. (IS), Polytechnic University 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

This core curriculum represents a new vision of liberal education. It 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 in 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 Machines and Humanity
LA 143 Information, Communications 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
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*	12
		15

Junior Year

LA	141 Materials and Social Issues	3
LA	142 Machines and Humanity	3
CS	or EL*	9
		15

LA	143 Information, Communication 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	161 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*, SS 104*)	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 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 Machines and Humanity   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 Information, Communication 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.

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, Associate Professor of English and Acting Head of Humanities & Communications

Frederick Eirich, Distinguished Professor of Polymer Chemistry

Donald Hockney, Professor of Humanities and Communications, of Computer Science.

Burton Lieberman, Associate Professor of Mathematics

Ernest M. Loebl, Professor of Physical Chemistry

Carl Mitcham, 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, Associate 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 student employees are paid salaries and, in most cases, receive company benefits. Students will be given work directly related to their career goals and levels of academic experience.

The Cooperative Education Program is optional. Completion of the co-op courses is not required for graduation.

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;
- 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 prerequisite 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 upon the students 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	0:6:NC

Prerequisite: CP 301

CP 401 Fifth Co-op Field Assignment 0:6:NC
Prerequisite: CP 302

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

Ernest B. Racz, Associate Provost and Director of Career Services and Cooperative Education
B.A., Franklin & Marshall College; M.Div., Lancaster Theological Seminary; M.A., Ed.D., Columbia Univ.

Beatrice Hackenerg, Assistant Director, Long Island Campus.
B.S., SUNY-Empire State College; M.S., Polytechnic Institute of N.Y.

Kathleen L. Kennedy, Assistant Director, Career Services and Cooperative Education.
B.S. Univ. of Dayton; M.S. Wright State University

Dina Yershova, Coordinator of Job Development

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 1985 Gourman Report shows Polytechnic EE programs as best in the New York City area and high nationally. 12th for BS and 13th for MS; and 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, are described in the computer science section 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
    Electrical Engineering Option
    Computer Engineering Option

Computer Science
Bachelor of Science

GRADUATE

Electrical Engineering
Master of Science
Electrical Engineer
Doctor of Philosophy

System Engineering
Master of Science
System Engineer
Doctor of Philosophy

Electrophysics
Master of Science
Doctor of Philosophy

Computer Science
Master of Science
Doctor of Philosophy

Information Systems
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; signal 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 material 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, both options) is accredited by the Accreditation Board for Engineering and Technology (ABET), on which the Institute of Electrical and Electronics Engineers (IEEE) is a participant.

UNDERGRADUATE OPTIONS

There are two programs with somewhat different course requirements, the *electrical engineering option* and the *computer engineering option;* the two curriculum tables are shown below. Both options are accredited by the Accreditation Board for Engineering and Technology (ABET) as electrical engineering degrees. The two options differ in *five* courses, out of the total 36 required courses:

Electrical engineering option: EE 162, EE 167, EE 180, EE 196, EE 197.
Computer engineering option: CS 203, CS 204, CS 205, CS 298, CS 299.

Changes from one option to the other can be made at any time and do not require departmental approval. Depending on their initial choice of option, entering freshman register for slightly different courses: electrical engineering option students take SS 104 in the first semester and CS 112 in the second semester, whereas students in the computer engineering option start with CS 112 and continue with CS 204 in the second semester. Initially

undecided students should start with CS 112 because it is somewhat simpler to switch from the computer engineering option to the electrical engineering option than the other way around.

The freshman year courses in the BS (EE) computer engineering option and in the BS (CS) degree program are identical, but thereafter the curricula diverge. See page 86 for details of the computer science degree program.

Curriculum of Study for the Bachelor of Science Degree in Electrical Engineering (for Freshmen entering in 1988)

ELECTRICAL ENGINEERING OPTION

Freshman Year[3]

First Semester		Hours/Week		
No.	Subject	Cl.	Lab.	Cr.
MA 101	Calculus I[13]	4	0	4
PH 101	Introductory Physics I	3	0	3
CM 101	General Chemistry I	2½	0	2½
CM 111	General Chemistry Lab I	0	1½	½
HU 101	Writing & the Humanities I[1]	3	0	3
SS 104	Main Themes in Contemporary World History[7]	3	0	3
PE 101	Physical Education[2]	0	2	0
				16

Second Semester		Hours/Week		
No.	Subject	Cl.	Lab.	Cr.
CS 112	Programming in Pascal	3	0	3
MA 102	Calculus II[13]	4	0	4
PH 102	Introductory Physics II	3½	1½	4
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
PE 102	Physical Education[2]	0	2	0
				17

Sophomore Year

		Cl.	Lab.	Cr.
EE 101	Elec. Circuits I	3	0	3
EE 193	Soph. EE Lab. I	1½	1½	1
MA 104	Appl. Diff. Equations[13]	3	0	3
PH 103	Introductory Physics III	2½	1½	3
	Hum./Soc. Sci. electives[7]	6	0	6
PE 103	Physical Education[2]	0	2	0
				16

		Cl.	Lab.	Cr.
EE 102	Elec. Circuits II	3	0	3
EE 194	Soph. EE Lab. II	1½	1½	1
MA 103	Calculus III[13]	3	0	3
PH 230	Atom. & Nucl. Physics	2	0	2
AM 115	Eng. Mechanics[8]	4	0	4
	Hum./Soc. Sci. elective[8]	3	0	3
PE 104	Physical Education[2]	0	2	0
				16

Junior Year

		Cl.	Lab.	Cr.
EE 103	Signals & Transforms	4	0	4
EE 111	Solid State Circ. I	3	0	3
EE 161	Lines and Waves	4	0	4
EE 195	Jr. EE Lab. I	1	3	2
CS 236	Switching & Dig. Sys.[16]	3	0	3
	Hum./Soc. Sci. elective[8]	3	0	3
				19

		Cl.	Lab.	Cr.
EE 104	Feedback Systems	3	0	3
EE 112	Solid State Circ. II	3	0	3
EE 162	Electromagnetic Fields	4	0	4
EE 196	Jr. EE Lab. II	1	3	2
MA 223	Probability[17]	3	0	3
	Hum./Soc. Sci. elective[8]	3	0	3
				18

Senior Year

		Cl.	Lab.	Cr.
EE 113	Solid State Circ. III	3	0	3
EE 140	Communications[17]	3	0	3
EE 167	Quantum Electronics[24]	3	0	3
EE 180	Elec. Machinery I[21]	3	0	3
EE 197	Sr. EE Lab. I	1	3	2
	Technical elective[20]	3	0	3
				17

		Cl.	Lab.	Cr.
EE 199	Sr. EE Lab. II[26]	1	3	2
CS 237	Computer Architecture	3	0	3
	Technical electives[20]	9	0	9
	Free elective[20]	3	0	3
				17

Total credits required for graduation: 136

COMPUTER ENGINEERING OPTION

Freshman Year[3]

First Semester			Hours/Week	
No.	Subject	Cl.	Lab.	Cr.
CS 112	Programming in Pascal	3	0	3
MA 101	Calculus I[13]	4	0	4
PH 101	Introductory Physics I	3	0	3
CM 101	General Chemistry I	2½	0	2½
CM 111	Gen. Chemistry Lab. I	0	1½	½
HU 101	Writing & the Humanities I[1]	3	0	3
PE 101	Physical Education[2]	0	2	0
				16

Second Semester			Hours/Week	
No.	Subject	Cl.	Lab.	Cr.
CS 204	Introduction to Data Structures	3	0	3
MA 102	Calculus II[13]	4	0	4
PH 102	Introductory Physics II	3½	1½	4
CM 102	General Chemistry II	2½	0	2½
CM 112	General Chemistry Lab II	0	1½	½
SS 104	Main Themes in Contemporary World History[5]	3	0	3
PE 102	Physical Education[2]	0	2	0
				17

Sophomore Year

		Cl.	Lab.	Cr.
EE 101	Elec. Circuits I	3	0	3
EE 193	Soph. EE Lab. I	1½	1½	1
CS 203	Computer Programming II	3	0	3
MA 104	Appl. Diff. Equations[13]	3	0	3
PH 103	Introductory Physics III	2½	1½	3
HU 200	Writing & the Humanities II[1]	3	0	3
PE 103	Physical Education[2]	0	2	0
				16

		Cl.	Lab.	Cr.
EE 102	Elec. Circuits II	3	0	3
EE 194	Soph. EE Lab. II	½	1½	1
MA 103	Calculus III[13]	3	0	3
PH 230	Atom. & Nucl. Physics	2	0	2
AM 115	Eng. Mechanics[8]	4	0	4
	Hum./Soc. Sci. elective[8]	3	0	3
PE 104	Physical Education[2]	0	2	0
				16

Junior Year

		Cl.	Lab.	Cr.
EE 103	Signals & Transforms	4	0	4
EE 111	Solid State Circ. I	3	0	3
EE 195	Jr. EE Lab. I	1	3	2
CS 205	Ass'y and Machine Lang.	3	0	3
CS 236	Switching & Dig. Sys.	3	0	3
	Hum./Soc. Sci. elective[8]	3	0	3
				18

		Cl.	Lab.	Cr.
EE 104	Feedback Systems	3	0	3
EE 112	Solid State Circ. II	3	0	3
EE 188	Computer Lab. I	2	3	3
CS 237	Computer Architecture	3	0	3
MA 223	Probability[13]	3	0	3
	Hum./Soc. Sci. elective[8]	3	0	3
				18

Senior Year

		Cl.	Lab.	Cr.
EE 113	Solid State Circ. III	3	0	3
EE 140	Communications[17]	3	0	3
EE 161	Lines and Waves	4	0	4
CS 299	Computer Lab. II	1	3	2
	Technical elective[20]	3	0	3
	Hum./Soc. Sci. elective[8]	3	0	3
				18

		Cl.	Lab.	Cr.
EE 199	Sr. EE Lab. II[26]	1	3	2
	Technical electives[20]	9	0	9
	Hum./Soc. Sci. elective[8]	3	0	3
	Free elective[20]	3	0	3
				17

Total credits required for graduation: 136

[1]Newly admitted students take the English Composition Placement Test administered by the Department of Humanities and Communications. Most students are placed in HU 101 or HU 103. A few may be exempted from HU101 and placed directly in HU 200; others may first be required to take the non-credit HU 008 or HU 009.

[2]Full-time students take four semesters of Physical Education; the same PE course number may be repeated. Polytechnic ROTC courses MS 101, 102, 201, and 202 may be substituted on a zero-credit basis.

Physical Education is waived for students who attend part-time for their first 68 credits, and for students who receive 68 transfer credits. Waivers are prorated when part-time attendance or transfer is less than 68 credits.

[3]CP 101-102 are required of full-time students in the Cooperative Education Program and must be completed before assignment to the first work period. These courses are not a B.S. degree requirement.

[4]IS140-141 may be substituted for HU200 plus SS104.

[5]Take HU, IS, LA, ML, or SS lettered courses in consultation with the adviser.

As part of the requirements in the humanities and social sciences for engineering undergraduates, students should select an area of concentration (such as literature, communications, the arts, or philosophy and comparative religions in the department of humanities and communication, or economics, history, anthropology, or psychology in the department of social sciences) and to elect a number of 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.

[8]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.

[13]Students with superior mathematical aptitude may replace the MA101-MA104 sequence by MA111-MA114. Consult the Department of Mathematics about your eligibility and course availability.

[14]AM 115 may be replaced by AM 116-117.

[17]Students may start their electives and defer MA223 and EE140 by one semester.

[20]Technical electives are chosen from a list of approved courses, departmental and out-of-department, published and updated each year. A free electives can be any course which is a not duplication of material studied under another course number. See footnote 26 for restriction on project courses.

ROTC cadets may use a maximum of six credits of junior/senior level ROTC courses to replace three credits of free electives and three credits of technical electives. Eligible courses are MS 301, 303, 401, 403.

[26]EE 199 may be replaced by EE 396 or by EE 397. Not more than six credits of projects courses may be offered toward the BS (EE) degree.

ELECTIVE CONCENTRATIONS

There are 10 elective courses, in both options, of which five must be in the humanities and social sciences subjects, and the balance in the physical sciences, mathematics, or engineering. Most 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. One popular concentration is to take courses in the *other* option as electives. Other elective concentrations which have found acceptance are as follows:

Electrophysics Concentration — for students whose interests lie in electromagnetics and solid-state devices. Courses offered prepare students to work in such areas as antennas, microwave components, lasers, optics and integrated circuits.

Power Engineering Concentration — for students whose interests lie in the area of power and energy. Most of these specialized courses are available only on the Brooklyn campus.

Bioengineering Concentration — for students who wish to combine a career in the life sciences with electrical or computer engineering. These specialized courses are available only on the Brooklyn campus.

Other recommended elective concentrations are mathematics, operations research, materials engineering, and management. For qualified students additional areas are open through enrollment in graduate courses.

EVENING UNDERGRADUATE PROGRAM

The electrical engineering option can be completed in Brooklyn entirely by attending classes Monday through Thursday from 6 p.m. to 10 p.m., on a part-time basis. Brooklyn evening students who wish to pursue the computer engineering option will have to take some computer courses during the day. On the Long Island campus evening course sections are offered on an irregular basis; 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.

HONORS PROGRAM

Full-time students in electrical engineering can be admitted into BS/MS honor a 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.

Graduate courses (non-daggered) may be taken as electives by senior students whose junior year grade-point averages in technical courses exceed 2.7. Daggered electrical engineering graduate courses may be taken as senior electives by any undergraduate.

DEPARTMENTAL STANDARDS AND PROBATION

To earn a B.S. degree in electrical engineering, students must have a minimum C average (2.00 grade-point

average) in the *major,* consisting of the courses in electrical engineering and computer science plus other technical subjects. This requirement for a minimum *technical* average is above and beyond the Polytechnic B.S. degree requirements 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 the probation may lead to academic *disqualification* from the B.S. (E.E.) degree program.

Probation action may be occasioned by a semester or cumulative technical average of less than 2.00; grades lower than C in important courses, particularly EE 101-102; failure to adhere to course prerequisites; or excessive or unauthorized course withdrawals. 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 D+, D, or I in EE 101 or EE 102 will be asked to repeat the course; the same holds for CS 112 and CS 204 for students in the computer engineering option. 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 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. Exclusion of the first grade of a repeated course in the computation of the *technical* 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 are obliged to consult their advisers after their 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 all students contains further details on honors, probation, approved electives, projects, elective concentrations, 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 of the departmental office 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 and computer science.

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.

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 the 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 ionic propulsion for space vehicles.

Quantum Electronics and Material Science — Quantum electronics and material 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 masers and lasers, nonlinear optics, quantum optics, holography, and electric, magnetic and thermal properties of material.

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.

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. Students without an electrical engineering B.S. degree may also want to consider the departmental master's degree programs in electrophysics and in system engineering.

Outstanding students should apply for financial aid in the form of research fellowship, teaching fellowship or partial tuition remission.

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 671 Switching and Automata 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.

Theses: Exceptional students 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 need not be original, but 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 engineer in electrical engineering degree 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 goal towards the doctorate. The degree of Ph.D. is awarded after completing the program of studies and research described below and preparation and defense of a dissertation representing an original and significant contribution worthy of publication in a recognized scientific or engineering journal.

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 a master's degree 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, generally at the opening of the academic year in September. These examinations are divided into three sections: (a) basic section—a written examination requiring broad knowledge and problem-solving ability at the undergraduate level; (b) 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) concentration section—an oral examination concentrating mainly on the student's declared area of interest. Principal areas of concentration are: communications; computers; automatic control; electronics; electromagnetics; electro-optics; and power. 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 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. 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 Student Manual* and the Schedule of Classes for changes of courses, course content and prerequisites in effect after the publication of this catalog.

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 101-2, PH 101-2, and CS 112 (all with grade C or better); Co/ Prerequisites: MA 104 and PH 103.

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. Complex Fourier series. Three-phase systems. Prerequisites: EE 101 (grade C or better), PH 103, and MA 104.

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, discrete Fourier series and Fourier integral. Prerequisites: EE 102 (grade C or better) and MA 104.

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.

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 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).

ELECTRICAL ENGINEERING

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.

EE 113 Solid-State Devices and Circuits III   3:0:3
Voltage sweeps and function generators, multivibrators, comparators. Digital circuit and system applications including counters, shift registers, adders and memories. Sinusoidal oscillation and peak detection. Prerequisite: EE 112.

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. Nonlinear 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 112.

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 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.

EE 143 Computer Processing of Signals*   3:0:3
Processing of signals from speech, biomedical, seismic and traffic-flow measurements. Information extraction filtering, spectral analysis, model parameter estimation. Simulation of dynamic systems and signals. Pattern processing and recongnition. Projects with small and large computers. Prerequisite: 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. Spherical acoustic waves. Vectors, Maxwell's equations in free space in integral form. Prerequisites: EE 102 (grade C or better), PH 103, MA 103 and MA 104.

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.

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 230 or PH 232 and Co/Prerequisite: EE 161.

EE 199 Semiconductor Laboratory
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.

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 161.

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 102 (grade C or better).

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.

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 189 Computer Laboratory II   **1:3:2**
An introduction to the use of small computers as system 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. (Last offered fall, 1986.) Prerequisites: EE 188 and CS 237.
Also listed under CS 299.

EE 193 Sophomore Electrical Engineering Laboratory I   **½:1½:1**
Introduction to electrical measurements. Lab fee required. Co/Prerequisite: EE 101.

EE 194 Sophomore Electrical Engineering Laboratory II   **½:1½:1**
Electrical circuits laboratory. Lab fee required. Prerequisites: EE 101 and EE 193; Co/Prerequisite: EE 102.

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 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 162, EE 104 and EE 112.

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, and EE 161; Co/Prerequisite: EE 113.

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. (Alternative prerequisites are specified for special sections.)

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, PH 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: 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 and PH 102; Co/Prerequisite: 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 EE Laboratory Project I   **0:3:1**
First phase of a project which requires the design, construction, testing, and documentation of a piece of equipment or of a software package, under the supervision of a faculty adviser. Definition of problem. Preparation of outline of procedure, equipment requirements, and cost estimate. Summary report required. Prerequisite: senior status.

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.

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. Prerequisite: senior status and approval of head of 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. Prerequisite: senior status.

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.

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, delta and 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.

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 contraints. 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* 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 nonrecursive filters. Effects of finite precision arithmetic and round-off errors. Hardware realizations of digital filters. Introduction to spectral analysis. Prerequisites: EL 610 and 611.

EL 911-912 Selected Topics in Systems and Networks I, II* 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. Nonlinearities, 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 stabilizating 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 921-922 Selected Topics in Control Engineering I, II* 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 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 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
Concepts of M-ary communications, optimum receivers, signal design, block coding, achievement of channel capacity. Convolution coding and decoding, decoding algorithms. Transmission over band-limited channels. Intersymbol interference, fixed, adaptive and feedback equalization, concepts of modern design. 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 braodcast 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.

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 non-stationary Gaussian noise. Nonparametric methods in detection and estimation. Diversity reception systems. Prerequisite: EL 633.

**EL 931-932 Selected Topics in Information
Science I, II*   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 162 and EE 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 the microwave program 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.

EL 642 Advanced Electronic Circuitry II   2½:0:3
Three-stage amplifiers, discrete and integrated circuits. Complete, integrated, operational amplifiers. Tuned circuits and impedance transformers, narrow-band linear amplifiers. Tuned-circuit sine-wave oscillators and mixers. 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". Tuned and untuned power amplifiers. 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.
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.

EL 941-942   Selected Topics in
Electronics I, II*   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 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. Discussion of 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 951-952   Selected Topics in Quantum Electronics,
Material Science and Electro-Optics I,II*
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 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
Introduction: 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: graduate status.

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: graduate status.

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: EL 621.

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 667   Introduction to Thermonuclear Power*   2½:0:3
Survey of problems associated with attaining controlled thermonuclear power. Fusion reactions, thermonuclear reaction rates, plasma physics, radiative losses from plasmas, methods of plasma containment, energy extraction from plasmas. Prerequisite: graduate status.
Also listed under NU 619

EL 647   Power Electronics
See course listings under electronic devices, circuits and systems.

EL 961-962   Selected Topics in Power I, II*   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 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 162.

**EL 672   Electrodynamics: Wave Propagation
and Guidance**   3½:0:3
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 624

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 971-972 Selected Topics in Electromagnetic
              Theory I, II***   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 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 AM 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 981-982 Selected Topics in Plasmas I, II*   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 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

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Enrico Levi, Professor of Electrophysics
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ELECTRICAL ENGINEERING

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Quantum and nonlinear optics, laser-induced fusion

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Wave propagation

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Signal theory

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B.S., M.S., Polytechnic Institute of New York

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.E.E., City College of New York

ELECTRICAL ENGINEERING

Frank Gruppuso, Lecturer
B.S., M.S., Polytechnic Institute of New York

Howard Hausman, Lecturer
B.S., M.S., Polytechnic Institute of Brooklyn

John Howard, Lecturer
B.S., University of Wales; M.S., Ph.D., University of London

Charles W. Kulisan, Lecturer
B.S., M.S., Polytechnic Institute of New York

Robert Leahy, Lecturer
B.E.E., M.E.E., Polytechnic Institute of Brooklyn

Jack Richman, Lecturer
B.C.E., City College of New York; M.S., New York University

Doru T. Roll-Mecag, Lecturer
B.S., M.S., Polytechnic Institute of New York

Heinz Schreiber, Lecturer
B.E.E., City College of New York; M.S., Adelphi; Ph.D., Polytechnic Institute of New York

RETIRED FACULTY

Frank E. Canavaciol, Professor Emeritus
E.E., Polytechnic Institute of Brooklyn; D.Eng. (hon.), Polytechnic Institute of New York

Rudolf F. Drenick, Professor Emeritus
Ph.D., University of Vienna (Austria)

Herman Farber, Associate Professor of Electrophysics
B.A., Brooklyn College; M.E.E., Polytechnic Institute of Brooklyn

Anthony B. Giordano, Professor Emeritus and Dean Emeritus
B.E.E., M.E.E., D.E.E., Polytechnic Institute of Brooklyn

Rudolf G.E. Hutter
State Exam, University of Berlin (Germany); Ph.D., Stanford University

William A. Lynch, Professor Emeritus
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

Arthur A. Oliner, Professor of Electrophysics
B.A., Brooklyn College; Ph.D., Cornell University

Marvin Panzer
B.E.E., Cooper Union; M.E.E., D.E.E., Polytechnic Institute of Brooklyn

Beulah Rudner, B.A., Hunter College; M.E.E., Polytechnic Institute of Brooklyn

Sidney S. Shamis, Professor of Electrical Engineering and Associate Provost
B.E.E., Cooper Union; M.S., Stevens Institute of Technology

Edward J. Smith, Professor 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 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 an 800-foot antenna range, a microwave anechoic chamber, an ionospheric sounder, laser laboratories, an ultrasonics laboratory devoted to microwave acoustics, a solid-state and millimeter wave device laboratory and plasma laboratories. The Brooklyn campus has laboratories devoted to modern optics, ultrasonics, magnetic materials and thin films. The thin-film laboratory has extensive facilities for vacuum deposition, integrated circuit fabrication, and a scanning electron microscope.

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.   21-15 units

    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.

Specific requirements for this degree parallel those for the Ph.D. in E.E. as described elsewhere in this catalog and in the departmental *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, 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 twelfth 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

Stanley H. Gross, Professor of Electrophysics

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

Eli Absalom Mishkin, Professor of Applied Physics

Istvan Palocz, Professor of Electrical Engineering and Electrophysics

Harry Schachter, Professor of Electrical Engineering

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

Maurice C. Newstein, Associate Professor of Electrophysics

Saul W. Rosenthal, Associate Professor of Electrophysics

Gerhard Schaefer, Associate Professor of Electrophysics

Leo M. Silber, Associate Professor of Electrophysics

Macro Guglielmi, Assistant Professor of Electrical Engineering

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

ENERGY PROGRAM

The energy program is an interdepartmental effort administered by the Division of Engineering. Recognizing the multifaceted, interdisciplinary nature of energy problems and studies, the program integrates resources at Polytechnic to provide cohesive curricula, in technological, economic, managerial, social, political and humanistic areas. Thus Polytechnic resources are applied to education for global, regional and local energy problems.

GRADUATE PROGRAMS IN ENERGY ENGINEERING AND POLICY

Interdisciplinary programs in energy engineering and policy lead to master's degrees in various engineering disciplines, operations research and management.

Common to all programs are two interdisciplinary courses:

ES 927	Energy Policy Issues	3 units
ES 928	Energy Resources and Conversion Technology	3 units

These courses are cross-listed in all participating departments and accepted as departmental courses. Students may enter the energy programs in two ways:
1. Admission through regular departments with admission and requirements determined by the departments for the M.S. degree.
2. Enrollment for a Certificate in Energy Policy and Engineering through participating departments.

DEGREE AND CERTIFICATE REQUIREMENTS

1. Departmental Master of Science Degree (e.g., master of science in mechanical engineering and certificate in energy policy and engineering).

a. Students must satisfy minimum requirements of master of science programs in the department.
b. Students must complete the two required interdepartmental courses, ES 927 and ES 928. Another interdepartmental energy-related course (e.g., ES 929 Selected Topics in Energy) may be substituted for ES 928 with permission of the energy program adviser.
c. Students must complete four additional courses from the list of energy electives. At least two courses must be from a single energy elective category; i.e., these four courses may not be from different categories. The energy elective categories are the broad functional classifications listed below under electives.

2. Certificates in Energy Policy and Engineering Upon completion of ES 927 and ES 928 and two energy electives from a single category, a certificate in energy policy and engineering will be awarded.

*Also energy elective

TYPICAL PROGRAMS

Chemical Engineering
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 821	Process Dynamics & Control*	3
CH 902	Guided Studies in Chemical Engineering	6
ES 927	Energy Policy Issues	3
ES 928	Energy Resources and Conversion Technology	3
Energy electives		6
		36

Civil Engineering
Required courses dependent upon C.E. option selected:		12-18
ES 927	Energy Policy Issues	3
ES 928	Energy Resources and Conversion Technology	3
Energy electives (4) courses		12
Additional energy electives or other electives must be approved by departmental graduate advisers.		6-0
		36

Electrical Engineering
EL 531	Probability	3
EL 610	Linear Systems	
	or	
EL 611	Signals, Systems and Transforms	3
EL 661	Intro. to Power System Engineering*	3
EL 662	Intro. to Power System Planning*	3
EL 665	Power System Stability I*	3
EL 666	Power System Stability II*	3
EL 671	Fields and Waves	3
ES 927	Energy Policy Issues	3
ES 928	Energy Resources and Conversion Technology	3

Recommended Electives:		
IE 600	Engineering Economy	
EL 621	Feedback Control I*	
EL 647	Power Electronics*	
EL 663	Electrical Transients in Power Systems*	9
EL 664	Relay Fault Protection*	
EL 568	Electric Drives I*	
EL 569	Electric Drives II*	
EL 961-2	Selected Topics in Power I, II and/or electives approved by departmental graduate adviser	
		36

Energy Management
ES 927	Energy Policy Issues	3

ENERGY

ES 928	Energy Resources and Conversion Technology	3

Electives: select two

MG 631	Theories of Complex Organizations*	
MG 640	Resource Economics*	
MG 664	Legal Environment of Business*	6
MG 865	Research, Development and Management of Innovation*	
MG 866	Technology Management and Policies	

Additional electives must be approved by management division graduate advisers.   <u>24</u>
          36

Industrial Engineering

IE 611	Statistical Quality Control*	3
IE 619	Production Planning and Controls	3
IE 628	Operations Research: Stochastic Models	3
Major electives		12
ES 927	Energy Policy Issues	3
ES 928	Energy Resources and Conversion Technology	3
Electives		<u>9</u>
		36

Management

MG 600	Management Processes	3
MG 601	Organizational Behavior	3
MG 602	Computers in Management	3
MG 603	Economic Environment of Management*‡	3
MG 604	Managerial Accounting‡	3
MG 605	Statistical Analyses‡	3
MG 606	Managerial Finance	3
MG 607	Marketing Management	3
ES 927	Energy Policy Issues	3
ES 928	Energy Resources and Conversion Technology	3
Energy electives		9

Additional electives must be approved by departmental graduate advisers.   <u>9</u>
          48

Aerospace Engineering or Mechanical Engineering
(Thermal fluids/energy option)

AM 701	Thermodynamics I*	3
AM 710	Convection	3
AM 740	Principles of Fluid Dynamics	3
AM 971-72	Seminar in Mechanical and Aerospace Engineering	0
Major area electives		12
ES 927	Energy Policy Issues	3
ES 928	Energy Resources and Conversion Technology	3
Energy electives		<u>9</u>
		36

Mechanical Engineering

(Mechanical analyses and design options)

AM 601-02	Stress Analysis I, II	6
AM 651-2	Advanced Dynamics I, II or	6
AM 653-54	Dynamics of Machines; Mechanical Vibrations	
AM 971-72	Seminar in Mechanical and Aerospace Engineering*	0
Major area electives		6
ES 927	Energy Policy Issues	3
ES 928	Energy Resources and Conversion Technology	3
Energy electives		<u>12</u>
		36

Metallurgy

MT 610	Thermodynamics of Metals and Alloys	3
MT 620	Plastic Deformation and Fracture	3
MT 640	Reactions in Solids	3
ES 927	Energy Policy Issues	3
ES 928	Energy Resources and Conversion Technology	3
Energy electives		12

Additional energy electives, electives approved by departmental graduate adviser, and project or thesis.   <u>9</u>
          36

Operations Research

IE 600	Engineering Economy	3
IE 631	Linear Programming*	3
IE 650	Queuing Systems I	3
Major electives		12
ES 927	Energy Policy Issues	3
ES 928	Energy Resources and Conversion Technology	3
Electives		<u>9</u>
		36

Transportation Planning and Engineering

TR 600	Characteristics of Transportation Demand	3
TR 601	Travel Demand Forecasting*	3
TR 629	Transportation Workshop	3
TR 630	Urban Planning Principles	3
TR 701	Traffic Engineering	3
TR 750	Transportation Economics and Finance	3
TR 830	Energy in the Transportation Sector‡	3
ES 927	Energy Policy Issues	3
ES 928	Energy Resources and Conversion Technology	3
Energy electives		<u>9</u>
		36

Transportation Management

MG 600	Management Process	3
MG 604	Managerial Accounting	3*
TR 600	Characteristics of Transportation Demand	3
TR 751	Transportation Financial Control	3

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*Also energy elective
‡ Suitable equivalent course is acceptable
‡ Suitable equivalent course is acceptable

TR 757	Transportation Management‡	3
ES 927	Energy Policy Issues	3
ES 928	Energy Resources and Conversion Technology	3
TR 966	Master's Project in Transportation Management	3
Departmental electives as selected		12
		36

ACCEPTABLE ENERGY ELECTIVES

Energy Conversion

AM 761	Energy Conversion	3
AM 763	Solar Thermal Engineering I	3
AM 764	Solar Thermal Engineering II	3
AM 769	Special Topics in Energy Conversion	3
CH 791	Electrochemical Engineering	3
EL 564	Electromechanical Power Conversion	3

Energy Transfer Processes

AM 711	Convective Heat Transfer	3
AM 712	Conductive Heat Transfer	3
AM 713	Radiative Heat Transfer	3
AM 715	Heat Transfer	3
AM 716	Reactor Heat Transfer	3
AM 717	High Performance Heat Exchangers	3
AM 718	Multi-phase Flows with Heat Transfer	3
CH 766	Process Heat Transfer	3

Environmental Impact of Energy Systems

AM 685	Noise and Acoustics I	3
AM 686	Noise and Acoustics II	3
AM 751/CE 763	Aerodynamics of the Urban Environment I	3
AM 752/CE 764	Aerodynamics of the Urban Environment II	3
CE 741	Analysis of Water Quality Systems	3
CE 747	Analysis of Stream and Estuary Systems	3
CE 752	Air Pollution	3
CE 758/CH 752	Air Pollution Engineering Control	3
TR 630	Urban Planning Principles	3

Fluid Energy Systems

AM 718	Multiphase Flows with Heat Transfer	3
AM 746	Fluid Dynamics of Rotating Machinery	3
AM 749	Magnetofluid Dynamics	3

Machinery

EL 668	Electric Drives I	3
EL 669	Electric Drives II	3
AM 746	Fluid Dynamics of Rotating Machinery	3

Management and Economics of Energy Systems

MG 603	Economic Environment of Management	3
MG 631	Organization Theory	3
MG 664	Management and the Legal System	3
MG 800	Policy Analysis and Planning	3
MG 866	Technology Management and Policy	3
IE 600	Engineering Economy	3
IE 620/MG 810	Project Planning and Control	3
SS 675	Technology Transfer to Developing Countries	3
IE 665	Microeconomic Models	3
MG 640	Resource Economics	3
MG 671	Business and Economic Forecasting	3
MG 672	Technological Forecasting	3
CH 611	Unit Processes of Chemical Technology	3
AM 765	Energy Conversion and Environmental Controls	3

Materials

MT 726	Metallurgy of Nuclear Reactor Materials	3
MT 652	Special Topics in Advanced Engineering Metallurgy II: Nondestructive Testing	3
MT 700	Welding Metallurgy	3
MT 715	Corrosion and Oxidation Mechanisms in Metals	3
CH 917	Introduction to Polymeric Materials I	3

Plasma and Controlled Fusion

EL 581	Introduction to Plasma Engineering	3
EL 667	Introduction to Thermonuclear Power	3

Power Plant Construction and Engineering

CE 625/AM 661	Structural Dynamics	3
CE 627	Dynamic Responses of Civil Engineering Structures	3
CE 711	Hydraulic Design of Structures	3
CE 890	Earthquake Engineering I	3
AM 605	Limit Analysis of Structures	3
AM 630	Design Methods for Power Plant Structures	3
AM 632/CE 632	Introduction to Piping Analysis	3
AM 634	Pressure Vessel Analysis	3

Safety, Reliability and Control of Energy Systems

AM 675	Mechanical Servomechanisms I	3
AM 676	Mechanical Servomechanisms II	3
CH 821	Process Dynamics and Control	3
EL 617/IE 685	System Reliability	3
EL 618/IE 686	Component Reliability	3
EL 621	Feedback Control I	3
EL 622	Feedback Control II	3
EL 647	Power Electronics	3
EL 661	Intro. to Power System Engineering	3
EL 663	Electrical Transients in Power Systems	3
EL 664	Relay Fault Protection	3

EL 665	Power System Stability I	3
EL 666	Power System Stability II	3
IE 611	Statistical Quality Control	3
IE 612	Advanced Quality Control	3
IE 765	Human Factors in Engineering Design	3
IE 775	Industrial Safety Engineering	3

System Organization

EL 662	Introduction to Power System Planning	3
EL 723	System Optimization Methods	3
IE 614	Modeling of Social Systems I	3
IE 621	Facility Layout and Design	3
IE 627	Operations Research Deterministic Models	3
IE 628	Operations Research Stochastic Models	3
IE 631	Linear Programming	3
IE 632	Nonlinear Programming	3
IE 634	Dynamic Programming	3
IE 680	System Simulation I	3
EL 723	System Optimization Methods	3

Thermodynamics, Combustion and Chemical Processes

AM 701	Thermodynamics I	3
AM 704	Aerothermochemistry	3
AM 705	Combustion I	3
AM 706	Combustion II	3
CH 771	Chemical Engineering Thermodynamics I	3
CE 770	Solid Waste Management	3

Transportation

TR 660	Urban Public Transportation	3

REQUIRED COURSES

Registration for these courses is restricted to graduate students enrolled in the energy program, except as permitted by the energy program adviser.

ES 927 Energy Policy Issues‡   2½:0:3
Review of economic and societal aspects of energy production and consumption; energy demands exhaustible energy resources; contemporary energy technologies and their problems; fossil fuel technologies; nuclear fission; technical efficiency; energy logistics. Alternative energy technologies — short, medium and long term prospects; energy R & D; societal perspectives. Policy analyses; energy policy frameworks.

ES 928 Energy Resources and‡
       Conversion Technologies   2½:0:3
Summary of present energy resources and global energy requirements. Twentieth-century advances in science and technology being applied or soon to be applied to United States energy economies. Attention to principles behind practical devices and to limitations imposed by fundamental laws of physics. Fossil fuel power generation; nuclear fission and fusion; solar, magneto-hydrodynamic, and thermal differential converters. Chemical and mechanical storage; new electrical distribution systems.

ES 929 Selected Topics in Energy*   2½:0:3
Topics of current interest: energy economics; energy resources; social impact of energy technologies. Available for credit in lieu of ES 928, when offered, as the second required course of the energy program.

PARTICIPATING FACULTY

STEERING COMMITTEE

Edward S. Cassedy, Jr., Professor of Electrical Engineering
Chair, Energy Program Steering Committee

Irving Cadoff, Professor of Physical and Engineering Metallurgy

Joachim I. Weindling, Professor of Operations Research and System Engineering

Anthony J. Weiner, Professor of Management

Paul R. Cardenas, Jr., Associate Professor of Civil and Environmental Engineering

Leonard I. Stiel, Associate Professor of Chemical Engineering

Romualdas Sviedrys, Associate Professor of Social Sciences

Richard S. Thorsen, Associate Professor of Mechanical and Aerospace Engineering

Richard E. Wener, Assistant Professor of Social Sciences

FACULTY PARTICIPANTS

Raphael Aronson, Professor of Nuclear Engineering and Physics

Martin H. Bloom, Institute Professor

Alvin S. Goodman, Professor of Civil and Environmental Engineering

Seymour Kaplan, Associate Professor of Operations Research

Enrico Levi, Professor of Electrical Engineering and Computer Science

Wheeler K. Mueller, Jr., Professor of Mechanical and Aerospace Engineering

Pasquale M. Sforza, Professor and Head of Mechanical and Aerospace Engineering

Richard A. Haddad, Associate Professor of Electrical Engineering and Computer Science

Melvyn Meer, Assistant Professor of Management

Alan H. Molof, Associate Professor of Civil and Environmental Engineering

Zivan Zabar, Associate Professor of Electrical Engineering and Computer Science

HUMANITIES AND COMMUNICATIONS

The Department of Humanities and Communications offers undergraduate degree programs with concentrations 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 programs and the undergraduate concentrations 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, religion, or modern languages—or to put together a combination of courses providing a coherent introduction to the humanities. Courses in public speaking and technical writing are especially practical for students preparing for careers in engineering or science. Advising booklets are available which list recommended sequences of courses in the humanities and social sciences. See Degree Requirements for further information.

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.

CONCENTRATIONS IN 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. They may specialize in print journalism, broadcast journalism, science journalism, technical writing or corporate communications. Generally they also fulfill the requirements of the contemporary liberal arts core curriculum outlined in that section of the catalog, pp. 95-97. 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	11
Science	12
Interdisciplinary courses	25
	57
Journalism and Technical Writing Courses	33
Electives	
Humanities electives	6
Social Sciences electives	6
Free electives	24
	36
Total credits required for graduation	126

CONCENTRATION IN 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

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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 00.

departmental adviser. Generally they also fulfill the requirements of the contemporary liberal arts core curriculum outlined in that section of the catalog, pp. 95-97. 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. 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	11
Science	12
Interdisciplinary courses	25
	57
Humanities Courses	39
Electives	
Social Sciences electives	6
Free electives	24
	30
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, page 95.

GRADUATE PROGRAMS

Specialized Journalism

The Department of Humanities and Communications offers Master of Science degrees 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 candidates. 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 financial developments and trends for both 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.

Trade-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.

Industrial Advertising and Public Relations

Industrial advertising and public relations work is concerned with the promotion of corporate products and the ability to sell such 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 trade magazines and technical journals, write speeches for engineering and management personnel and prepare corporate 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 sub-contract 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 trade-magazine articles for scientists and engineers.

REQUIREMENTS FOR MASTER OF SCIENCE DEGREES

M.S. degrees requires 36 units of graduate work. All students must take JW 605 (Libel Law and Press Ethics), JW 701 (Specialized Project in Professional Writing) and four courses (12 units) selected from the following list in consultation with advisers:

		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 510	Technical Writing about Digital Electronics I	3	
JW 520	Technical Writing about Digital Electronics II	3	
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

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 510	Technical Writing about Digital Electronics I	3
JW 520	Technical Writing about Digital Electronics II	3
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, 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 parrs 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

Please note: HU 101 or HU 103 is a prerequisite for all courses in this section except for HU 121, which has no prerequisite.

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 a 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 Techniques　　**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 layman. 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 121　Public Speaking　　　　　　　　　**3:0:3**
Training and practice in speaking before groups, preparation of materials for oral presentations, extemporaneous speaking, individual criticisms by instructor and fellow students. Special sections for English as a Second Language students also include work with pronunciation and vocabulary.

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.

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 101 or HU 103 is a prerequisite for all courses in this section.

(See also Literature in Translation (ML 311-313, ML 318-319) and Interdisciplinary Studies)

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 verse.

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

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

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. Parellel 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

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

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 course 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 101 or HU 103 is a prerequisite for courses in this section.

**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. One complete work by each of the following novelists: Hermann Hesse, Franz Kafka, Thomas Mann, Heinrich Boll, Gunther Grass, Hermann Kant. Course work directed toward understanding these men and their works within their own varying social and cultural settings. Students are encouraged to pursue interests in individual authors.

**ML 312 Currents of Unrest in 20th Century: French
Literature (in English translation)**   3:0:3
Study of modern French authors: Jean-Paul Sartre, Albert Camus, Samuel Beckett, Eugene Ionesco, Jean Genet. One complete work of each writer. Students are encouraged to pursue interests in individual authors.

**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. Students are encouraged to pursue interests in individual authors.

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 101 or HU 103 is a prerequisite for 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. Open to undergraduate and graduate students. 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.

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.

GRADUATE COURSES

SCIENCE, TECHNICAL AND FINANCIAL WRITING AND JOURNALISM

JW 510   Technical Writing about Digital Electronics I   2:0:3
Introduction to digital circuits; symbols, truth tables, Boolean Equations of logic elements. Detailed functional discussions of the application of logic elements in such functional combinations as adders, comparators, decoders, and signal controllers.

JW 520   Technical Writing about Digital Electronics II   2½:0:3
Development of an understanding of the practical application of logic gates and flip-flops. Sequential circuits such as up counter, down counters, shift registers, and parallel to serial converters. Students learn to recognize circuits, develop timing diagrams, and write functional descriptions.

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. Some sections also provide instruction in writing correct English.

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 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 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 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.

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 offerd 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

ADJUNCT FACULTY

Barbara Bartholomew, Adjunct Instructor of
Communications
B.A., San Diego State University; M.S., Polytechnic
Institute of New York
(Specialized Journalism)

Edward Bell, Adjunct Instructor of Communications
B.A., City College, City University of New York

Jerry E. Bishop, Adjunct Instructor of Communications
B.A., University of Texas

Gerard Cardillo, Adjunct Instructor of Communications

Allen M. Cobrin, Adjunct Instructor of Communications
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Columbia University

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Ph.D., Columbia University

Manning Dandridge, III, Adjunct Instructor of English
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University

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Humanities and Communications
M.A., M.F.A., Columbia University

Robert L. Guenther, Adjunct Instructor of
Communications
B. Journalism, University of Missouri

Eric Jay, Adjunct Instructor of English
B.A., Amherst College

Doann Houghton-Alico, Adjunct Instructor of
Communications
B.A., Cedar Crest College

Eric Katz, Adjunct Assistant Professor of Philosophy
B.A., Yale University; M.A., Ph.D., Boston University

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State University of New York at Stony Brook

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B.A., Hunter College; M.A., University of Arizona; M.S.,
Polytechnic University

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University of Massachusetts

Dolores Massari, Adjunct Instructor of Communications
B.S., Fordham University

Isobel Mendelson, Adjunct Instructor of English
B.A., Syracuse University

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B.A., State University of New York at Geneseo; M.A.,
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Alan M. Nedler, Adjunct Instructor of English
B.A., Queens College, City University of New York; M.A.T.,
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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

Bonnie J. Phillips, Adjunct Instructor of English
B.A., Calvin College; M.A., Boston College

Larry Reibstein, Adjunct Instructor of Communications
M.A., Ohio State University

Colleen M. Sandford, Adjunct Assistant Professor of
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B.A., Washburn University; M.A., Ph.D., University of
Illinois

Valerie Sayers, Adjunct Instructor of English
B.A., Fordham University; M.F.A., Columbia University

Wolfgang Schirmacher, Visiting Adjunct Assistant 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

Kathleen R. Slowik, Adjunct Instructor of English
B.A., Utica College of Syracuse University; M.A., Columbia
University

David Soracchi, Adjunct Instructor of English
B.A., St. John's University; M.A., San Francisco State
University

HUMANITIES AND COMMUNICATIONS

Walter Stiller, Adjunct Instructor of English
M. Phil., City University of New York

James E. Tourtelott, Jr., Adjunct Assistant Professor of English
B.A., St. John's College (Maryland); M.A., Ph.D., State University of New York at Stony Brook

Roberta L. Ventsias, Adjunct Instructor of English
B.A., M.F.A., Brooklyn College, City University of New York

Michael Waldholz, Adjunct Instructor of Communications
M.A.T., University of Pittsburgh

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 such as remote sensing, computer graphics, and digital imaging.

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 1982, offers a graduate program in these disciplines which provides the intellectual foundation for all imaging technologies.

Drawing on faculty from five departments, 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. Curriculum may be pursued either part-time or full-time, with normal completion in 3 years or 1½ years respectively. All courses are open and may be taken under non-degree status. Candidates for the Masters 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	1½
IM 702	Image Processing Laboratory	1½
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 Masters Project with his adviser. He also registers at that time for two elective courses to support that project.

No.	Electives (Two from list) Course Title	Units
IM 730	Medical Imaging	3
IM 731	Pattern Recognition, Principles and Methods	3
CS 651	Computer Graphics and Imaging Processing	3
EL 635	Principles of Communication Networks	3
MT 705	Semiconductor Technology	3
EL 658	Fiber Optic Communications	3
IM 740, IM 741	Special Topics in Imaging	3

No.	MS Project Course Title	Units
IM 990	Project in Imaging Science	6
	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 6 credits. All other courses, with the exception of IM 701 and 702, are 3 credit courses as shown in the course descriptions. 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) included. Prerequisite: IM 602.

IM 701   Image Analyses   1½:0:1½
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 605.

IM 702   Image Processing Laboratory   1½:0:1½
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. Prerequisite: IM 603.

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. Prerequisites: IM 603 and 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. Prerequisites: IM 603 and 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, IM 741   Special Topics in Imaging   2½:0:3
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, microlithography, radiation-sensitive materials, and photogrammetry.

IM 990, 991   Project in Imaging Science   5:0:6
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, Course Director, Professor of Chemistry, Deputy Director, Institute of Imaging Sciences
Dr. Ing. (Prague); D. Sc. (London); formerly Head of Photochemistry Laboratory, Kodak, England; 1981 Henderson Medal of Royal Photographic Society

Isreal Abramov, Professor of Psychology, Brooklyn College of CUNY; Professor of Psychophysics, Rockefeller University.
B.A., University College, London; Ph.D., Indiana University.

Stephen Arnold, professor of Physics
B.S., University of Toledo; Ph.D., City University of New York; Fellow, Alfred P. Sloan Foundation

Leo Beiser, Consultant in Laser Technology
B.S. and M.S. (Physics), Hofstra University.
*Formerly Director of Dennis Gabor Laboratory of CBS;
Governor of Society of Photo-Optical Instrumentation
Engineers*

Leonard Bergstein, Professor of Electro-Optical Sciences.
Ph.D., Polytechnic Institute of New York

George R. Bird, Professor of Chemistry, Rutgers University.
B.A., M.A. and Ph.D., Harvard University.
*Formerly head of Physcial Chemistry Laboratory, Polaroid Corporation
Spectroscopy; fundamental photographic science*

J. Warren Blaker, Consultant in Optics.
Ph.D., Massachusetts Institute of Technology.
Formerly Head of Physics Department, Vassar College.

Michael Bruno, Founder and first president of the Technical Association of Graphic Arts (TAGA); 1983 Gold Medal of Institute of Printing (England).

Irving Cadoff, Professor of Metallurgy.
B.M.E., City College of New York; M.M.E., D. Eng. Sc.,
New York University.

Patrick T. Cahill, Professor of Physics, Professor of
Radiology, Cornell University Medical School.
B.S. and M.S., University of New Hampshire; Ph.D.,
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William J. Heacock, Senior Consulting Engineer, Fairchild
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B.E.E., Pratt Institute; M.E.E., Polytechnic Institute of New
York

Irving Hirschberg, Director Technology Developments,
Fairchild Weston Systems.
B.E.E., Cornell University; M.S.E.E., Columbia University

Aaron Kershenbaum, Associate Professor of Computer
Science.
B.S. and M.S., Polytechnic Institute of Brooklyn; Ph.D.,
Polytechnic Institute of New York

Leonard Shaw, Professor and Head of Dept. of Electrical
Engineering.
B.S., University of Pennsylvania; M.S. and Ph.D., Stanford
University

Rodney Shaw, Physicist, Eastman Kodak Company.
Ph.D., Cambridge University; Journal Award and 1976
Charles E. Ives Award of The Society of Photographic
Scientists and Engineers (SPSE)

Richard Thorsen, Associate Professor of Mechanical and
Aerospace Engineering.
B.M.E., City College of New York; M.M.E. and Ph.D., New
York University

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
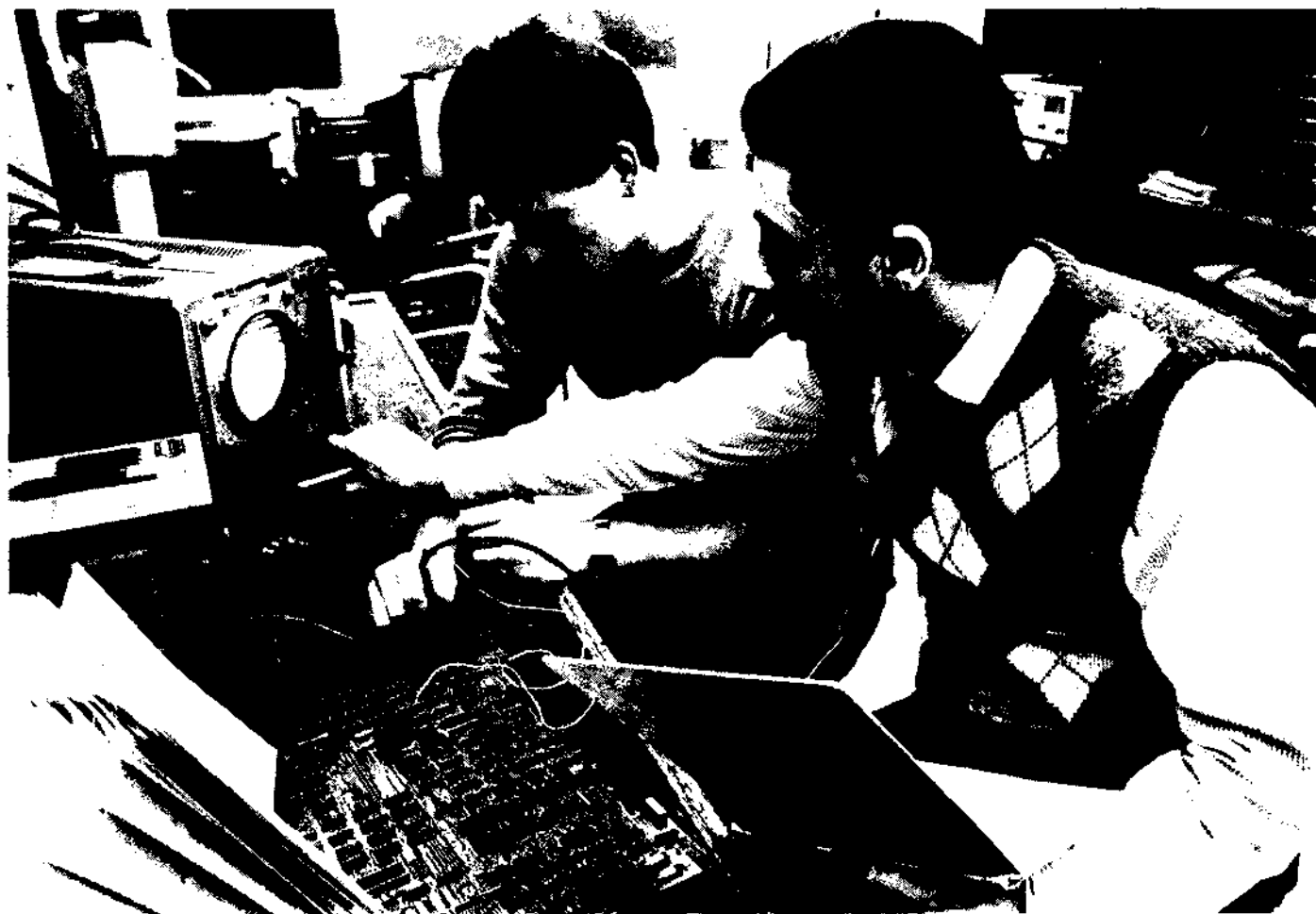
INDUSTRIAL ENGINEERING

The Department of Transportation 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."

Industrial engineers are asked 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.

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. 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 APPLE and IBM-PC 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 recognized 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 other engineers work primarily toward the creation of better products, industrial engineers are 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 all endeavors.

Senior Project

An important part of the program is the cap-stone 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 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.

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 101-103, CM 101-102, CM 111-112, CS 100, HU 101, HU 200, SS 104, SS 189, SS 251-252, plus 14 credits of acceptable courses, the student can complete the requirements shown on page .

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 educational needs, provided they do not violate prerequisites and Polytechnic time limits.

See footnotes on following page.

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[1], MA 102[1], MA 103[1], MA 104[1], MA 223, MA 224	20
Science:	CM 101, CM 102, CM 111, CM 112, CS 100[1], PH 101, PH 102, PH 103	18
Humanities:	HU 101, HU 200[1], SS 104[1], SS 189, SS 251, SS 252	18
Physical Ed:	PE 101, PE 102, PE 103, PE 104	0
Engineering:	AM 101, AM 115, CE 202, EE 370, EE 374, MT 301	16
Management:	MG 304	3
Major:	IE 254, 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]	24
	Total	136

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.

In particular, the actual number of elective and total credits in any given semester will vary by 1 or 2 credits because most electives are 3 credits.

Freshman Year

First Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
CS	100	Intro. to Computer Progmg.[1]	2	0	2
HU	101	Writing & the Humanities I	3	0	3
MA	101	Calculus I[1]	4	0	4
PH	101	Introductory Physics I	3	0	3
SS	251	Micro-Economics	3	0	3
PE	101	Physical Education I[3]	0	2	0
					15

Second Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
AM	101	Graphics	1	3	2
HU	200	Writing & the Humanities II[1]	3	0	3
MA	102	Calculus II[1]	4	0	4
PH	102	Introductory Physics II	3½	1½	4
SS	252	Macro-Economics	3	0	3
PE	102	Physical Education II[3]	0	2	0
					16

Sophomore Year

AM	116	Engineering Mechanics I	2	0	2
CM	101	General Chemistry I	2½	0	2½
CM	111	General Chemistry Lab. I	0	1½	½
IE	254	Intro. to Industrial Engineering	3	0	3
MA	104	Appl. Differential Equ.[1]	3	0	3
PH	103	Introductory Physics III	2½	1½	3
SS	104	Contemporary World History	3	0	3
PE	103	Physical Education III[3]	0	2	0
					17

AM	117	Engineering Mechanics II	2	0	2
CE	202	Mechanics of Materials	3	0	3
CM	102	General Chemistry II	2½	1½	2½
CM	112	General Chemistry Lab. II	0	1½	½
EE	370	Princ. of Electrical Engrg.	3	0	3
EE	374	Instrumentation Laboratory	0	3	1
MA	103	Calculus III[1]	3	0	3
MG	304	Accounting Fundamentals	3	0	3
PE	104	Physical Education IV[3]	0	2	0
		Elective[2]			3
					18

Junior Year

IE	306	Work Design & Measurement	2½	1½	3
IE	327	Operations Research I	3	0	3
IE	380	System Simulation	3	0	3
MA	223	Introduction to Probability	3	0	3
MT	301	Mech. Behavior of Materials	2	3	3
SS	189	Introduction to Psychology	3	0	3
					18

IE	300	Engineering Economy	3	0	3
IE	328	Operations Research II	3	0	3
IE	340	Manufacturing Processes	3	0	3
IE	365	Hum. Factors in Engrg. Design	2½	1½	3
MA	224	Intro. to Math Statistics	3	0	3
		Elective[2]			9
					17

Senior Year

IE	311	Statistical Quality Control	3	0	3
IE	319	Production Planning & Control	3	0	3
IE	389	Project Laboratory	1	3	2
		Electives[2]			9
					17

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

[1]Students may substitute IS 140-IS 141 for HU 200, SS 104. Students with strong mathematical background may substitute MA 111-MA 114 for MA 101-MA 104. Students may substitute CS 112 for CS 100; the extra credit may be counted as technical elective. Students may substitute AM 115 for AM 116-117.

[2]The 24 credits of electives are to be distributed as follows. All require adviser's approval.
  6 credits of industrial engineering courses
  3 credits of engineering science selected from courses
    below (excess credits count as technical electives):
    AM 201 Thermodynamics
    AM 252 Dynamic System Response I
    CE 222 Fluid Mechanics

    CS 236 Switching Circuit & Digital Syst.
    MT 407 Transport Methods in Metallurgy
    NU 301 Intro. to Nuclear Engineering I
    MT 407 Transport Methods in Metallurgy
  3 credits of technical electives—engineering or science
  6 credits of humanities and social science
  6 credits of free electives

[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 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		
No.		Subject	Cl.	Lab.	Cr.
AM	116	Engineering Mechanics I	2	0	2
IE	254	Intro. to Industrial Engineering	3	0	3
IE	306	Work Design & Measurement	2½	1½	3
IE	327	Operations Research I	3	0	3
MT	301	Mech. Behavior of Materials	2	3	3
MA	223	Introduction to Probability.	3	0	3
		Elective²			1
					18

Second Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
AM	117	Engineering Mechanics II	2	0	2
CE	202	Mechanics of Materials	3	0	3
IE	300	Engineering Economy	3	0	3
IE	328	Operations Research II	3	0	3
MA	224	Intro. to Math. Statistics	3	0	3
MG	304	Accounting Fundamentals	3	0	3
		Electives²			1
					18

Senior Year

			Cl.	Lab.	Cr.
IE	311	Statistical Quality Control	3	0	3
IE	319	Production Planning & Control	3	0	3
IE	389	Project Laboratory I	1	3	2
IE	380	System Simulation	3	0	3
		Electives²			7
					18

			Cl.	Lab.	Cr.
EE	370	Princ. of Electrical Engrg.	3	0	3
EE	374	Instrumentation Laboratory	0	3	1
AM	101	Graphics	1	3	2
IE	321	Facility Layout & Location	3	0	3
IE	340	Manufacturing Processes	3	0	3
IE	365	Human Factors in Engrg. Des.	2½	1½	3
IE	390	Project Laboratory II	1	3	2
		Electives²			1
					18

Total credits required for graduation: 136

See four-year program for notes.

MANUFACTURING ENGINEERING CONCENTRATION

In its beginning, the industrial engineering profession was devoted largely to manufacturing operations. Over the years, industrial engineers have been called upon to enlarge their expertise to include much wider ranges of applications, from hospital management to banking information systems. The consequent broadening of industrial engineering education led necessarily to a relative de-emphasis of manufacturing engineering.

But today more than ever before, manufacturing enterprises must operate with heightened efficiency and precision to compete in the international market. In helping American industry, Polytechnic has developed a concentration to emphasize manufacturing in its industrial engineering program.

This 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 24 credits of electives are satisfied as follows:

6 credits industrial engineering courses
    IE 342 Robotics Applications (Term 8)
    IE XXX Elective (Term 8)
3 credits engineering science
    MT 407 Transport Methods in Metallurgy (Term 8)
3 credits technical elective
    MT 417 Welding Metallurgy (Term 7)

6 credits humanities and social science
    Selected in consultation with adviser (Term 8)
6 credits free elective
    AM 331 Computational Medthods in Computer-Aided Design (Term 6)
    AM 332 Computer Graphics in CAD (Term 7)

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, are heavily indebted to 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 projects for the senior IE 389-390 laboratory courses.

All courses required for the standard degree are also required in the Transportation concentration. The 24 credits of electives are satisfied as follows:
6 credits of industrial engineering courses
    IE 350 Logistics
    IE XXX Elective
3 credits engineering science
    AM 201, AM 252, CE 222, CS 236, MT 407, or NU 301
3 credits technical elective
    TR 361 Transportation Demand Models
6 credits humanities and social science

Selected in consultation with adviser
6 credits of free electives
  TR 360 Traffic Planning and Operations
  TR 362 Public Transportation

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 information science, system simulation, quality control, experimental design, man-machine systems, social systems dynamics, 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 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 or PL/I, is assumed. Students without this knowledge must take IE 531 without credit.

Applications should be made to the department with industrial engineering 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 Degrees of Master of Science in Industrial Engineering

A. Basic Required Courses[1]

Many students are 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 505, and MG 630.
  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   9 units
  IE 611 Statistical Quality Control
  IE 619 Production Planning & Control
  IE 621 Facility Planning & Design

C. Major Electives: (Select four courses[2])   12 units
  IE 614 Modeling of Social Systems
  IE 680 System Simulation
  IE 846 Urban Systems Analysis

  IE 765 Human Factors in Engrg. Design
  IE 775 Industrial Safety Engineering

  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

[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 groups B and C, or other graduate courses in this or other disciplines.
[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.

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)
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. An examination is required in one foreign language ordinarily French, German or Russian.

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 students have taken the equivalent of any required courses as undergraduates,or more than one as graduate students, 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 System Simulation I
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, with Computer Applications 3:0:3
Basic principles of industrial and manufacturing engineering. Introduction to work design, manufacturing processes, inventories and modeling in industrial engineering. Extensive use of spreadsheets, data bases and IE packages on PCs. Use of PC as word processor for reports.

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. 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.

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 324 Computers in Operational Analysis* 1:3:2
Cases involving problems in forecasting, inventory, scheduling, line balancing, maintenance, queuing, Markov chains, simulation, linear and integer programming, and materials requirement planning. Students may write their own computer programs or use existing packages to analyze the cases and design improved alternatives. Use of UNIX is encouraged. Written reports required. Prerequisites: IE 327 and IE 328.

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.

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 3:0:3
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: MT 301.
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, IE 328 and senior standing.

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 377   Manufacturing Improvement Curves*   3:0:3
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 turnover cost, inventory control, price policy and production schedules. Prerequisite: IE 306.

IE 380   System Simulation   3:0:3
Modeling and simulation of discrete stochastic systems. Generation of psuedo-random numbers, variates from discrete, continuous, theoretical and empirical distributions. Extensive study of SIMSCRIPT, introduction to other languages. Students program, code and run several simulation models. Prerequisite: knowledge of computer programming and junior standing.

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 prerequisites 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 specialized 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 internship. Arrangements to be made prior to beginning internship experience. Prerequisite: completion of junior year and departmental approval.

**IE 399   Senior Honors Work in
Industrial Engineering and
Operations Research**   credit arranged
Independent work undertaken by qualified honors students in industrial engineering or operations research under faculty guidance. Prerequisites: senior standing and adviser's approval.

GRADUATE COURSES

IE 531   Introduction to Digital Computing*   2½:0:3
First course in computing, concentrating on analysis of problems for computer solution. Organization and characteristics of computers. Structure and properties of algorithms and programs. Flow charting. Debugging and verification, documentation. Number systems, data representation, numerical error analysis. FORTRAN IV language used. (Not open to students who have taken CS 100 or equivalent.)
Also listed under CS 531

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, 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. (Not open to students who have take 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 measurement, including time study, work sampling and standard data systems. Laboratory sessions in methods analysis, rating, work allowances 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 analysis. 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 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 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 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. (Not open to students who have taken IE 319.) Prerequisite: IE 627 or IE 631.

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IE 620 Project Planning and Control   2½:0:3
Network-planning techniques for project management and re-source 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. (Not open to students who have taken IE 320.) Prerequisite: knowledge of computer programming.
Also listed under MG 810.

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 existing and new layout design. Other topics include computerized layout planning, materials handling systems, evaluation and improvement 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 624 Computer-Augmented Case Studies
in Management Science***   2½:0:3
Cases involving problems in forecasting, inventory, scheduling, line balancing, maintenance, queuing, Markov chains, simulation, linear and integer programming, and materials requirement planning. Students may write their own computer programs or use existing packages to analyze the cases and design improved alternatives. Use of UNIX is encouraged. Written reports required. (Not open to students who have taken IE 324.) Prerequisites: IE 627 and IE 628 and either IE 606 or permission of instructor.

**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 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. 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.

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, over-flow traffic, alternate routing, feedback, priorities, control. Formulation of standards based on cost-benefit view-point. Prerequisite: IE 650 or MA 815.

IE 665 Microeconomic Models*   2½:0:3
Utility theory and decision-making under risk and uncertainty. Demand analysis and pricing in classical theory of the firm under various economic environments. Production functions. Linear programming and the firm. Analysis of short-run costs. Capital investment and analysis under capital rationing: deterministic and stochastic models. Prerequisites: IE 627 or MG 630 or permission of instructor, and MA 561.

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 673   Time Series: Forecasting and Control*   2½:0:3
Strict and weak stationarity. Autocorrelation and correlogram. Moving average (MA), autoregressive (AR) and mixed ARIMA processes. Nonstationarity and integrated ARIMA processes. Box-Jenkins' approaches to problems of identification, estimation, diagnostic checking and forecasting. Spectral theory and the periodogram. Adaptive methods. Feedback and feed forward controls. Applications to management and planning. Prerequisite: IE 608.

IE 680   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, 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.

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 616

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: IE 601 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 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 768   Case Studies in Electronics Manufacturing   2:0:3
Industrial experts will be invited to lecture on the actual experience in design, design modification, facility layout and "clean" design, yield and product respecification in the electronic device manufacturing industries. Topics to include: Evolution and Accomplishments of VLSI Yield Management; Metrology in Mask Manufacturing; High Speed Lithography Methods and Submicron Structures; Semiconductor Final Test Logistics and Product Dispositioning Systems; Quality and Reliability Assurance Systems; Identification and Evaluation of Failure Mechanism; and Evolution of Package Design.

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.

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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, imcomplete 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.

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, Professor of Transportation and System Engineering: Head, Department of Transportation 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.

Edmund J. Cantilli, 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., Cal. (Traffic))
Transportation and industrial safety, environmental impacts of transportation urban planning, pedestrian, bicycle planning, and human factors.

John Chu, Professor of Operations Research and Management Science
B.S., University of Chekiang (China); M.S., Ph.D., Iowa State University
Managerial decisions, behavioral approach, national and international affairs.

John C. Falcocchio, Professor of Transportation Engineering
B.S.C.E., M.S., Ph.D., Polytechnic Institute of Brooklyn; Professional Engineer (N.Y., Pa., Cal. (Traffic))
Transportation planning public transportation, transportation of disadvantaged groups.

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

John H. K. Kao, Professor of Industrial Engineering and Operations Research
B.S., National Central University (China); M.S., Eng.Sc.D., Columbia University
Probability and statistics, quality control and reliability, scientific computing, electronic data processing

Joachim I. Weindling, 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

Philip A. Habib, Associate Professor of Transportation Engineering Administrative Officer
B.E., CCNY, M.S., Ph.D., Polytechnic Institute Brooklyn, Professional Engineer (N.Y.)
Goods movement, highway engineering, transportation planning, terminal planning, ferry planning.

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

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

ADJUNCT FACULTY

Maureen Dolan, Adjunct Lecturer
B.A., Molloy College; M.S., Stevens Institute of Technology; M.S., Polytechnic Institute of New York

Chaim Steinberger, Adjunct Assistant Professor
M.S., Polytechnic Institute of New York

INFORMATION MANAGEMENT

Information management deals with information needed by people for decision making. It includes, but is not limited to, electronic data processing (EDP), data base management (DBM) and management information systems (MIS). Computers are widely used to provide executives with timely facts needed to make decisions.

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 trains information management professionals who, after graduation, are usually assigned individual or team tasks, which they are able to complete independently and with minimal supervision.

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 203, 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
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 Courses of Studies for the
Bachelor of Science Degrees in Information Management

Freshman Year

First Semester No.		Subject	Cl.	Lab.	Cr.
HU	101	Writing and the Humanities	3	0	3
LA	110	Technol. & Soc. in Hist. 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
PE	101	Phys. Ed. I	0	2	0
					16

Second Semester 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

			Cl.	Lab.	Cr.
CS	203	Comp. Prog. II	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

			Cl.	Lab.	Cr.
CS	204	Data Structures	3	0	3
CS	211	COBOL Programming	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

			Cl.	Lab.	Cr.
CS	308	Intro. to Database	3	0	3
IE	320	Project Plan. & Cont.	3	0	3
LA	142	Machines: Ext. of Man	3	0	3
MG	300	Management Process	3	0	3
		Elective			3
					15

			Cl.	Lab.	Cr.
IE	300	Engineering Economy	3	0	3
IE	314	Modeling of Soc. Syst.	3	0	3
LA	143	Info., Comm. & Society	3	0	3
MA	231	Statistical Methods	3	0	3
		Electives			6
					18

Senior Year

			Cl.	Lab.	Cr.
IE	380	System Simulation	3	0	3
LA	150	Making of Connect.	3	0	3
MG	301	Organizational Behav.	3	0	3
		Electives			6
					15

			Cl.	Lab.	Cr.
MG	316	Com. Data Proc. Des.	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

The program is administered by the Division of Management. The faculties of industrial engineering, operations research and management, which play major roles in Information Management, are listed below.

Melvin L. Meer, Assistant Professor of Management

John T. Chu, Professor of Operations Research and Management Science

Norbert Hauser, Professor Industrial Engineering and Management Science

Walter Helly, Professor of Operations Research

John H.K. Kao, Professor of Industrial Engineering and Operations Research

A. George Schillinger, Professor of Management, Chairman, Management Division

Joachim I. Weindling, Professor of Operations Research and Systems Engineering

Anthony J. Wiener, Professor of Management

Herman Grau, Associate Professor of Industrial Engineering

Seymour Kaplan, Associate Professor of Operations Research and Management Science

Harold G. Kaufman, Associate Professor of Management

Ravinder Nanda, Associate Professor of Industrial Engineering and Operations Management, Co-Director of Operations Management Program

Byron L. David, Instructor of Management

Vincent K. Omachonu, Instructor of Industrial Engineering and Operations Management

Madhuri Kadiyala, Academic Associate, Management

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

Program Aims

Engineers and scientists increasingly find themselves drawn into problem areas requiring interactions with public policy planners. Similarly, public administrators find themselves increasingly confronted with problems of substantial technical impact. The joint program between New York University and Polytechnic (developed under National Science Foundation sponsorship) leads simultaneously to the degrees of master of science and master of public administration, and are designed to provide ideal solutions for these overlapping areas.

Cooperating Science and Engineering Programs at Polytechnic

The M.P.A. degree is awarded by New York University upon successful completion of the program. The M.S. degree is awarded simultaneously by Polytechnic University in any of the following programs:

Aeronautics and Astronautics
Applied Mechanics
Bioengineering
Chemical Engineering
Chemistry
Civil Engineering
Electrical Engineering
Industrial Engineering
Mathematics
Mechanical Engineering
Metallurgical Engineering
Operations Research
Physics
Systems Engineering
Transportation Planning

Program Eligibility and Duration

The Program is open to qualified students with acceptable undergraduate backgrounds in mathematics, science or engineering; some departments accept students from quantitatively-oriented social science programs. Students must be admitted through one of the cooperating departments at Polytechnic University for one of the M.S. programs, as well as through the Graduate School of Public Administration of New York University. The joint program involves two years of full-time study or equivalent part-time study. The joint program provides for significant time saving compared with sequential study for two master's degrees.

It is assumed that students have undergraduate science or engineering backgrounds which are essentially equivalent to Polytechnic degrees. Students with deficiencies in undergraduate preparation may be required to take additional credits for completion of degrees. Students are expected to be familiar with elementary digital computational procedures and with a programming language such as FORTRAN or PL/1. Students without these backgrounds should take IE 601 (Introduction to Digital Computing) or CS 530 (Introduction to Computer Science).

Joint Program Requirements

The following requirements must be met by all students in the program. The minimum of 60 credits is divided into six groups:

1. Departmental Engineering or Science Courses
(24 credits). The specific required courses and suggested electives for each of the cooperating engineering and science programs conform to those shown in their respective sections of this catalog. Brochures summarizing them are available.

2. Courses in Mathematical Methods and Statistics
(6 credits). Two courses in mathematical methods, of which one must be in statistical methods, unless an undergraduate or graduate course in that subject has been previously taken.

*3. Required Courses in Public Administration
(12 credits). All students take the following courses:

P11.1013 American Public Administration and its Political Environment
P11.1016 Organization Theories in a Public Context
P11.1018 Microeconomics for Public Management, Planning and Policy Analysis

*4. Elective Courses in Public Administration
(12 credits). Three courses, usually in accordance with the suggestions shown by the Polytechnic program.

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5. Project
(6 credits). In the following course description, the XX is replaced by the initials of the Polytechnic department:

XX 935 Engineering/Science Project
Related to Public Administration   each 3 units
Students work in groups of two to four on projects relevant to public policy and/or administration, selected in consultation with the faculty advisers from Polytechnic and New York University Graduate School of Public Administration, who jointly supervise the project. Two semesters are required of all students during the second half of the joint M.S./M.P.A. program. A third term may be approved by the advisers. Prerequisite: completion of at least 27 credits in the joint program.

6. Seminar
(no credit). Joint seminars including guest speakers covering technical and scientific problems related to public policies. Participation will be required of all students in the program.

Project Topics — Actual topics will be determined by students and their advisers.

Admission — Applications for admission to the combined program are available from program coordinators. Applicants should complete the application forms for Polytechnic — clearly indicating the desired Polytechnic program — and that for NYU/GPA, and send them to the program coordinators enclosing separate checks for the two application fees; only one set of transcripts and references is required. Admission to both schools is then coordinated through the Polytechnic office.

Financial Aid — Limited financial aid may be available to full-time students entering the program. Requests for financial aid in terms of assistantships should be indicated on application forms.

Registration — Students formally register for their first year at Polytechnic and their second year at NYU/GPA. Students may take courses at both institutions during both years of the program. A minimum of 27 credits must be completed at Polytechnic and a minimum of 24 credits at NYU/GPA within the total minimum of 60 credits for both master's degrees. At the time of the first registration, students will be assigned to Polytechnic advisers with whom overall program should be planned. In addition, students will be assigned an adviser from NYU/GPA by the liaison office of that school.

Further Information — Additional information may be found in the NYU/GPA catalog. Brochures and application forms are available from the program director:
Professor Joachim I. Weindling
POLY/NYU Program Director
Polytechnic University
333 Jay Street
Brooklyn, NY 11201

COOPERATIVE (3-2) ENGINEERING PLAN

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. The 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 PLAN

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.

*Note: Any changes in the requirements by New York University for the M.P.A. degree may have the effect of increasing the number of credits required for groups (3) and (4) above, and therefore, the number of credits required for the joint M.S./M.P.A. program. Contact the program director for the latest information.

(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:

Professor L. Mendelsohn, Dept. of Physics
Brooklyn College (CUNY)
Bedford Avenue & Avenue H
Brooklyn, New York 11210
Phone: (718) 780-5418

POLYTECHNIC/MARIST JOINT ENGINEERING PROGRAM

Polytechnic University and Marist College conduct a joint program on the Marist campus in Poughkeepsie, New York, for the purpose of providing undergraduate education in electrical and computer engineering for residents of the mid-Hudson valley. The course offerings are selected from the Polytechnic electrical and computer engineering curricula (as described elsewhere in this catalog). Marist College provides the instruction for the non-engineering courses (mathematics, physics, chemistry, humanities, social sciences); Polytechnic faculty teach all of the engineering courses.

For further information call or write:
Professor Sidney Shamis
Engineering Program
Marist College
Poughkeepsie, New York 12601
Phone: (914) 471-3240 ext. 569

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's representative at the Polytechnic Long Island Campus.

MANAGEMENT

Among the programs offered by the Division of Management are an undergraduate bachelor of science degree in information management*, and four graduate degrees: master of science in management**, master of science in organizational behavior, master of science in telecommunications management****, and master of science in operations management***. The graduate degrees are primarily evening programs offered to both full-time and part-time students. These graduate programs are open to any students who have earned bachelors' degrees with B averages from accredited schools and have satisfactory scores on the Graduate Management Admission Test (GMAT). Students who show potential for advanced studies but have undergraduate averages below B, or have not yet taken the GMAT, may be admitted as Special Students at registration for any semester; satisfactory performance at Polytechnic will permit later application for degree status.

In addition to the programs listed below, students may be interested in University offerings in Industrial Engineering and Operations Research. These programs are listed elsewhere in this catalog.

MASTER OF SCIENCE PROGRAMS IN MANAGEMENT

The Program — This 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. In contrast to many M.B.A. programs the M.S.M. program emphasizes *management* rather than staff skills in a choice of 9 concentrations:
* Construction Management
* Economics and Finance
* Human Resources Management
* Information Management
* Management and Administration
* Management Science
* Public Policy
* Technology Management
* Transportation Management

These management skills can be applied to a broad range of professional settings in the private as well as the public sectors; in labor-intensive as well as in capital-intensive industries; in production-oriented as well as in service-oriented activities; and in low-technology as well as in high-technology environments. The program emphasizes pragmatic approaches to management and is intended to train professional managers who can function effectively in complex managerial systems, especially those in which technology plays significant roles.

Admission — In addition to holding accredited bachelors degrees, all students must take the Graduate Management Admission Test (GMAT) or an acceptable equivalent test. Students who have not taken the test can be admitted as provisional students and are required to take it before completion of their second semester in order to be admitted as degree candidates.

Degree Requirements — The M.S.M. requires completion of 12 courses, or 36 units,† as descibed below, with a minimum of a B average. †Students who are less well-prepared may be required to take up to 4 additional courses, or 12 units, as described in the next paragraph. Transfer credits may be granted of 9 units 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

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*See Section "Information Management"
**Masters of science in management (MSM) are recognized, along with masters of business administration (MBA), by the Graduate Management Admission Council as graduate professional management degrees. Most M.S.M. programs have developed links to strong engineering programs, and are frequently taken by working engineers and scientists on part-time, employee-sponsored bases during evenings and on Saturdays. Many M.B.A. programs enlist liberal arts graduates for two-year full-time day programs, but there are many important exceptions to these patterns. Polytechnic M.S.M. classes include graduates from all fields of concentration.
***See Section "Operations Management"
****See Section "Telecommunications Management"

of four 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 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.

Information Management
Select four:
MG 626 Human Resources Information Systems
MG 654 Economics of Information Systems
MG 716 Commercial Data Processing Systems and Design
MG 736 Management Information Systems
MG 820 Project Management
CS 603 Information Structures and Algorithms
CS 681 Information Privacy and Security

Construction Management
Select four:
MG 631 Organizational Theories
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

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

Management and Administration
Required:
MG 630 Operations Management

Select three:
MG 612 Human Resources Management
MG 624 Organization Development
MG 633 Research Methods
MG 664 Management and the Legal System
MG 700 New Enterprise and Small Business Mgmt.
MG 705 Managerial Planning Process
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 810 Project Planning and Control
MG 714/IE 614 Modeling of Social Systems
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

Public Policy
Select four:
MG 640 Resource Economics
MG 740 Process of Policy Formation
MG 746 Public Sector Management
MG 800 Policy Analysis and Planning
MG 865 Research Development and Management of Innovation
MG 866 Technology Management and Policy
ES 927 Energy Policy Issues
MG 714/IE 614 Modeling of Social Systems

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 645 Productivity Management
MG 672 Technological Forecasting
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
MG 714/IE 614 Modeling of Social Systems

Transportation Management
Select four:
MG 853/TR 751 Transportation Finance

TR 753 Management of Transportation & Distribution Operations
TR 754 Logistics Analysis
TR 755 Legal & Regulatory Aspects of Transporation
TR 758 Transportation Management & Decision-Making
TR 759 Transportation Policy & Decision-Making

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, which includes theoretical and practical courses relevant to organizational behavior, integrates contributions from management, psychology and sociology.

Admission — Applicants must hold an accredited bachelor's degree in any field. Those without undergraduate courses in psychology will be required to remove this deficiency. Applicants must take the Graduate Record Examination (GRE) or Graduate Management Admissions Test (GMAT) and have scores submitted directly to Polytechnic in advance of their applications.

The Curriculum

1. **Required Core courses.** An organizational behavior base consists of four core courses upon which the student can build a variety of specializations within the degree program. Core courses provide intensive introduction to several areas basic to organizational behavior. Students who have previously completed courses in any of these areas or 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.

The core courses are:	**Units**
MG 600 Management Process	3
MG 601 Organizational Behavior	3
MG 631 Organization Theory	3
MG 633 Research Methods	3
Total units required:	12

2. **Areas of Concentration.** Students must choose two areas of concentration, each consisting of two courses. These may be two of those listed below or, with adviser's approval, may consist of a series of four 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

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

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.** Three appropriate graduate courses may be chosen from any programs at Polytechnic. These could include courses from any concentrations 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 a research project as part of the course.

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 a B or better, students are issued certificates. Those who choose to work toward master's degrees are able to apply all courses taken toward a certificate, upon admission, toward fulfillment of degree programs. 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:

    Computer Applications
    Construction Management
    Economics
    Finance
    Human Resources
    Management & Administration
    Operations Management
    Public Policy
    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.

UNDERGRADUATE COURSES

MG 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. Students have access to Texas Instrument's professional computers.

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. Prerequisites: SS 189.
Also listed under SS 199

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 calculators. 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 leaadership, 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 609   Managerial Accounting and Finance   2½:0:3
Aspects of accounting and finance of practical use to managers. Relations among accounting, economic and financial perspectives. Analysis of principles and practices of the finance function and its application in organizations.

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.

MG 613   Industrial Relations   2½:0:3
Policies and philosophies of management, organized labor problems. Evaluation of industrial relations problems, particularly those of collective bargaining, emphasizing interrelationship with social, economic and legal trends. Co/Prerequisite: MG 600 or permission of instructor.

MG 614   Collective Bargaining   2½:0:3
Analysis of the 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 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 676.

**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   2½:0:3
Analytic techniques for designing and operating production and service systems, including facility layouts and locations, assembly 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 organizationi 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 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 world oil markets and domestic markets for natural gas and coal are discussed, as well as policy problems. Prerequisites: SS 251 and MA 103, or IE 665, 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 652   Telecommunications Policy, Regulation, and
           Law   2½:0:3**
Relationships between the development of the telecommunications policy issues and policy making organizations. Analyses of the major issues which impact the telecommunications industry and commerce and society generally. Options and opportunities afforded by recent regulatory and policy issues.

MANAGEMENT

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 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 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 727 Case Studies in Management Science* 2½:0:3
Applications of scientific and analytic methods for solving decision-making problems, drawn from current practice and literature. Prerequisite: permission of the instructor. Prerequisite: MG 630.

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.

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.

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.

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 stndard and direct cost-accounting systems. Prerequisite: MG 504.

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, the SST 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. This course will also be comparative in nature. The strategic management of technology in several different countries and industries will be studied and compared. The course will employ 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 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 source of capital and cash flow. Short- and long-term financial managment 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.

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.

FACULTY

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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, and robotics applications;

- 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 accomplishing 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

The Industrial Engineering Program has a manufacturing engineering concentration within its ABET-accredited undergraduate degree, as does the Mechanical Engineering Program.

THE MS (MANUFACTURING ENGINEERING OF ELECTRONIC MATERIALS)

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 are the emphases on the processes, materials, facilities designs 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 curricula are not designed for materials specialists or manufacturing engineers only. It is oriented for other engineers and scientists working in the 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 the 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 be 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/MT 625	Design of Clean Rooms	3
IE 785	Computer Integrated Manufacturing Systems	3
MT/IE 788	Case Studies in Electronics Manufacturing	3
MT 996	Master's Report	3
		24
Electives		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

Electives are chosen in conjunction with assigned academic advisers to meet the career needs of students while providing balance in the education. Elective concentrations are encouraged, emphasizing materials, materials handling, computer aided engineering, quality control and reliability, or robotics in electronics manufacturing. The materials emphasis may be broadened to cover lasers, polymers, and/or optical materials as well as ceramics.

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
AM 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 the 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 laboratory growth relates to materials handling, production and assembly, flexible automation, and robotics.

Illustrative courses in Industrial Engineering related to Manufacturing Engineering are:

- Work Design and Measurement
- Production Planning and Control
- Project Planning and Control
- Facility Planning and Control
- Manufacturing Processes
- Robotic Applications
- Industrial Safety Engineering
- Manufacturing Resource Planning
- Manufacturing Improvement Curves

Mechanical and Aerospace Engineering

The Department of Mechanical and Aerospace 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:

    CH 625 Design of Clean Rooms
    CH 672 Fundamentals of Biochemical Engineering
    CH 781-782 Chemical Process Kinetics I & II
    CH 921 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 Manufacturing Processes and in Semiconductor Technology are also cross-listed with Transportation & Industrial Engineering and with Electrical Engineering and Computer Science, respectively.

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

This encompasses 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.

Computer Aided Engineering

Polytechnic also has a decentralized CAD/CAM facility based upon an IBM 4341. The Industrial Engineering laboratories include three CAD/CAM work stations linked to this facility. Electrical Engineering uses its work station for circuit design and chip layout.

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 implanta-
tion, 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 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 619 Production Planning & Control   **2½:0:3**
Analytical techniques for designing and operating production sys-
tems. Assemblyline 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. 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 moni-
toring; circulation, inert gases. Clean room; interlocks, tempera-
ture, humidity, ambient light. Cascading of solvents and etchants.
Deionized water; containers, generation and monitoring. Safety of
handling. Waste disposal. Toxicity. Vacuum systems; inert atmos-
phere. 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 sev-
eral 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**
Industrial experts will be invited to lecture on the actual experience
in design, design modification, facility layout and "clean" design,
yield and product respecification in the electronic device manufac-
turing industries. Topics to include: Evolution & Accomplishments
of VLSI Yield Management; Metrology in Mask Manufacturing; High
Speed Lithography Methods for Submicron Structures; Semicon-
ductor Final Test Logistics & Product Dispositioning Systems;
Quality & Reliability Assurance Systems; Identification & Evalua-
tion of Failure Mechanism; and Evolution of Package Design.

**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 depart-
mental 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
(Manufacturing Engineering Program)

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 Trans-
portation and Industrial Engineering; Director of Transpor-
tation Training and Research Center
B.E.E., Manhattan College; M.S., Ph.D., Polytechnic Insti-
tute of Brooklyn
*Transportation and traffic engineering; distribution; 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

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*

Walter Helly, Professor of Operations Research
B.S., Cornell University; M.S., University of Illinois; Ph.D.,
Massachusetts Institute of Technology
*Stochastic modeling; tele- and vehicular traffic; urban
systems*

John H.K. Kao, Professor of Industrial Engineering and
Operations Research
B.S., National Central University (China); M.S., Eng.Sc.D.,
Columbia University
*Probability and statistics; quality control and reliability;
scientific computing; electronic data processing*

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 economic 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; manufacturing 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

Yoshiyuki Okamoto, Professor of Chemistry
B.S., Osaka University of Science and Engineering (Japan); Ph.D., Purdue University
Polymer synthesis, characterization, and applications

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

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. Friedrich	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.
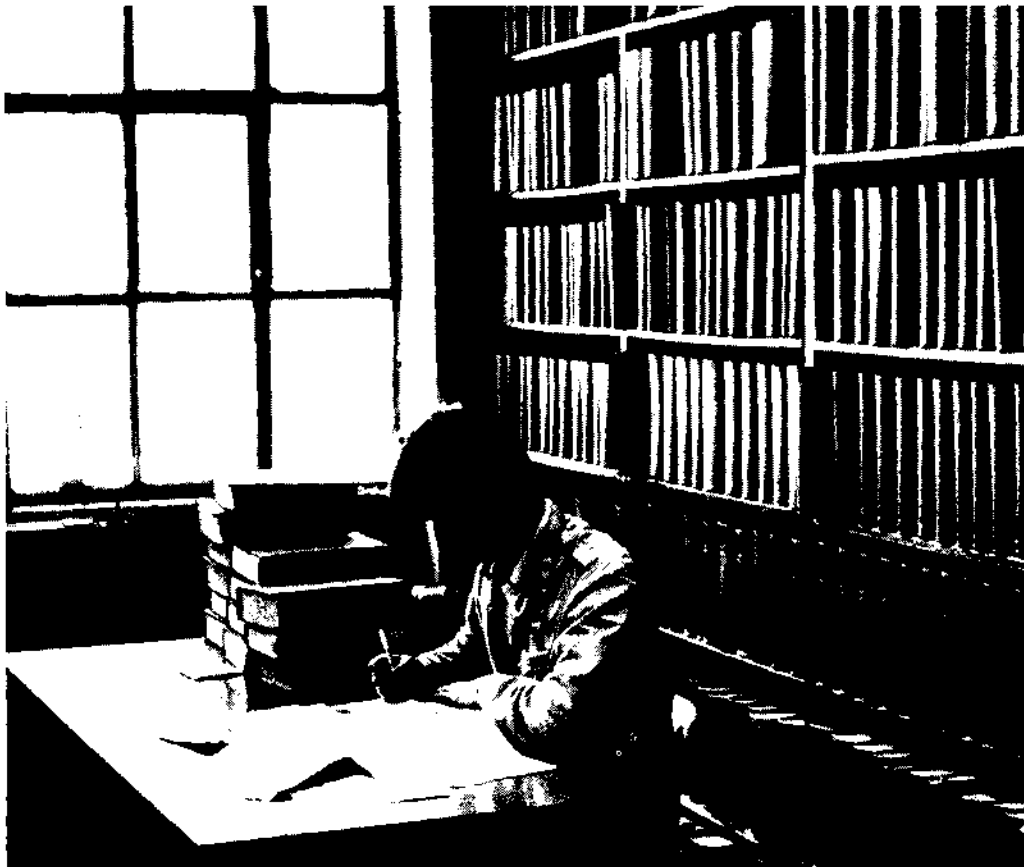
MATHEMATICS AND STATISTICS

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 and subsequent research in abstract and applied mathematics and training for those students who expect to terminate their formal education with 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 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 174). Students particularly interested in applying mathematics knowledge and techniques to other fields may elect course of study II, emphasizing applied mathematics (see page 175). Students wishing to incorporate computer science into their mathematical training may elect course of study III, 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, or	36
Minor specialty‡	12, or	0
Humanities/Social Science electives Free electives	20, or	14
	128	128

*If less than 12 credits are needed, the remaining credits should be taken in the humanities/social science areas.

†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 IE 327, 328	205, 206, 306, 308

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 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
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, IE 252 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 crdits 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 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 combine 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 *they 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 large.

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.
†It is suggested that some of these be CS courses.

Typical Course of Study I for the Bachelor of Science Degree in Mathematics (Abstract)

Freshman Year

First	Semester		Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
MA	111	Calculus Ia	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
PE	101	Physical Education	0	2	0
					16

Second	Semester		Hours/Week		
No		Subject	Cl.	Lab.	Cr.
MA	112	Calculus IIa	4	0	4
PH	102	General Physics II	3½	1½	4
HU	200	Writing and the Humanities II	3	0	3
MA	153	Elem. Linear Algebra	3	0	3
		Language course	3	0	3
PE	102	Phys. Ed.	0	2	0
					17

Sophomore Year

MA	113	Calculus IIIa	3	0	3
MA	154	Elem. Abstract Algebra	3	0	3
PH	103	General Physics III	2½	1½	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

MA	114	Differential Equations	3	0	3
MA	570	Intro. Geometry	3	0	3
CM	102	General Chemistry II	2½	0	2½
CM	112	General Chemistry Lab. II	0	1½	½
		Language course	3	0	3
		Electives*			3
PE	104	Phys. Ed.	0	2	0
					15

Junior Year

MA	211	Analysis I	3	0	3
MA	217	Complex Variables	3	0	3
MA	223	Intro. to Probability	3	0	3
SS	104	Contemp. World History	3	0	3
		Minor Specialty†			3
		Electives*			2
					17

MA	212	Analysis II	3	0	3
MA	333	Partial Diff. Equations	3	0	3
		Minor specialty†			3
		Electives*			7
					16

Senior Year

	Minor specialty	3
	Electives	13
		16

	Minor specialty†	3
	Electives*	13
		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.

Typical Course of Study II for the Bachelor of Science Degree in Mathematics (Applied)

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	SS	104 Contemp. World History	3	0	3
	Language courses	3	0	3		Language course	3	0	3
PE	101 Physical Education	0	2	0	PE	102 Phys. Ed.	0	2	0
				16					17

Sophomore Year

MA	103 Calculus III	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 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 Phys. Ed.	0	2	0
				15					15

Junior Year

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
MA	333 Partial Diff. Equations	3	0	3	IE	328 Operations Res. Models II	3	0	3
IE	327 Operations Res. Models I	3	0	3		Minor specialty			3
	Minor Specialty*			3		Electives			4
	Electives			2					16
				17					

Senior Year

MA	154 Elem. of Abstract Algebra	3	0	3		Minor specialty			3
	Minor specialty*			3		Electives			13
	Electives			10					16
				16					

Total credits required for graduation: 128

*See minor specialty.

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	203		3	0	3
		Language course	3	0	3			Language course	3	0	3
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	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	204		3	0	3	SS	104		3	0	2
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	205		3	0	3	IE	328	Oper. Res. Models II	3	0	3
IE	327	Operations Res. Models I	3	0	3	CS	206		3	0	3
CM	101		2½	0	2½	CM	102		2½	0	2½
CM	111		0	½	½	CM	112		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	308		3	0	3
CS	306		3	0	3			Electives*	13	0	13
MA	333		3	0	3						16
		Electives	7	0	7						
					16						

Total credits required for graduation: 128

Typical Course of Study for the Bachelor of Science Degree in Mathematics (Actuarial 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 or	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
PE	101 Physical Education	0	2	0	PE	102 Physical Education	0	2	0
				16					17

Sophomore Year

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

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

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.

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. Doctors 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 for 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

With requirements for doctor's degrees primarily qualitative rather than quantitative, all students' programs must have the approval of the guidance committee.

The number of graduate units of courrse 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.

Bachelor's degrees with at least a minor in mathematics, which should include a one-year course in advanced calculus, is required.

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 areeas 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

MATHEMATICS AND STATISTICS

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 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 or MA 102.

MA 103   Calculus III   3:0:3
Solid geometry and vectors, partial derivatives. Multiple integrals. Parametric equations. Prerequisite: MA 102 or MA 112.

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 MA 112.

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.

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 MA 112.

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 MA 112.

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 differentiation, 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.

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. Statistical tests. Confidence intervals. Simple regression and correlation. Prerequisite: MA 102.

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, and MA 233 or equivalent.

MA 260 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 Combinatorics and Linear Graph Theory. Logic and Proof Techniques. Relations and Functions. Boolean Algebra and other Algebraic Structures. Prerequisite: junior status or permission of instructor.

MA 342 Discrete Computational Structures II   **3:0:3**
Extends Graph Ttheory 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 programming for digital computers.

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 505-6   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, analysis of variance, linear and non-linear regression, spectral analysis. Prerequisite: MA 102 not accepted for graduate credit in Department of Mathematics.

MA 552   Applied Statistics II
(Experimental Design   2½:0:3
Statistical principles useful in designing comparative and descriptive experiments and their applications. Randomized block designs, latin square, factorial, saturated, response surface designs, sequential experimentations. Prerequisite: MA 551 or MA 232.

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. Prerequisite: 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.

MA 558-559   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, touring 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. Improper 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-Mikodym 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.

MATHEMATICS AND STATISTICS

MA 755-756   Topology I, II   each 2½:0:3
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 2½:0:3**
Elementary theory of manifolds. Tangent space, mappings, submanifolds, 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: MA 770. 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. Prerequisites: MA 751 and instructor's approval.

MA 788   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: MA 751 and 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, nonlinear 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 digital 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. Elements of nonography. 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 linn equations. Eigenvalues of matrices. Numerical solution of ordinary differential equations. Prerequisite: MA 153 and some experience in programming for digital computers.

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 programming for digital computers.

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 systemcs 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 835   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, canonic 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. Appliations 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
Appliation of transform methods of partial differential equations of mathematical physics. Includes introduction to Wierner-Hopf technique. Prerequisites: MA 631 or MA 620 or 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 233.

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. Euleriand and Hamilton digraphs, tournaments, networks. MA 816 prerequisites: MA 103 and MA 104. MA 817 prerequisite: MA 816.

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 inear 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 and 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 asymptotic 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. Appliations. 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.

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 on specialized area. Reading done under guidance of faculty member and devoted mainly to scholarly papers. Prerequisite: permission of department.

READING, PROJECT, THESIS, DISSERTATION

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 is 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 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†). A list of such courses follows.

MA 153	Elements of Linear Albegra	3 cr.
MA 154	Elements of Abstract Algebra	3 cr.
MA 194	History of Mathematics	3 cr.
MA 223	Introduction to Probability	3 cr.
MA 224	Introduction to Mathematical Statistics	3 cr.
MA 231-232	Statistical Methods I, II	3 cr. ea.
MA 238	Applied Probability	3 cr.
MA 531-532	Applied Mathematics in Engineering and Science	3 cr. ea.
MA 541-542	Fundamental of Discrete Mathematics I, II	3 cr.
MA 558-559	Topics in Geometric Optimization I, II	3 cr.
MA 561	Elements of Probability	3 cr.
MA 562	Elements of Mathematical Statistics	3 cr.

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

Andrew J. Terzuoli, Emeritus Professor of Mathematics and Administrative Officer
B.S., Brooklyn College; M.S., New York University
Probability, statistics

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

Ronald Hirshon, Professor of Mathematics
B.S., M.S., Brooklyn College; Ph.D., Adelphi University
Group theory

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
*Infinite groups, ring theory, algebraic topology,
optimization*

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

Barbara Cain, lecturer
B.S., Syracuse University; M.S., New York University

James Camacho, Jr., Lecturer
M.S., Polytechnic Institute of New York

Daniel Drance, Lecturer
M.S., State University of New York, Stony Brook

Wallace Goldberg, Lecturer
B.A., Yeshiva University; M.S., New York University; Ph.D.,
Polytechnic Institute of New York

Carlos Huerta, Lecturer
M.S., Polytechnic Institute of New York

Alfred Kalfus, Lecturer
M.S., Adelphi 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

EMERITUS FACULTY

Aaron Fialkow, Professor Emeritus
B.S., M.S., CCNY; Ph.D., Columbia University
Differential geometry, network theory

Ronald M. Foater, Professor Emeritus
B.A., Harvard; D.Sc. (Hon.), Farleigh Dickinson University; D.Sc. (Hon.), Polytechnic Institute of New York
Network theory; graph theory

MECHANICAL AND AEROSPACE ENGINEERING

At the undergraduate level the Department of Mechanical and Aerospace Engineering offers two distinct programs, each leading to the degree of bachelor of science: one in aerospace engineering and one in mechanical engineering. Each is offered at both the Brooklyn and Long Island campuses. At the graduate level, four separate curricula are offered: the first in applied mechanics; the second in aeronautics and astronautics; and the third and fourth 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 four curricula, graduate degrees are offered at the master of science, engineer, and doctor of philosophy levels.

UNDERGRADUATE PROGRAMS

Aerospace Engineering — 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, waste disposal, 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 recognized by the Accreditation Board for Engineering and Technology.

Mechanical Engineering — For undergraduates in mechanical engineering, a strong program in mathematics, physics, chemistry, and computer usage provides the base for subsequent 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.

A valuable feature of the program is the availability of technical electives in each of the last four semesters. In consultation with faculty advisers, students may construct a minor in one of many technical areas outside traditional mechanical engineering. Alternatively, students may pursue areas of mechanical engineering in greater depth. In either case, the mechanical engineering 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.

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.
MA	101 Calculus I	4	0	4	MA	102 Calculus II	4	0	4
PH	101 Introductory Physics I	3	0	3	PH	102 Introductory Physics II	3½	1½	4
CS	100 AEIntro. to Programming	2	0	2	AM	111 Mechanics I	3	0	3
HU	101 Writing and the Humanities I	3	0	3	HU	200 Writing and the Humanities II	3	0	3
SS	104 Main Themes in Contemp. World Hist.	3	0	3		Hum./Soc. Sci.⁴	3	0	3
PE	101 Physical Education	0	2	0	PE	102 Physical Education	0	2	0
				15					17

Sophomore Year

		Cl.	Lab.	Cr.			Cl.	Lab.	Cr.
MA	103 Calculus III	3	0	3	MA	104 Applied Diff. Equations	3	0	3
PH	103 Introductory Physics III	2½	1½	3	CM	102 General Chemistry II	2½	0	2½
CM	101 General Chemistry I	2½	0	2½	CM	112 General Chemistry Lab. II	0	1½	½
CM	111 General Chemistry Lab. I	0	1½	½	AM	121 Mechanics of Materials	3	0	3
AM	101 Graphics	1	3	2	AM	341 Intro. to Aerodesign	2	3	3
AM	112 Mechanics II	3	0	3	MT	302 Metallurgy for Engineers	2	0	2
	Hum./Soc. Sci. or HU 110⁴	3	0	3		HU 110 or Hum./Soc. Sci.⁴	3	0	3
PE	103 Physical Education	0	2	0	PE	104 Physical Education	0	2	0
				17					17

Junior Year

		Cl.	Lab.	Cr.			Cl.	Lab.	Cr.
MA	333 Partial Diff. Equations	3	0	3	AM	232 Fluids II	3	0	3
AM	201 Thermodynamics I	3	0	3	AM	251 Dynamics	3	0	3
AM	231 Fluids I	3	0	3	AM	252 Dynamic System Response	3	0	3
AM	271 Fund. Stress Analysis I	3	0	3	AM	273 Fund. Stress Analysis II	2½	1½	3
AM	311 Mechanics of Flight I	3	0	3	AM	342 Aircraft Design I	2	3	3
	Hum./Soc. Sci.⁴	3	0	3		Hum./Soc. Sci.⁴	3	0	3
				18					18

Senior Year

		Cl.	Lab.	Cr.			Cl.	Lab.	Cr.
AM	233 Fluids III	3	0	3	AM	241 Propulsion	3	0	3
AM	261 Vibrations	3	0	3	AM	344 Spacecraft Design	2	3	3
AM	281 Advanced Stress Analysis I	2½	1½	3	AM	350 Fluids Laboratory	0	3	1
AM	312 Mechanics of Flight II	3	0	3		Technical electives³	9	0	9
AM	343 Aircraft Design II	2	3	3					16
	Free Elective¹ ²	3	0	3					
				18					

Total credits required for graduation: 136

¹Free electives are subject to departmental advisers' approval.

²ROTC students may substitute four (4) military science courses of zero (0) credits for PE 101-104. Additionally, up to six (6) credits from the following four (4), 2-credit courses: MS 301, 303, 401, or 403, may be used to substitute for the free elective(s) which exist in the aerospace and mechanical engineering programs.

³Approved technical electives are listed as follows: AM 234, AM 282 and AM 331. The choice of any of the above electives or possible other technical electives must be accompanied by a departmental adviser's approval.

⁴Requirements in humanities and social sciences — the student must take HU 101, HU 110, 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) 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. Any student whose last name falls in the range A-L will register for HU 110 in the fall semester. Any student whose last name falls in the range M-Z will register for HU 110 in the Spring.

For the remaining credits in the humanities/social science requirement, the student should select courses in areas other than that of the concentration. Additional courses in the humanities and social sciences may be take as free electives, the total number of humanities and social science credits required being at least twenty-four.

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.
MA 101	Calculus I	4	0	4	MA 102	Calculus II	4	0	4
PH 101	Introductory Physics I	3	0	3	PH 102	Introductory Physics II	3½	1½	4
CS 100	Intro. to Programming	2	0	2	CM 101	General Chemistry I	2½	0	2½
ME					CM 111	General Chemistry Lab. I	0	1½	½
HU 101	Writing and the Humanities I	3	0	3	HU 200	Writing and the Humanities II	3	0	3
SS 104	Main Themes in Contemp. World Hist.	3	0	3		Hum./Soc. Sci.*	3	0	3
PE 101	Physical Education	0	2	0	PE 102	Physical Education	0	2	0
				15					17

Sophomore Year

		Hours/Week					Hours/Week		
MA 103	Calculus III	3	0	3	MA 104	Applied Diff. Equations	3	0	3
PH 103	Introductory Physics III	2½	1½	3	MT 302	Metallurgy for Engineers	2	0	2
CM 102	General Chemistry II	2½	0	2½	AM 112	Mechanics II	3	0	3
CM 112	General Chemistry Lab. II	0	1½	½	AM 121	Mechanics of Materials	3	0	3
AM 101	Graphics	1	3	2		Science elective	3	0	3
AM 111	Mechanics I	3	0	3		HU 110 or Hum./Soc. Sci.*	3	0	3
	Hum./Soc. Sci. or HU 100*	3	0	3	PE 104	Physical Education	0	2	0
PE 103	Physical Education	0	2	0					
				17					17

Junior Year

		Hours/Week					Hours/Week		
MA 333	Partial Diff. Equations	3	0	3	AM 202	Thermodynamics II	3	0	3
AM 201	Thermodynamics I	3	0	3	AM 232	Fluids II	3	0	3
AM 231	Fluids I	3	0	3	AM 252	Dynamic System Response	3	0	3
AM 301	Synth. of Mech. Systs.	3	0	3	AM 302	Anal./Design of Mach. Elem.	3	0	3
AM 351	ME Laboratory I	½	1½	1	AM 331	Comp. Meth. in Design	2	3	3
	Free elective[1,2]	3	0	3		Free elective[1,2]	3	0	3
				16					18

Senior Year

		Hours/Week					Hours/Week		
AM 203	Heat Transfer	3	0	3	AM 204	Energy Transfer Design	3	0	3
AM 261	Vibrations	3	0	3	AM 272	Stress Anal. of Mech. Comp.	3	0	3
AM 271	Fund. Stress Analysis I	3	0	3	AM 321	Instrumentation & Control	3	0	3
AM 352	ME Laboratory II	½	1½	1	AM 353	ME Laboratory III	½	1½	1
AM 361	Project Proposal	0	6	2	AM 362	ME Project	0	6	2
	Technical elective[5]	3	0	3		Technical elective[5]	3	0	3
	Hum./Soc. Sci.*	3	0	3		Hum./Soc. Sci.*	3	0	3
				18					16

Total credits required for graduation: 136

See footnotes on previous page.
[2]Technical Minors — A valuable feature of the mechanical engineering program is availability of technical electives in each of the last four semesters. In consultation with a faculty adviser, the student may construct a minor in numerous and diverse technical areas outside traditional mechanical engineering.

EVENING PROGRAM

Mechanical Engineering

The degree requirements for part-time evening students in the mechanical engineering program are in all respects identical to those for full-time students. The evening program is structured so that students may complete all requirements in eight years without summer work.

The first four years consist of the basic mathematics, humanities, social sciences, physical sciences and engineering sciences contained in the freshman-sophomore years of the full-time program. In the remaining four years, the program consists of advanced undergraduate engineering courses, these four years being offered on an alternating basic. The fifth and sixth years are interchangeable as are the seventh and eighth.

Course of Study for the Evening Program in Mechanical Engineering

First Year

First Semester No.	Subject	Cl.	Lab.	Cr.
HU 101	Writing and the Humanities I	3	0	3
MA 101	Calculus I	4	0	4
				7

Second Semester No.	Subject	Cl.	Lab.	Cr.
MA 102	Calculus II	4	0	4
PH 101	Introductory Physics I	3	0	3
SS 104	Main Themes in Contemp. World History	3	0	3
				10

Second Year

No.	Subject	Cl.	Lab.	Cr.
HU 200	Writing and the Humanities II	3	0	3
MA 103	Calculus III	3	0	3
PH 102	Introductory Physics II	3½	1½	4
				10

No.	Subject	Cl.	Lab.	Cr.
AM 101	Graphics (87-88, 89-90) **or**	1	3	2
CS 100	Intro. to Programming (86-87, 88-89)	2	0	2
MA 104	Applied Diff. Equations	3	0	3
PH 103	Introductory Physics III	2½	1½	3
				10

Third Year

No.	Subject	Cl.	Lab.	Cr.
AM 116	Engineering Mechanics I	2	0	2
CM 101	General Chemistry I	2½	0	2½
CM 111	General Chemistry Lab. I	0	1½	½
	Hum./Soc. Sci. elective	3	0	3
				8

No.	Subject	Cl.	Lab.	Cr.
AM 117	Engineering Mechanics II	2	0	2
AM 101	Graphics (86-87, 88-89) **or**	1	3	2
CS 100	Intro. to Programming (86-87, 88-89)	2	0	2
CM 102	General Chemistry II	2½	0	2½
CM 112	General Chemistry Lab. II	0	1½	½
				7

Fourth Year

No.	Subject	Cl.	Lab.	Cr.
AM 118	Engineering Mechanics III	2	0	2
AM 121	Mechanics of Materials	3	0	3
	Hum./Soc. Sci. elective	3	0	3
				8

No.	Subject	Cl.	Lab.	Cr.
MT 302	Metallurgy for Engineers	2	0	2
	Science elective	3	0	3
	Hum./Soc. Sci. elective	3	0	3
				8

Fifth Year* (87-88, 89-90)

No.	Subject	Cl.	Lab.	Cr.
MA 333	Partial Diff. Equations	3	0	3
AM 201	Thermodynamics I	3	0	3
	Hum./Social Sci.	3	0	3
				9

No.	Subject	Cl.	Lab.	Cr.
AM 231	Fluids I	3	0	3
AM 252	Dynamic System Response	3	0	3
	Hum./Soc. Sci. elective	3	0	3
				9

Sixth Year* (86-87, 88-89)

No.	Subject	Cl.	Lab.	Cr.
AM 271	Fund. Stress Analysis I	3	0	3
AM 302	Ana./Design of Mech. Elem.	3	0	3
	Free elective	3	0	3
				9

No.	Subject	Cl.	Lab.	Cr.
AM 272	Stess Anal. of Mech. Comp.	3	0	3
AM 301	Synth. of Mech. Systems	3	0	3
	Free elective	3	0	3
				9

Seventh Year† (87-88, 89-90)

No.	Subject	Cl.	Lab.	Cr.
AM 202	Thermodynamics II	3	0	3
AM 261	Vibrations	3	0	3
AM 351	ME Laboratory I	½	1½	1
				7

No.	Subject	Cl.	Lab.	Cr.
AM 232	Fluids II	3	0	3
AM 321	Instrumentation & Control	3	0	3
AM 352	ME Laboratory II	½	1½	1
	Technical elective	3	0	3
				10

Eighth Year† (86-87, 88-89)

No.	Subject	Cl.	Lab.	Cr.
AM 203	Heat Transfer	3	0	3
AM 331	Comp. Meth. in Design	2	3	3
AM 361	Project Proposal	0	6	2
				8

No.	Subject	Cl.	Lab.	Cr.
AM 204	Energy Transfer Design	3	0	3
AM 353	ME Laboratory III	½	1½	1
AM 362	ME Project	0	6	2
	Technical Elective	3	0	3
				9

Total credits required for graduation: 136

*Fifth and sixth years are interchangeable.
†Seventh and eighth years are interchangeable.

GRADUATE PROGRAM

Programs of study are offered leading to the degrees of master of science, engineer, and doctor of philosopher in mechanical engineering, in aeronautics and astronautics, 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

AM 601-02	Stress Analysis I & II	
	or	6
AM 603-04	Elasticity I & II	
AM 651-52	Advanced Dynamics I & II	
	or	6
AM 653-54	Dynamics of Machines; Mechanical Vibrations	
AM 971-72	Seminar in Mechanical and Aerospace Engineering	0
		12

Students who have not achieved the level of mathematical proficiency required by MA 333 are required to complete MA 531-32.

B. For mechanical engineering (thermal/fluids/energy option) and aeronautics and astronautics

AM 701	Thermodynamics I	3
AM 710	Convection	3
AM 740	Principles of Fluid Dynamics	3
AM 971-72	Seminar in Mechanical and Aerospace Engineering	0

Students who have not achieved the level of mathematical proficiency required by MA 333 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		
AM 601-602	Stress Analysis I, II	
AM 603-04	Elasticity I & II	
AM 613-14	Theory of Plates and Shells	6
AM 651-52	Advanced Dynamics I & II	
	Electives	18
		36

A2 — Applied Mechanics

Core Courses (A) [1]		12
AM 603-04	Elasticity I & II	6
AM 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		
AM 702	Thermodynamics II	
AM 711	Convective Heat Transfer	
AM 712	Conductive Heat Transfer	
AM 713	Radiative Heat Transfer	
AM 731	Analytical Methods in Thermal & Fluid Mechanics	12
AM 732	Computational Methods in Thermal & Fluid Mechanics	
AM 741	Compressible Flow	
AM 742	Viscous Flow	
	Electives	15
		36

B2 — Aeronatutics and Astronautics

Core Courses (B)		9
Select 12 additional units from		
AM 731	Analytical Methods in Thermal & Fluid Mechanics	
AM 732	Computational Methods in Thermal & Fluid Mechanics	12
AM 741	Compressible Flow	
AM 742	Viscous Flow	
AM 803	Vehicle Dynamics I	
AM 810	Theory of Propulsion	
	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 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 departmental courses (including thesis or project) at Polytechnic.

The department limits to nine the total of transfer, reading (guides 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 fulfilment of degree requirements. All courses submitted for degrees

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[1] Either the core courses or the electives must include AM 651-52, Advanced Dynamics I & II.

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 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 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 AM 971-72 (Seminar in Mechanical and 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 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 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 AM 971-72 (Seminar in Mechanical and 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.

UNDERGRADUATE COURSES

AM 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.

AM 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.

AM 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. Prerequisite: PH 101 and Co/Prerequisite: MA 102.

AM 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: AM 111.

AM 115   Engineering Mechanics   **4:0:4**
Equivalent to AM 116 and AM 117. Prerequisites: MA 102 and PH 101.

AM 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. Prerequisite: PH 101. Co/Prerequisite: MA 102.

AM 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: AM 116.

AM 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. AM 116, AM 117 and AM 118 equivalent to AM 111 and AM 112. Prerequisite: AM 117.

AM 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: AM 111 or AM 115 or AM 116.
Also listed under CE 202

AM 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 102.

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MECHANICAL AND AEROSPACE ENGINEERING

AM 202 Thermodynamics II 3:0:3
Continuation of AM 201. Irreversibility and availability. Power and refrigeration cycles. Maxwell's equations and other thermo-dynamic relations. Properties of mixtures; air-conditioning. Energy and equilibrium aspects of chemical reactions; flame temperatures. Introduction to phase and chemical equilibrium. Prerequisite: AM 201.

AM 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. Prerequisite: AM 231.

AM 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. Prerequisite: AM 202 and AM 203.

AM 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: AM 201.

AM 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: AM 201.

AM 213 Transport Processes* 3:0:3
Extensions of principles developed in AM 201, AM 203, and AM 231. Energy release and momentum, heat and mass transfer processes. Unified treatment using transport phenomena methods. Senior elective. Prerequisite: AM 203.

AM 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: MA 333 and AM 201.

AM 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 obliaue shocks. Expansion fans. Effects of friction and heat addition. Prerequisite: AM 231.

AM 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: AM 232.

AM 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: AM 232.

AM 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: AM 232.

AM 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.

AM 243 Turbomachinery* 3:0:3
Thermodynamics, fluid mechanic principles and elements of turbomachinery (fans, pumps, compressors, turbines) including design principles and operation of turbomachines. Senior elective. Prerequisite: senior status.

AM 251 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: AM 112 and MA 104.

AM 252 Dynamic Systems Response 3:0:3
Basic dynamic behavior of mechanical, fluid, thermal and electrical elements for simple element behavior to complex systems. Modeling and formulation of system equations. Analogies stressed and computer simulations introduced. Generalized first-and second-order dynamic systems subject to various excitations. Prerequisite: AM 112 or AM 115 or AM 117.

AM 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: AM 251 or Am 252.

AM 262 Noise and Acoustics* 3:0:3
Nature of sound waves, sound propagation and generation. Engineering manipulations with acoustic units and quantities. Subjective responses to noise and damage criteria. Fundamentals of noise creation and transmission. Environmental and aircraft noise sources. Acoustic instrumentation. Noise control approaches. Prerequisite: junior status.

AM 263 Advanced Vibrations* 3:0:3
Lagrangian mechanics. Normal mode analysis of free and forced vibration. Energy and numerical methods in vibration analysis. Nonlinear oscillatory systems. Prerequisite: AM 261.

AM 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-molded section beams, shear center. Prerequisite: MA 104 and AM 121.

AM 272 Stress Analysis of Mechanical Components 3:0:3
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. Prerequisite: AM 271.

AM 273 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: AM 271.

AM 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 AM 273. Prerequisite: AM 273.

AM 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: AM 273.

AM 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: AM 112 or AM 115 or AM 117.

AM 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: AM 121 and MA 333.

AM 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: AM 112 or AM 115 or AM 117 and AM 341.

AM 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: AM 311.

AM 321   Instrumentation and Control   3:0:3
Operation of mechanical and electromechanical instrument components. Active and passive transducer elements for steady and non-steady temperature, pressure, displacement, acceleration, measurements. Instruments and feedback control systems. Introduction to statistical analysis of data. Design of measurement or control systems. Prerequisite: AM 251 or AM 252.

AM 322   Machine Control Systems*   3:0:3
Application of feedbac principles to machine systems. Uses of classical and transform methods for transient and steady-state solutions. Prerequisite: AM 321.

AM 331   Computational Methods in
**   Computer-Aided Design   2:3:3**
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 AM 101.

AM 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: AM 331.

AM 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: AM 301 and AM 302.

AM 341   Introduction to Aerodesign   2:3:3
Consideration of the nature of design systhesis and analysis as it pertains to aerospace. Qualitative and quantitative aspects of feasibility, design methodology, modeling, uses of computers, iteration and optimization in terms of design project. Co/Prerequisite: AM 121.

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

AM 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: AM 342.

AM 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: AM 343.

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

AM 351   ME Laboratory I   ½:1½:1
Instrumentation principles. Experiments related to thermodynamics, system modeling and basic instrumentation. Co/Prerequisites: AM 201 and AM 112.

AM 352   ME Laboratory II   ½:1½:1
Experiments related to thermodynamics, fluid properties, systems dynamics, vibrations, Co/Prerequisite: AM 261.

Am 353   ME Laboratory III   ½:1½:1
Experiments in heat transfer, fluid flow, stress and strain. Prerequisite: AM 203.

AM 361   ME Project Proposal   0:6:2
Basic design and analysis of engineering project. Formulation of formal plan of execution of design project. Prerequisite: senior status.

AM 362   ME Project   0:6:2
Execution of design project as proposed in AM 361. Prerequisite: AM 361.

AM 363-366   ME Project or Study   1-4 cr. as arranged
Continuation of AM 362 on approval of project adviser. Directed studies or special topics in mechanical engineering. Prerequisite: AM 362.

MECHANICAL AND AEROSPACE ENGINEERING

AM 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.

AM 383-384 Senior Honors Work in Aerospace
Engineering I, II   credit to be arranged
For aerospace majors; equivalent in scope to AM 381-382.

AM 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.

AM 393-394 Guided Studies in Aerospace
Engineering I, II   credit to be arranged
For aerospace majors; equivalent in scope to AM 391-392.

GRADUATE COURSES

AM 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.

AM 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 multi-cellular structures. Prerequisite: AM 601.

AM 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.

AM 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: AM 601 or AM 603.

AM 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: AM 602.

AM 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, lasticity, viscoelasticity and creep, and fluid mechanics. Prerequisite: adviser's approval.

AM 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: AM 121 or CE 202.
Also listed under CE 621

AM 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: adviser's approval.

Am 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: AM 613.

AM 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: adviser's approval.

AM 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: AM 615.

AM 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: Adviser's approval.

Am 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 Fouier, Ritz, Galerkin, least square and collocation methods.

AM 624 Computational Methods in Mechanical and
Aerospace Engineering II*   2½:0:3
Continuation of AM 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: AM 623.

AM 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.

AM 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 diimensional surfaces by means of holography and other optical techniques. Prerequisite: AM 625.

AM 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.

AM 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: AM 601.
Also listed under CE 632.

AM 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: AM 601.

AM 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: AM 602 or AM 603.

AM 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: AM 637.

AM 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.

AM 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.

AM 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.

AM 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: AM 653.

AM 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

AM 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: AM 601 and AM 654 or AM 661.

AM 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: AM 654.

AM 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: AM 615

AM 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.

AM 672 Kinematic Synthesis of Mechanisms* 2½:0:3
Kinematic analysis of planar motion. Geometric and algebraic methods in linkage synthesis for path function generation. Errors in dimensional systhesis.Eular-Savary equation and the cubic of stationary curvature. Cognate linkages, Roberts-Chebyshev theorem. Synthesis of spatial linkages. Prerequisite: AM AM 671

AM 675 Mechanical Servomechanisms I* 2½:0:3
Analysis of linear control and feedback systems. Feedback loops, transfer functions end block diagrams. Proportional, rate, integral control. Root-locus methods, Bode and Nyquist plots, stability criteria.

AM 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: AM 675.

AM 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: AM 604.

AM 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: AM 661.

AM 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: AM 654.

AM 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.

AM 685 Noise and Acoustics I* 2½:0:3
Survey of mathematical methods, random signals, acoustic fields, room acoustics, subjective criteria, environmental criteria.

AM 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: AM 685.

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MECHANICAL AND AEROSPACE ENGINEERING

**AM 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.

**AM 691-694   Special Topics: ME and Applied
                   Mechanics***   each 2½:0:3
Topics of particular current interest in mechanical engineering and applied mechanics. Prerequisite: adviser's approval.

AM 701   Thermodynamics I S2½:0:3
Availability functions, general thermodynamic relations, equations of state, general thermodynamics equilibrium criteria. Prerequisite: AM adviser's approval.

AM 702   Thermodynamics II*   2½:0:3
Continuation of AM 701. Applications of thermodynamics equilibrium criteria to various problems, including chemical reactions. Prerequisite: AM 701.

AM 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: AM 701.

AM 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: AM 701.

AM 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: AM 705.

**AM 709   Special Topics:
                   Thermodynamics and Combustion***   2½:0:3
Topics of particular current interest in thermodynamics and combustion. Prerequisite: AM adviser's approval.

AM 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: AM 740 or equivalent.

AM 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: AM 710.

AM 712   Conductive Heat Transfer*   2½:0:3
Theoretical development of transient and steady-state temperature distributions in finite and infinite solids. Appropriate mathematical techniques introduced as required. Solids undergoing phase change and two-dimensional fields. Prerequisite: AM 203.

AM 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: AM 203.

AM 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: AM adviser's approval.

AM 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 AM 715 will not be granted if AM 203 was taken. Prerequisite: AM adviser's approval.

AM 716   Reactor Heat Transfer*   2½:0:3
Heat transfer problems and solution techniques associated with nuclear reactors including BWR, PWR, LMFBF 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: Am 715 or AM 203.

AM 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: AM 203 or AM 715.

AM 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: AM 701, AM 710, AM 740.

AM 729   Special Topics: Heat Transfer*   2½:0:3
Topics of particular current interest in heat transfer. Prerequisite: AM adviser's approval.

**AM 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: AM adviser's approval.

**AM 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: AM adviser's approval.

AM 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: AM adviser's approval.

AM 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: AM 740.

AM 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: AM 710.

AM 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: AM 741 and AM 742.

AM 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: AM adviser's approval.

AM 746   Fluid Dynamics or Rotating Machinery*   2½:0:3
Methods of analysis of floe in rotating machines. Cascades, performance, radial equilibrium, secondary flows, viscous flows. Supersonic and transonic flows in compressors and turbines. Prerequisite: AM 741.

AM 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: AM adviser's approval.

AM 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: AM adviser's approval.

AM 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: AM adviser's approval.

AM 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.

AM 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: AM 751

AM 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: adviser's approval.
Also listed under EL 781-782

AM 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: AM adviser's approval.

AM 759   Special Topics: Fluid Mechanics*   2½:0:3
Topics of particular current interest in fluid mechanics. Prerequisite: AM 740.

AM 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: AM 701.

AM 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 gorund-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.

AM 764   Solar Thermal Engineering II   2½:0:3
Extension of AM 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: AM 763.

AM 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: AM adviser's approval.

AM 769   Special Topics: Energy Conversion*   2½:0:3
Topics of particular current interest in energy conversion. Prerequisite: AM adviser's approval.

AM 771   Computational Geometry for Computer-Aided Design   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: AM adviser's approval.

AM 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: AM 332 or AM 771.

AM 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: AM adviser's approval.

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AM 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: AM 801.

AM 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 reentry trajectories. Land and seaborne vehicles: automobile, tracked vehicles, ship and GEM vehicles. Prerequisite: AM advisers approval.

AM 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: AM 803.

AM 808   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: graduate status or instructor's permission.

AM 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: AM adviser's approval.

AM 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: AM adviser's approval.

AM 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: AM adviser's approval.

AM 819   Special Topics:
Aeronautics and Aatronautics*   2½:0:3
Topics of particular current interest in aeronautics and astronautics. Prerequisite: AM adviser's approval.

AM 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.

AM 927   Energy Policy Issues   2½:0:3
See Energy Program for details (ES 927).

AM 928   Energy Resource Distribution and
Conversion Technology   2½:0:3
See Energy Program for details (ES 928).

AM 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

AM 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.

AM 996   Project   each 3 units
Engineering project pursued with guidance of faculty ember. 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.

AM 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 AM 996, on recommendation of project adviser. Continuous registration required. Maximum of twelve units of AM 996-997 counted toward degree. Reregistration fee: 3-unit charge. Prerequisite: AM 996.

AM 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 AM 996-997 counted toward degrees. Reregistration fee: 3-unit charge. Prerequisite: post-master status.

AM 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 urits per semester required until dissertation completed. Reregistration fee: 3-unit charge. Prerequisite: degree status.

FACULTY

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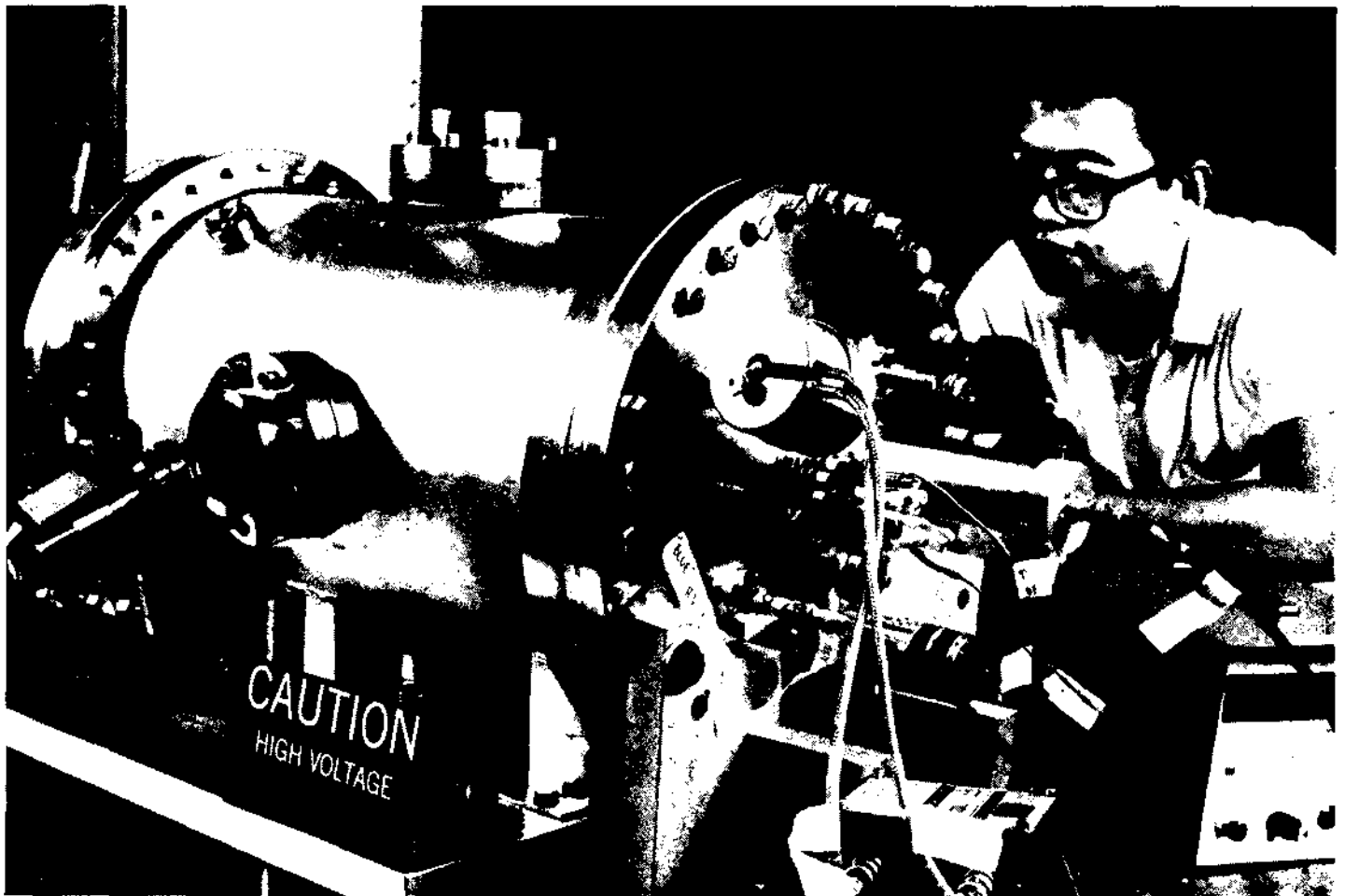
METALLURGY AND MATERIALS SCIENCE

Metallurgists and material scientists are specialists in the most effective utilization of metals, alloys, ceramics, semiconductors, composites, plastics, and polymers. They are 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 trememdous 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.

Physical Metallurgy

Physical metallurgy is concerned with the study and understanding of fundamental properties of materials and how these properties are related to the macroscopic and microscopic behavior of metals and alloys. Chemical composition, processing variables, atomic bonding, crystal structure and microscopic imperfections are correlated with the strength, corrosion resistance, electrical properties, and physical and chemical characteristics of metals and alloys. Because the same basic concepts relating microstructures to physical properties also apply to other classes of solids, metallurgists often find themselves involved with many non-metallic materials such as ceramics and glasses, semiconductors, ionic solids, and even polymers.

Materials Science

It is estimated that nearly 40% of all engineering reserach is in the area of materials science, which is defined simply as the study of the interrelation among atomic structure, crystal structure, microstructure and properties of materials. With this understanding it is possible to "tailor make" materials requiring specific properties for particular applications. The fundamental principles which involve basic physics and chemistry are universally applied to metals, ceramics, polymers, and semiconductors. For thirty years, metallurgists have been using electron microscopy, vacuum technology, x-ray diffraction, and thermomechanical processing to influence and evaluate the structures of new alloys and semiconductors for structural and electronic device applications. It has been found that instrumentation and equipment necessary to study and develop processes for metallic materials are ideally suited to nonmetallics. It has therefore been a natural evolution for metallurgically

oriented academic programs to encompass the broader spectrum of electronic materials, ceramics, and composites.

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 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 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*
- 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 basis from which the graduate may proceed along any avenue of professional development from graduate study and research to industrial assignments. 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 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 concentrating the technical elective sequence of 12 credits in several areas: material science, computer science, industrial engineering, mathematics or the sciences as approved by advisors.

Students may (with advisers' 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 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.

*Subject to registration by N.Y.S. Education Department.

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 baccaaureate degrees in related disciplines are admitted, if undergraduate deficiencies are removed.

Both fundamental and applied research are carried on with 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.

Typical Course of Study for the
Bachelor of Science Degree in Metallurgical 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
HU	101	Writing and the Humanities I	3	0	3	HU	200	Writing and the Humanities II	3	0	3
SS	104	Contemp. World History	3	0	3	MA	102	Calculus II	4	0	4
MA	101	Calculus I	4	0	4	PH	102	Intro. Physics II	3½	1½	4
PH	101	Intro. Physics I	3	0	3	CS	100	Intro. to Computer Progr.	2	0	2
PE	101	Physical Education	0	2	0	PE	102	Physical Education	0	2	0
					16						16

Sophomore Year

AM	115	Eng. Mechanics	4	0	4	EE	370	Princ. Elec. Eng.	3	0	3
AM	101	Graphics	1	3	2	EE	374	Inst. Lab.	0	3	1
PH	103	Intro. to Physics III	2½	1½	3	AM	121	Mechs. of Materials	3	0	3
MA	103	Calculus III	3	0	3	MA	104	Appl. Diff. Eqs.	3	0	3
PE	103	Physical Education	0	2	0	PE	104	Physical Education	0	2	0
		Hum./Soc. Sci. elective	3	0	3			Hum./Soc. Sci. elective	3	0	6
					15						16

Junior Year

MT	401	Physical Metallurgy I	3	0	3	CM	161	Physical Chemistry I	3	0	3
MT	402	Mechan. Metallurgy I	3	3	4	MT	403	Physical Metallurgy II	3	0	3
MT	404	Metallography Lab.	0	6	2	MT	406	Mechanical Metallurgy II	3	0	3
MT	405	Metallurgical				MT	407	Metallurgy Transport	3	0	3
		Thermodynamics	3	0	3	MT	408	Phys. Metallurgy Lab.	0	6	2
		Hum./Soc. Sci. elective	3	0	3	MT	494	Literature Search	1	3	2
		Elective*	3	0	3			Elective*	3	0	3
					18						19

Senior Year

MT	410	Solid-State Metallurgy	3	0	3	CM	771	Intro. to Polymer			
CM	515	Polymer Organic						Chemistry	3	0	3
		Chemistry	2½	0	3	MT	413	Process Metallurgy	3	0	3
MT	416	Electromet. & Corrosion	2	3	3	MT	423	Ceramic & Refract. Mat.	3	0	3
MT	421	Metal. Failure Analysis	2	3	3	MT	497	Thesis	0	9	3
MT	496	Thesis or Technical Elec.	0	9	3			Hum./Soc. Sci. elective	3	0	3
		Elective*	3	0	3			Elective*	3	0	3
					18						18

Total credits required for graduation: 136

MATERIAL SCIENCE CONCENTRATION
Freshman and Sophomore courses as in regular program

Junior Year

First Semester					Second Semester				
No.	Subject	Cl.	Lab.	Cr.	No.	Subject	Cl.	Lab.	Cr.
MT	401 Physical Metallurgy I	3	3	3	CM	161 Physical Chemistry I	3	0	3
MT	402 Mechanical Metallurgy I	3	3	4	MT	403 Physical Metallurgy II	3	0	3
MT	404 Metallography Lab.	0	6	2	MT	406 Mechanical Metallurgy II	3	0	3
MT	405 Met. Thermodynamics	3	0	3	MT	407 Metallurgy Transport	3	0	3
CM	122 Organic Chemistry	3	0	3	MT	408 Physical Metallurgy Lab.	0	6	2
	Hum./Soc. Sci. elective	3	0	3	MT	494 Informational Search	1	3	2
				18	CM	123 Organic Chemistry II	3	0	3
									19

Senior Year

		Cl.	Lab.	Cr.			Cl.	Lab.	Cr.
MT	410 Solid State Metallurgy	3	0	3	MT	413 Process Metallurgy	3	0	3
MT	416 Electromet. & Corrosion	2	3	3	MT	423 Ceramic & Refractory Mat.	3	0	3
MT	421 Metal. Failure Analysis	2	3	3	MT	497 Thesis or technical elective	0	9	3
MT	496 Thesis or technical elective	0	9	3	CM	771 Introductory Polymer			
CM	515 Polymer Organic					Chemistry	3	0	3
	Chemistry	3	0	3		Hum./Soc. Sci. elective	3	0	3
	Technical elective	3	0	3		Elective*	3	0	3
				18					18

* The 12 credits of electives taken during the last three years comprise 9 credits of technical electives and 3 credits of free electives.

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 deficiences 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 & Fractures	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.	6-12

Elective Course Work:
12-18 units chosen from the Department courses listed on pages XX of the Catalog. 12-18

General Electives
With adviser's approval may be chosen from among University courses offered in this catalog. 0-9

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 (15 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
CH 917	Introduction to Polymeric Materials	3
		15

Project or Thesis

MT 996	Report Project for M.S.	3-6
	or	
MT 997	Thesis for M.S.	6-12

Elective Course Work:
With Advisor approval courses from catalog, others in areas related to materials science, e.g., metallurgy, chemistry and polymers.   9-18

                                        Total   36

REQUIREMENTS FOR THE ENGINEER DEGREE

Applicants for admission to this program must hold master's degrees (or equivalent) comparable in content to that of the Department. This must include at least the equivalent of the required courses in the MT 600-650 series listed under the requirements for master's degrees. Applicants holding master's degrees 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 advisor, are removed during the time students are enrolled in the program.

No.	Required Subjects	Units
MT 621-622	Special Topics in Plastic Deformations & Fractures	6
MT 651-652	Special Topics in Advanced Engineering Metallurgy	6
MT 762	Seminar - presented by students cirtically reviewing technical papers selected by students with approval of faculty advisers.	

Selected electives in science, mathematics, economics or engineering, in consultation with department advisers.   18
MT 998   project   6

                                        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 Secretary in the publication, *Guide for Doctoral Students in Metallurgy or Materials Science.*

A typical program consists of a minimum of 66 units of course work beyond the B.S. level and 24 units of research for the doctoral dissertation. Courses include major concentrations in Metallurgy/Materials Science of 36 units and minor areas of 12 units in related areas of physics, chemistry, 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, fatigue properties. Effects of temperature on mechanical behavior of metals. Creep. Stress rupture. Prerequisite: MA 103.

MT 403   Physical Metallurgy II   3:0:3
Nonferrous alloys. Diffusion-controlled phase transofrmations. Distortion-controlled phase transformations. Elementary alloy theory. Prerequisite: 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 photogaraphic techniques. Sample preparation techniques for electron microscopy. Prerequisite: MT 401.

MT 405   Metallurgical Thermodynamics   3:0:3
laws 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   Transport Methods in Metallurgy   3:0:3
Methods of engineering analysis applied to metallurgical systems. simultaneous development of concepts of mass, energy and momentum. Introduction to irreversible thermodynamics and its application to solid state diffusion. Prerequisites: MA 104 and PH 103.

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 anslyses and phase diagram determinations by x-ray techniques. Qualitative and quantitative chemical analysses by x-ray techniques. Prerequisites: MA 104 and PH 103.
Also listed under PH 372.

MT 413   Process Metallurgy   3:0:3
Metallurgy of iron, steel and principal nonferrous metals. Gases in steel. Reduction and oxidation, slag-metal reaction. Kinetics of heterogeneous reactions. Material and energy balances. 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 material science literature. Topics may be related to bachelor's theses.

MT 496-497 Bachelor's Thesis in Metalurgical
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 theses are completed. Prerequisite: MT 494.

TECHNICAL ELECTIVE COURSES

MT 409 Materials Selections 3:0:3
Knowledge 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 Metal 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 2:3:3
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 inelastic behavior, creep, fatigue, brittle and ductile fractuer of metals.

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 metallurgical engineering 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. Prerequisite: MT 301 or MT 302 or MT 303 or consent of instructor.

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 or MT 401.
Also listed under IE 340.

MT 375 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, packaging. Prerequisite: EE 111.
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 MC 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 deformations of metals and alloys, recrystallizations, age hardening. Prerequisite: instructor's consent.

**MT 600   Structure-Property
                 Relationships in Materials   2½:0:3**
Dependences of properties, e.g., mechanical and electrical, on structures of materials. Crystalline vs. amorphous structure, occurrences and roles of defects. Bondings and structures. 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. Speciment 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
Elasticity theories. Dislocation concepts of mechanical behavior of metals. Theories of plastic flow, work hardening, strength, ductility. Movements of dislocations in metals. Peierls-Nabarro stress. Theories of yielding, brittle and ductile fracture and alloy hardening. 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; diffusions in multiphase, multicomponent metallic systems; theories of precipitation, of grain boundary migration and grain growth, of eutectoid transformations and of martensitic transformation. 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, structures, and properties of ceramics and glasses. Emphases on relation of microstructures 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 nonferrous alloys. Prerequisite: instructor's consent.

**MT 706   Magnetism and Magnetic
                 Materials*   2½:0:3**
Origins of magnetism in atoms and solids. Diamagnetic vs. paramagnetic behavior. Ferromagnetic domain theory. Antiferromagnetism and ferrimagnetism. Structures of 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
Instrumentations and techniques of electrochemical studies. Semiconductor electrodes. Organic electrode processes. Chemical etching and its application to semiconductors. Practical applications of electrolytic methods to semiconductors. Plasma effects.

**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 oxidations and metal-gas interactions. Testings, analyses of use 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
Characterizations 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
Crustal structures 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.
Also listed under NU 716.

MT 727   Bioengineering Metallurgy*   2½:0:3
Selection and application of metals and alloys for uses in body environments. he body as corrosive environment. Examinations of major problem areas. Principles and techniques for preparation of dental amalgams and other alloys. Designs 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 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 topics 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 0:2½:0
Preparation and presentation by students of seminars on topics of physical metallutgy, 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 927   Energy Policy Issues   2½:0:3
See Energy Program for details.

**MT 928   Energy Resource Distribution and
           Conversion Technology**   2½:0:3
See Energy Program for details.

**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**   3-12 units
Extension of project studies to thesis level with approval of division head. Regular conferences and reports during thesis investigation required.

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 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 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 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 Whang, Associate Professor of Metallurgy
B.S., Seoul National University (Keora); M.S., D.Eng.Sc., Columbia University
Physical metallurgy, materials science and metallurgical engineering

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

George Stern, Adjunct Professor of Metallurgy
B.Ch.E., C.C.N.Y.; M.S., University of Michigan

Anthony Vecchio, Adjunct Professor of Metallurgy
M.Met.E., Polytechnic Institute of Brooklyn

John Weeks, Adjunct Professor of Metallurgy
B.S., Colorado School of Mines; M.S., Ph.D., University of Utah

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 in the United States Army while earning their college degrees.

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. Subjects cover the following areas: first aid, national defense, drill, physical conditioning, map reading, survival techniques, mountaineering, 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 brigade. 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.

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 ($600). Contracted U.S. citizens also receive a living allowance up to $1,000 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 obtain a commission, but they do not receive the living allowance until they obtain U.S. citizenship.

2. Qualify for appointment as a second lieutenant prior to reaching 30 years of age.

3. Be approved by a 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.

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, each summer and enrolling in the advanced course in their last two years, provided they otherwise meet enrollment requirements.

OBLIGATIONS

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 of the full time active duty forces, only one third of each commissioning year group is 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 is usually preferred. 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 four-, three- and two-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 three- and two-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 of up to $1,000 each year the scholarship is in effect.

CREDITS TOWARD POLYTECHNIC DEGREES

BASIC COURSE

Students enrolled in any of the basic course zero credit courses (MS 101, 102, 201, or 202) may substitute these courses for the mandatory Polytechnic physical education requirements for graduation.

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.

ADVANCED COURSE

Up to six credits of the four two-credit courses (MS 301, 303, 401 or 403) may be substituted for free/technical electives as authorized by the individual departments.

PROFESSIONAL ACTIVITIES

Military science offers a variety of social and professional activities:

Scabbard and Blade is the advanced course 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 tactical military training and in organizing a ceremonial color guard.

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, ranger, airborne and orienteering.

HOW TO ENROLL

Students should visit the department of military science during the registration period so that the desired course can be integrated with normal registration procedures. Students interested in the two-year program should contact the department early in their sophomore year for application deadlines. If you have any questions concerning military science, telephone (718) 643-2105.

BASIC COURSES

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; an introduction to physical fitness training and planning; and basic rifle marksmanship. The course also includes a field trip which applies all skills taught. Extra credit field training exercises are available.

MS 102   Introduction to military science II
Development of self-confidence in students. Development of skills necessary to navigate using a map and compass. (A field trip is required which applies all military skills taught.) First aid measures consisting of basic life-saving steps. Extra credit field training exercises are available. Prerequisite: MS 101 or permission of instructor.

MS 201   Military Skills I   1:1:1
Basic skills associated with small unit leaders. Theoretical and practical applications of military marksmanship, tactics and communications skills. Basic marksmanship includes the supervised firing of small bore rifle and pistol during an off campus field trip. Tactics is taught at the small unit level, company and below. Oral and written communications techniques and skills required of successful leaders. Students are required to participate in practical exercises which apply all military skills from previous classes. Extra credit field training exercises are available. Prerequisite: MS 101 and 102 or permission of instructor.

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 and the leadership assessment program. How to prepare to conduct performance oriented training. The course also includes a field trip which applies all military skills previously taught. Extra credit field training exercises are available. Prerequisite: MS 201 or permission of the instructor.

ADVANCED COURSES

**MS 301   Leadership and Management Techniques   2:0:2 or
nc as arranged**
Theory and techniques used by successful leaders and managers. Management skills of problem analysis, decision-making, planning, organizing, delegation and control are developed and applied within contexts of realistic situations, using individual and small group practical exercises. Interpersonal skills needed to utilize skills in relations with others are developed and practiced.

MILITARY SCIENCE

MS 302   Leadership Skills I   3:0:0
Soldier skills, physical capabilities and high motivational attitudes required to meet demands of today's modern army officers. Cadets receive hands-on training 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 relaince. Leadership camp follows this course during the summer months. Students are required to attend various field training exercises to reinforce classroom training. Prerequisite: permission of the department head.

MS 303   American Military History   2:0:2 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.

MS 304   Leadership Skills II   3:0:0
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 just before advancec camp. Prerequisite: MS 302 and permission of the department head.

Advanced Summer Camp   nc
All candidates for commission through military science are required to successfully complete advanced camp, held at Fort Bragg, North Carolina. Stress placed on leadership and command responsibility, implemented by command rotation system that has each student assume varying positions of authority during the course of the normal military training program. 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: junior standing, MS 302 and 304.

MS 401   Military Law, Ethics and Professionalism   2:0:2 or nc as arranged
The military justice system and its jurisdiction, military crimes, rights of individuals and the non-judicial and judicial options available to maintain discipline in the Army. Ethics and professionalism are discussed and their relationship to the military environment are explored. Ethical reasoning and decision-making processes developed and utilized in relation to case studies.

MS 402   Applied Leadership   2:1:0
Leadership skills of the cadet officers necessary to funtion in areas such as formal classroom instruction, planning and conducting field training exercises, administration of the cadet battalion and exercising acquired leadership and managerial skills. 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: advanced camp completion or permission of the department head.

MS 403   Pre-Commissioning Seminar   2:1:2 or nc as arranged
Preparation of senior cadets for comissioning as second lieutenants in the U.S. Army. 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.

FACULTY

CPT John W. Tarver, Assistant Professor of Military Science
B.A. Hardin-Baylor

CPT Ralph S. Zellem, Assistant Professor of Military Science
B.S., St. John's University; M.B.A., Central Michigan University

CPT Dale A. Fye, Assistant Professor of Military Science
B.S. U.S. Military Academy

SGM Morgan Highsmith, Detachment SGM, Chief NCO Instructor

MSG William B. Tate, Operations NCO, Instructor

SSG David M. Lange, Administrative NCO, Instructor

SSG Arturo Sandoval, Supply NCO, Instructor

OPERATIONS MANAGEMENT

Operations management addresses specific manufacturing and service operations to maximize the cost leverage of the organization. There is a growing perception that productivity is the key to successful world market competition and that not enough managers have the pertinent skills. Today's operations managers require skills reaching beyond those based only on industrial engineering; they must understand accounting, psychology, various productivity measurement techniques and management information system.

The roles of operations managers reach beyond production, being integrated into corporate management rather than isolated in factories. In addition to purely manufacturing settings, production and operations management techniques are used in health care organizations, financial institutions, insurance companies, transportation operations, distribution outlets, hotels, etc. Students select this program to take advantage of the current opportunities for jobs in operations management without having to choose between MBA or industrial engineering degrees.

Courses in operations management cover viewpoints and skills drawn from the fields of management and industrial engineering, including statistics, computers, work design and measurement, organization design, accounting, productivity management, statistical quality control, and organizational psychology.

This multidisciplinary graduate program is administered by the Division of Management and prepares students to manage technological, social and economic developments which affect the means and methods of satisfying needs for products and services.

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 in one of the following areas: engineering (other than industrial); physical sciences, liberal arts; business or public administration; or social sciences. Students are expected to have adequate preparation in mathematics. Those lacking such backgrounds may be admitted but are asked to take courses to make up deficiencies. Knowledge of computer programming also is assumed, or can be satsified by taking IE 501 or MG 502. Effective writing skills are also assumed, or can be satisfied by taking HU 605. Such courses are in addition to other normal degree requirements.

			Units
A. Basic required courses*			12
MA	551	Applied Statistics I (Data Analysis)	
IE	600	Engineering Economy Analysis	
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

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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.

FACULTY

Ravinder Nanda, Associate Professor of Industrial Engineering and Operations Management

Byron L. David, Instructor, Director of Operations Management Program

Norbert Hauser, Professor of Industrial Engineering and Management Science

John H. K. Kao, Professor of Industrial Engineering
B.S., National Central University (China); M.S., D.Eng.Sc., Columbia University.

Anne Eisenberg, Associate Professor of Humanities and Communications

Seymour Kaplan, Associate Professor of Operations Research and Management Science
B.S., Newark College of Engineering; M.S., Ph.D., New York University

Richard E. Wener, Visiting Assistant Professor of Psychology

ADJUNCT FACULTY

Chaim Steinberger, Adjunct Assistant Professor

OPERATIONS RESEARCH

The department of Transportation and Industrial Engineering offers 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.

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.

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. 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 APPLE and IBM-PC computers, 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.

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.

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 101-103, CM 101-102, CM 111-112, CS 100, HU 200, SS 104, SS 251-252, plus 17 credits of acceptable electives, students can complete the requirements shown on pages 218 and 219.

REQUIREMENTS FOR THE DEGREE BACHELOR OF SCIENCE IN OPERATIONS RESEARCH

		Credits
Mathematics	MA 101,[1] MA 102,[1] MA 103,[1] MA 104,[1] MA 153, MA 223, MA 224, MA 555	26
Science	CM 101, CM 102, CM 111, CM 112, CS 100[1], PH 101, PH 102, PH 103	18
Humanities	HU 101, HU 200,[1] SS 104,[1] SS 251, SS 252	15
Physical Ed[3]	PE 101, PE 102, PE 103, PE 104	0
Major	IE 254, IE 300, IE 319, IE 327, IE 328, IE 346, IE 380	21
Electives[2]	Chosen by the student in consultation with department adviser	48
	Total	128

EVENING STUDY

Most 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 OF BACHELOR OF SCIENCE IN OPERATIONS RESEARCH (Computer Science Option)

		Credits
Mathematics	MA 101[1], MA 102[1], MA 103[1], MA 104[1], MA 153, MA 223, MA 224	23
Science	CM 101, CM 102, CM 111, CM 112, PH 101, PH 102, PH 103	16
Humanities	HU 101, HU 110, HU 200[1], SS 104[1], SS 251, SS 252	18
Physical Ed[2]	PE 101, PE 102, PE 103, PE 104	0
Industrial Engrg	IE 254, IE 300, IE 319, IE 327, IE 328, IE 346, IE 380	21
Computer Science	CS 111, CS 203, CS 204, CS 205, CS 206, CS 236, CS 237, CS 238, CS 297, CS 299	28
Electives	6 credits Industrial Engineering 12 credits Humanities/Social Science, 4 credits free	22
	Total	128

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

First Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
CS	100	Intro. to Computer Progrmg[1]	2	0	2
HU	101	Writing & the Humanities I	3	0	3
MA	101	Calculus I[1]	4	0	4
PH	101	Introductory Physics I	3	0	3
SS	251	Micro-Economics	3	0	3
PE	101	Physical Education I[3]	0	2	0
					15

Second Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
HU	200	Writing & the Humanities II[1]	3	0	3
MA	102	Calculus II[1]	4	0	4
PH	102	Introductory Physics II	3½	1½	4
SS	252	Macro-Economics	3	0	3
PE	102	Physical Education II[3]	0	2	0
		Electives[2]			3
					17

Sophomore Year

CM	101	General Chemistry I	2½	0	2½
CM	111	General Chemistry Lab I	0	1½	½
IE	254	Intro. to Industrial Engrg.	3	0	3
MA	104	Appl. Differential Eqns.[1]	3	0	3
PH	103	Introductory Physics III	2½	1½	3
PE	103	Physical Education III[3]	0	2	0
		Electives[2]			4
					16

CM	102	General Chemistry II	2½	0	2½
CM	112	General Chemistry Lab. II	0	1½	½
MA	103	Calculus III[1]	3	0	3
MA	153	Elem. of Linear Algebra	3	0	3
SS	104	Main Themes in Contemp. World History[1]	3	0	3
PE	104	Physical Education IV[3]	0	2	0
		Electives[2]			4
					16

Junior Year

IE	327	Operations Research I	3	0	3
IE	380	System Simulation	3	0	3
MA	223	Intro. to Probability	3	0	3
		Electives[2]			7
					16

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

IE	319	Prodctn. Planng. & Control	3	0	3
MA	555	Design of Experiments	3	0	3
		Electives[2]			10
					16

IE	346	Oper. Des. of Public Syst.	3	0	3
		Electives[2]			13
					16

Total credits required for graduation: 128

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 Engrg.	3	0	3	IE	300	Engineering Economy	3	0	3
IE	327	Operations Research I	3	0	3	IE	328	Operations Research II	3	0	3
IE	380	System Simulation	3	0	3	MA	153	Elem. of Linear Algebra	3	0	3
MA	223	Intro. to Probability	3	0	3	MA	244	Intro. to Math. Statistics	3	0	3
		Electives[2]			4			Electives[2]			4
					16						16

Senior Year

			Cl.	Lab.	Cr.				Cl.	Lab.	Cr.
IE	319	Prodctn. Planng. & Control	3	0	3	IE	346	Oper. Des. of Public Syst.	3	0	3
MA	555	Design of Experiments[1]	3	0	3			Electives[2]	0	0	13
		Electives[2]			10						16
					16						

Total credits required for graduation: 128

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.
CS	112	Programming in Pascal	3	0	3
MA	101	Calculus I[1]	4	0	4
PH	101	Introductory Physics I	3	0	3
CM	101	General Chemistry I	2½	0	2½
CM	111	General Chem Lab I	0	1½	½
HU	101	Writing & the Humanities I[1]	3	0	3
PE	101	Physical Education I[2]	0	2	0
					16

Second Semester			Hours/Week		
No.		Subject	Cl.	Lab.	Cr.
CS	203	Computer Programming II	3	0	3
MA	102	Calculus II[1]	4	0	4
PH	102	Introductory Physics II	3½	1½	4
CM	102	General Chemistry II	2½	0	2½
CM	112	General Chem Lab II	0	1½	½
HU	200	Writing & the Humanities II[1]	3	0	3
PE	102	Physical Education II[2]	0	2	0
					17

Sophomore Year

CS	204	Intro. to Data Structures	3	0	3
IE	254	Intro. to Industrial Engrg.	3	0	3
MA	104	Appl. Differential Eqns.[1]	3	0	3
PH	103	Introductory Physics III	2½	1½	3
HU	110	Basic Report Writing I	3	0	3
PE	103	Physical Education III[2]	0	2	0
					15

CM	236	Switch Circ. & Dig. Syst.	3	0	3
MA	103	Calculus III[1]	3	0	3
MA	153	Elem. of Linear Algebra	3	0	3
SS	104	Main Themes in Contemp. World History	3	0	3
PE	104	Physical Education IV[2]	0	2	0
		Electives			3
					15

Junior Year

CS	205	Assem. & Mach. Lang. Prog.	3	0	3
CS	237	Intro. to Comput. Arch.	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	206	Compilers	3	0	3
CS	297	Computer Lab I	1	3	2
IE	328	Operations Research II	3	0	3
MA	224	Intro. to Math. Statistics	3	0	3
SS	252	Macroeconomics	3	0	3
		Electives			3
					17

Senior Year

CS	238	Computer Systems	3	0	3
CS	299	Computer Lab II	1	3	2
IE	319	Prodctn. Planng. & Control	3	0	3
IE	380	System Simulation	3	0	3
		Electives			5
					16

IE	300	Engineering Economy	3	0	3
IE	346	Oper. Des. of Public Syst.	3	0	3
		Electives			9
					15

Total credits required for graduation: 128

[1]Students may substitute IS 140, IS 141 for HU 200, SS 104. Students with strong mathematical backgrounds may substitute MA 111-MA 114 for MA 101-MA 104.
[2]ROTC students should note that 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.

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.

Behavior- **Credits**
al Sci-
ence
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

Bioengineering
BE   201   Systems Approach to Biomedicine I
BE   202   Systems Approach to Biomedicine II
CM   122   Organic Chemistry I
CM   164   Phy.Chem. of Living Systems
LS   105   General Biology I
LS   106   General Biology II
LS   115   General Biology Lab. I
LS   116   General Biology Lab. II

Computer Science
CS   203   Computer Programming II
CS   204   Intro. to Data Structures
CS   205   Assem. & Mach. Lang. Prog.
CS   206   Compilers
CS   236   Switch. Circuits & Digital Syst.
CS   237   Intro. to Computer Architecture
CS   238   Computer Systems
CS   297   Computer Laboratory I
CS   299   Computer Laboratory II

Control Systems
EE   101   Electrical Systems I
EE   102   Electrical Systems II
EE   103   Electrical Systems III
EE   104   Feedback System Principles
EE   107   Control System Design
EE   111   Solid-State Devices & Circuits I
EE   141   Signal Processing

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   612   Human Resources Management
MG   664   Management and the Legal System
MG   606   Managerial Finance
MG   607   Marketing Management
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   Intro. to 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   361   Transportation Demand and Models
TR   362   Public Transportation
TR   753   Mgmt. of Transp. & Distrb. Opers.

Urban Systems
IE   346   Oper. Design of Urban Systems
LS   140   Environmental Biology
SS   180   Sociology of Urbanization
SS   182   Man and the Environment
SS   190   Environmental Psychology
SS   264   Urban Economics
TR   600   Char. of Transp. Demand & Syst.
TR   602   Urban Transportation Planning

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 information science, system simulation, management science, experimental design, mathematical programming, social systems dynamics, 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 IE 531 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 Systems
IE 680 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]   15 units
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 groups B and 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 505, and MG 630.

[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.

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.

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.

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	Information Structures & Algorithms
CS 613	Computer Architecture I
CS 623	Operating Systems I
CS 637	Programming Languages
CS 641	Compiler Design & Construction I

Two of the following three:
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: IE xxx

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. An examination in one foreign language is required, ordinarily French, German or Russian.

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.

*If a student must take more than four of the CS 500 series courses, the minimum total number of credits required is increased correspondingly.

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, Professor of Transportation and Industrial Engineering; Head, department of Transportation 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.

John T. Chu, Professor of Operations Research and Management Science
B.S., University of Chekiang (China); M.S., Ph.D., Iowa State University
Managerial decisions, behavioral approaches, national and international affairs

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

John H. K. Kao, Professor of Industrial Engineering and Operations Research
B.S., National Central University (China); M.S., Eng.Sc.D., Columbia University
Probability and statistics, quality control and reliability, scientific computing, electronic data processing

Joachim I. Weindling, 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

OPERATIONS RESEARCH

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, manu-
facturing engineering, industrial management*

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

Ravinder Nanda, Associate Professor of Industrial Engi-
neering and Operations Management
B.Sc., Banaras Hindu University (India); M.S., Ph.D.,
University of Illinois
*Production and operations planning, productivity analysis,
project control*

ADJUNCT FACULTY

Maureen Dolan, Adjunct Lecturer
B.A., Molloy College; M.S., Stevens Institute of Technolo-
gy; M.S., Polytechnic Institute of New York

Chaim Steinberger, Adjunct Assistant Professor
M.S., Polytechnic Institute of New York

PHYSICAL EDUCATION

The major goal of the required physical education program is to educate and interest students in a wide variety of physical activities so they may develop skill and success while experiencing an optimum condition of physical fitness in terms of strength, speed, ability and endurance. The program teaches skills in interesting lifetime sports: tennis, racquetball, badminton, as well as innovative programs in aerobics, self defense, weight training, and cardiopulmonary resuscitation (CPR), and team sports such as volleyball.

Athletics

Student athletes attending Polytechnic compete in a far-reaching intercollegiate athletic program that encompasses all phases of sports. All full-time undergraduate students in good academic standing are eligible to try out for positions on the seven varsity teams which carry the blue and white colors of Polytechnic in N.C.A.A. competition. Intercollegiate sports are men's baseball, basketball, cross-country, soccer, tennis, wrestling, lacrosse, Judo, & women's volleyball, softball, cross-country, and tennis.

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.

All undergraduate students are required to complete four semesters of physical education in any of the following course offerings:

PE 101   Team and Lifetime Sports   0:2:0
Fundamental conditioning exercises, basic skills and strategy needed while participating in team and carry-over sports, volleyball, basketball, soccer, tennis, badminton, softball, football, handball, paddleball and golf.

**PE 102   Cardiopulmonary Resuscitation
          and Weight Training   0:2:0**
This course is divided into two sections. One hour a week of CPR gives students principles and techniques of how to maintain breathing and circulation in a victum suffering from cardiac arrest. In the second hour, all students participate in an individual weight-training program.

PE 103   Aerobics   0:2:0
Exercise program set to music. The aim of the course is to increase the cardiovascular performance of the students.

PE 104   Weight Training   0:2:0
Individual weight-training programs produce increased strength and endurance through isotonic and isometric exercises.

PE 101S   Self Defense   0:2:0
Instruction in the art and skills of judo and karate as they appply to defending oneself in everyday situations.

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

Edward J. Collins, Instructor

Maureen Braziel, Instructor
B.A., Hunter College

Louis Zinser, Assistant Director of Athletics
B.S., University of Balitmore; M.S., Hofstra Unversity

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 the majority of 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 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

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 101-103, 115, 210, 250, 302, 311, 323-324, 334-335, 336, 340, 347, 360, 373, 374, 390	56
CM 101, 102, 111, 112; MA 101-104, 153, 260, 217; CS 111	33
HU 101; HU 200 and 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.

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, one of the country's largest, 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.

Typical Course of Study for the Bachelor of Science Degree in Physics

Freshman Year

First Semester No.	Subject	Cl.	Lab.	Cr.
CS 112	Programming in Pascal	3	0	3
MA 101	Calculus I	4	0	4
PH 101	Intro. to Physics I	3	0	3
PH 115	Seminar in Current Physics	2	0	2
	Hum./Soc. Sci. elective	6	0	6
PE 101	Physical Education	0	2	0
				18

Second Semester No.	Subject	Cl.	Lab.	Cr.
CM 101	General Chemistry I	2½	0	2½
CM 111	General Chemistry Lab.	0	1½	½
MA 102	Calculus II	4	0	4
PH 102	Intro. Physics II	3½	1½	4
	Hum./Soc. Sci. elective'	6	0	6
PE 102	Physical Education	0	2	0
				17

Sophomore Year

First Semester	Subject	Cl.	Lab.	Cr.
CM 102	General Chemistry II	2½	0	2½
CM 112	General Chemistry Lab. II	0	1½	½
MA 103	Calculus III	3	0	3
PH 103	Intro. Physics III	2½	1½	3
PH 210	Analyt. Mechanics	3	0	3
	Hum./Soc. Sci. elective'	3	0	3
PE 103	Physical Education	0	2	0
				15

Second Semester	Subject	Cl.	Lab.	Cr.
MA 104	Appl. Diff. Eqs.	3	0	3
MA 153	Elem. Linear Alg.	3	0	3
PH 334	Quantum Phys. I	2½	1½	3
PH 250	Electronics for Physical Scientists	3	3	4
	Hum./Soc. Sci. elective'	3	0	3
PE 104	Physical Education	0	2	0
				16

Junior Year

First Semester	Subject	Cl.	Lab.	Cr.
PH 311	Thermodynamics	3	0	3
PH 323	Electricity and Magnetism I	2	0	2
PH 335	Quantum Phys. II	3	0	3
MA 260	Vector Anal. & PDE	4	0	4
	Hum./Soc. Sci. elective	3	0	3
				15

Second Semester	Subject	Cl.	Lab.	Cr.
PH 302	Advanced Lab.	1	3	2
PH 324	Electricity and Magnetism II	2	0	2
PH 336	Quantum Mechanics	3	0	3
PH 340	Computer Meth. in Physics	3	3	4
PH 360	Special Topics	3	0	3
	Hum./Soc. Sci. elective'	3	0	3
				17

Senior Year

First Semester	Subject	Cl.	Lab.	Cr.
PH 347	Modern Optics	3	3	4
PH 373	Intro. Theo. Phys. I	3	0	3
MA 217	Complex Variables	3	0	3
PH 663	Stat. Mech. I² **or**			
PH 667	Quantum Mech.' I²	3	0	3
	Hum./Soc. Sci. elective'	3	0	3
				16

Second Semester	Subject	Cl.	Lab.	Cr.
PH 374	Intro. Theo. Phys. II	3	0	3
PH 390	Senior Seminar	2	0	2
PH 664	Stat. Mech. II² **or**			
PH 668	Quantum Mechanics II²	3	0	3
	Hum./Soc. Sci. elective²	6	0	6
				14

'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.

²Advanced Electives strongly recommended for students intending to pursue graduate studies in physics. Other posible electives include Advanced Lab. II (PH 303), X-ray Diffraction (PH 372), Readings in Physics (PH 381-2), courses in PH 6.. sequence.

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 101   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. Co/Prerequisite: MA 101.

PH 102   Introductory Physics II   3½:1½:4
Continuation of PH 101. Thermodynamics and kinetic theories of gases. Electromagnetic fields and forces and their interactions with particles. Principles and instruments of classical and modern measurements. Lab fees required. Prerequisite: PH 101 and Co/Prerequisite: MA 102.

PH 103   Introductory Physics III   2½:1½:3
Continuation of PH 102. Propagation of waves, particularly as illustrated through studies of physical and geometrical optics. Lab fee required. Prerequisite: PH 102.

PH 115   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 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 103.

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 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 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 334.

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 334   Quantum Physics I   2½:1½:3
Kinetic theory, relativity, quantization, x-rays, atomic physics, solid state, nuclear, high energy physics. Lectures, discussion sessions and six laboratory sessions during the semester. Prerequisite: PH 103.

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 or PH 334

PH 336   Quantum Mechanics   3:0:3
Introduction to the calculatical methods of quantum mechanics — with examples and appliations. Prerequisite: PH 335.

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, elementary quantum mechanics and the interpretation of experimental data will be discussed. Strategies to determine if computer results are physically reasonable. Numerical simulation techniques for experimental 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 diffractions of waves and wave packets, Fourier transform optics. Coherence and quantum aspects of light. The laboratory includes computer simulations of optical phenomena, and emphasizes lasers, holography, crystal optics, and nonlinear phenomena. Prerequisites: 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 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. Prerequisite: MA 104 and PH 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 equations. 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. Prerequisites: 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 magnetism, 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 107. 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 development 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 experimental physics, depending on requirements of thesis students and recommendations of advisers. Vacuum techniques, thin-films, preparation of samples for solid-state studies, crystal growing, cryogenics 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 functions of mathematical physics. Differential equations of mathematical 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 variations and eigenvalue problem. Green's function solutions to differential 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 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.
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 equations. Small vibrations of coupled systems, normal modes of oscillation. Prerequisite: PH 313 or equivalent.

PH 616   Theoretical Mechanics II   2½:0:3
Hamiltonian mechanics. Transformation theories of mechanics including the Hamilton-Jacobi and Poisson bracket formulation, Lagrangean formulation of mechanics of continuous media. Prerequisite: PH 615.

PH 624   Electromagnetic Theory I   2½:0:3
Maxwell's equations. Plane waves. Relativistic covariance of electromagnetic field. Motion of charges in fields. Fields of moving charges. Hertz and Lienard-Wiechert potentials. Radiation from charges, dipoles and quadrupoles. Prerequisite: PH 321.

PH 625   Electromagnetic Theory II   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 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 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 mechenics 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 renormalization 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; gravitational 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 and Head of Physics
B.A., Swarthmore College; Ph.D., Cornell University
Solid state physics and electron tunneling

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 Nuclear Engineering and 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; 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

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
Physics education

Walter Kiszenick, Associate Professor of Physics and Nuclear Engineering
B.S., Brooklyn College; M.S., Ph.D., Polytechnic Institute of Brooklyn
X-ray diffraction; medical physics

Meir Menes, Associate Professor of Physics
B.S., Cooper Union; Ph.D., New York University
Experimental solid-state physics; gaseous electronics

Peter Riseborough, Associate Professor of Physics
B.S., Ph.D., Imperial College (England)
Theoretical condenser matter physics

Donald B. Scarl, Associate Professor of Physics
B.A., Leigh University; Ph.D., Princeton University
Quantum optics; atomic physics

Peter Hanggi, Assistant Professor of Physics
B.S., College of Mathematics and Natural Sciences-Basel; M.S., Ph.D., University of Basel (Switzerland)
Statistical mechanics

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

Hubert W. Schleuning, Adjunct Research Professor of Physics
M.A., New York University; M.E., Polytechnic Institute of Brooklyn

Benjamin Bloch, Adjunct Assistant Professor of Physics
B.S., Columbia University; Ph.D., Polytechnic Institute of Brooklyn

EMERITUS FACULTY

John J. Dropkin, Professor Emeritus
B.A., Columbia University; M.S., Ph.D., Polytechnic Institute of Brooklyn
Solid-state 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
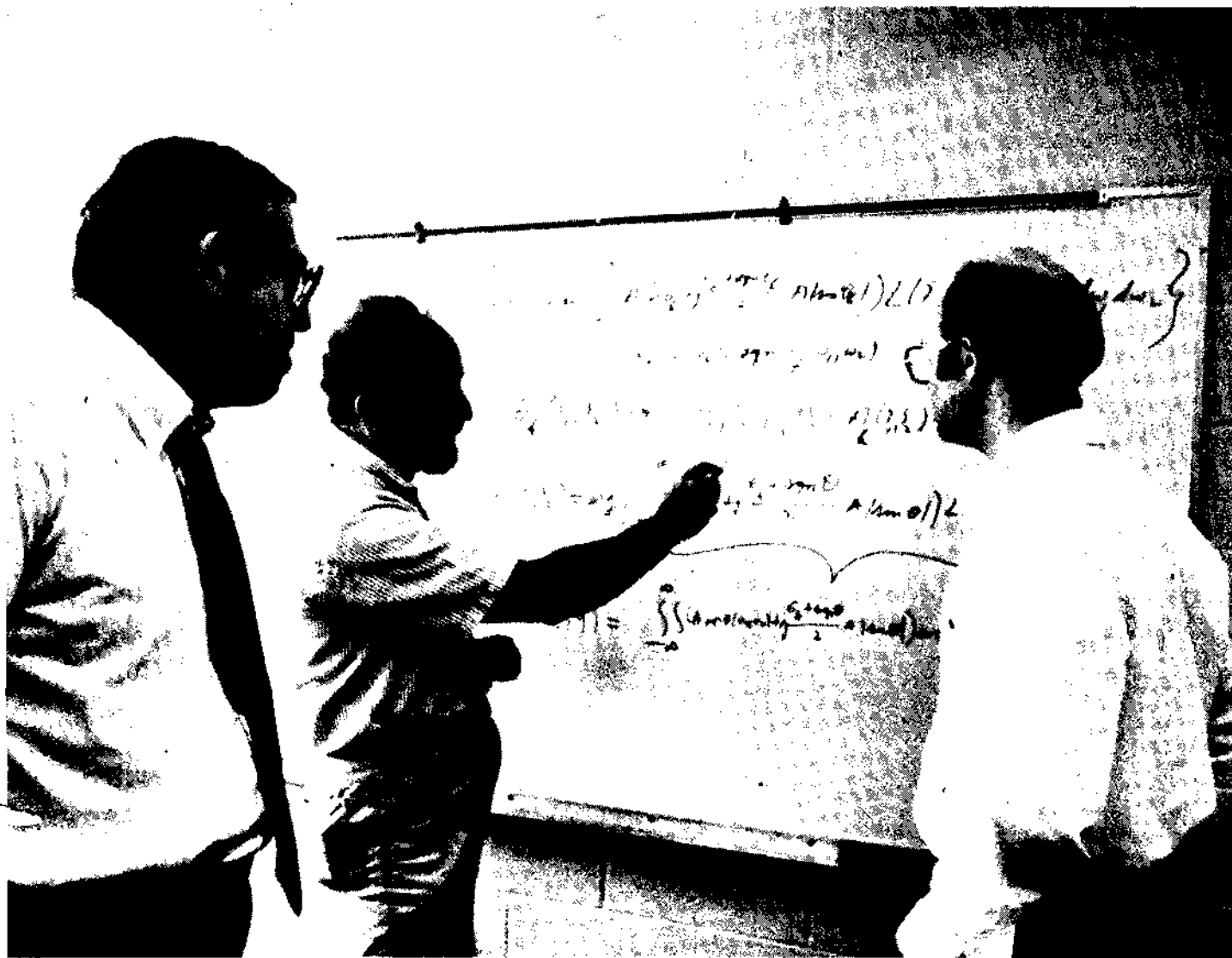
POLYMER SCIENCE AND ENGINEERING

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.

All candidates for doctorates must complete a minimum of 90 units of academic work beyond bachelor's degrees, including a minimum of 30 units of dissertation research. Although students 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 students have started dissertations, 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. All students must maintain overall B averages in those courses submitted for doctoral degrees.

*All electives are to be chosen in conference with the graduate adviser.

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, are available from the office of the polymer science and engineerig 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 opeations. 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 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

Frederick Elrich, Distinguished Professor of Polymer Chemistry

T.K. Kwei, Research Professor of Polymer Chemistry

Herbert Morawetz, Institute Professor

Yoshiyuki Okamotor, 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, Head of 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 T. Winter, Associate Professor of Polymer 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. Core curricula were 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 with 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 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, 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   . These courses may be used to fulfill requirements for Bachelor of Science degrees in social sciences.

MAJOR CONCENTRATIONS

(Students may choose from the following courses to fulfill requirements for major concentrations.

History[1]
SS 110	Renaissance and Reformation Era
SS 115	History of Africa
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 125	American Radicalism and Reform
SS 126	Afro-American History
SS 127	American Economic History in the Industrial Era
SS 128	History of Jazz
SS 129	Growth of the United States Constitution
SS 130	The American Revolution
SS 132	Problems of American Foreign Policy
SS 144	Colloquium in the Intellectual History of Europe during the 19th Century
SS 145	Colloquium in 20th Century Thought
SS 147	Colloquium in Imperialism
SS 148	Colloquium in the History of Socialism and Communism
SS 149	Colloquium in the History of Marxism
SS 153	Revolutions in Comparative Historical Perspective
SS 154	Russia, China, and the West
SS 161	Politics and Film
SS 179	Sociology of Human Diseases
SS 622	Theory and History

History of Science and Technology[1]
(SS 101-102 required)
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 139	Technological Forecasting
SS 140	Science and Technology in America
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 620	History of Biology
SS 621	Development of Physical Theory from Maxwell to Einstein
SS 622	Theory and History
SS 625	History of Technology: Antiquity through Early Industrial Revolution
SS 626	History of Technology: Industrial Revolution to the Present
SS 631	Seminar in the Sociology of Science
SS 635	History of Psychology

Behavioral Sciences
SS 139	Technological Forecasting
SS 157	Topics in Comparative Politics I
SS 158	Topics in Comparative Politics II
SS 177	Social Problems
SS 178	Minorities in the New World
SS 179	Sociology of Human Disease
SS 180	Sociology and Urbanization
SS 182	Man and the Environment
SS 187	World Prehistory
SS 188	Social Change and Evolution
SS 190	Environmental Psychology
SS 191	Social Psychology
SS 195	Abnormal Psychology
SS 196	Psychology of Stress and Relaxation
SS 197	Personality Development
SS 198	Psychology of Human Development
SS 199	Organizational Behavior
SS 203	Learning
SS 204	Physiological Psychology
SS 205	Comparative Psychology
SS 211	Cultural Backgrounds of African Nations
SS 212	Cultural Backgrounds of the Nations of Asia
SS 213	History and Culture of Americans Called Indians
SS 310	Genes, Gender, and Society
SS 631	Seminar in Sociology of Science

Psychology
SS 190	Environmental Psychology
SS 191	Social Psychology
SS 192	Experimental Psychology I (required)
SS 193	Experimental Psychology II (required)
SS 194	Drugs and Behavior
SS 195	Abnormal Psychology
SS 196	Psychology of Stress and Relaxation
SS 197	Personality Development
SS 198	Psychology of Human Development

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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
[1]History and History of Science options may be combined.

SS 199	Organizational Behavior
SS 203	Learning
SS 204	Physiological Psychology
SS 205	Comparative Psychology
SS 206	Human Cognition
SS 635	History of Psychology

Economics

SS 127	American Economic History in the Industrial Era
SS 138	Technology, Science and Contemporary Society
SS 139	Technological Forecasting
SS 255	The Contemporary American Economy: Boom and Bust
SS 257	History of Economic Thought
SS 258	Comparative Economic Systems
SS 259	Economic Development
SS 262	Collective Bargaining
SS 263	Labor Economics
SS 264	Urban Economics
SS 265	Money and Banking
SS 266	Libertarian Economics
SS 267	The Market for Engineers and Scientists
SS 700	Industrial Organization of The American Economy
SS 711	Advanced Economic Theory
SS 713	Econometrics

GRADUATE STUDY

The Department of Social Sciences offers courses leading to the Master of Science degree in the History of Science and Technology and 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 from 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. They will also learn how to use data gathering methods in developing functional programs for spaces.

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 listed courses as well as courses in the Departments of Transportation Planning, Social Sciences, and Operations Research. Interaction is possible with the Energy Engineering and Policy Program.

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, all of these, in the contexts of technology assessment, environmental impact assessment, risk assessment and cultural resources management.

Electives for this program may include the listed courses, and courses from Social Sciences, the History of Science and Technology Program, Industrial Engineering and Operations Research, Civil and Environmental Engineering, Humanities, and Management as well, and also may include cooperation with the Environmental Health Science Program.

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. Students utilize behavioral and psychophysical techniques to assess user responses to changes in communication networks, systems, and software. They develop assessment skills for environmental and organizational changes caused by new technologies. This new concentration is designed for planners, interior designers, architects, programmers and systems analysts, and people involved in designing office technologies.

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. The range of stresses which may be studied include crowding, noise pollution, electrical fields, building vibration, excessive light and heat, and air or water pollution. Effects to be monitored may include physiological measures such as sleep patterns, blood pressure, gastric pathology, and behavioral measures such as performance on learning tasks and reported levels of comfort. Electives for these programs may include listed courses as well as courses from the Department of Civil and Environmental Engineering and Mechnical and Aerospace Engineering.

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 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 115 History of Africa* 3:0:3

Pre-colonial African history; origin of man; Egypt, Ethiopia, Kush and Southwest Asian ties; medieval West African kingdoms and trade across Sahara; coastal trading cities of East Africa, India, Chian. Slave trade; European conquest; struggles for independence. Contemporary African states in world politics.

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

Revolution 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.

SS 127 American Economic History in the Industrial Era 3:0:3

The United States from late 19th century to present; rise of industry; closing of frontiers; progressive era; Great Depression and New Deal; World Wars and aftermath. Particular attention to economic roles of government.

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 129 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 tests.

SS 130 The American Revolution* 3:0:3

Origins, nature and consequences of American Revolution: growing struggle with Great Britain after 1760; military history of revolution—guerrilla versus conventional warfare. Political and economic history of revolution: roles of nationalists and libertarians; aftermath and consequences.

SS 132 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, international rivalries; impacts of domestic influences; diplomacy of infant republic; Monroe Doctrine; "manifest Destiny;" "white man's burden;" open-door policy; "dollar diplomacy;" World Wars and their settlements; Cold War and aftermath.

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 technology 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 Lavoisier 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 maturation 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 technology; social effects of recent technological and scientific developments; policy issues posed by restricted and unrestricted uses of technology and science.

SS 139 Technological Forecasting 3:0:3

Technological innovations. Forecasting methodologies for short- and intermediate-range forecasting. Long-range trends and technology of post-industrial society. Discussions of alternate scenarios. Predictable and unpredictable consequences of innovations. Long-range technology forecasting. Students prepare forecasts on topics of their choice.

SS 140 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 status.

SS 144 Colloquium in Intellectual History of 19th-Century Europe* 3:0:3

European thought and artistic and scientific tendencies against background of political, economic, social institutions and changes. Discussions of selected sources in politics, economics, science, the arts.

SOCIAL SCIENCES

SS 145 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.

SS 147 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 or equivalent.

SS 148 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.

SS 149 Colloquium in the History of Marxism* 3:0:3
Marxist writing in philosophy, sociology, political economy, history from 19th-century intellectual and historical perspective. Marx's impact on intellectual generations of 1890 and 1914. Creation of Marxism by Engels and his circle. Marxism and working-class movements. Leading Marxists of 19th and 20th century: Bernstein, Kautsky, Hilferding, Lenin, Trotsky, Gramsci, Korsch, Althusser, Luxemburg, Marcuse. Marxism and contemporary social 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 American political system. Clashing ideologies of democratic society.

SS 153 Revolutions in Comparative Historical Perspective* 3:0:3
Eighteenth-century quests for reason and rights of man. American and French Revolutions compared. Nineteenth-century extension of radical traditions. Bolshevik revolution as culmination and new departure. Twentieth century as age of global revolution; peasant societies of Thrid World. "Post-scarcity" transformations and possibilities in advanced West.

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, communism 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 157-158 Topics in Comparative Politics* each 3:0:3
Analyses and research of politics of advanced and emerging areas: party systems in United States, Soviet Union, People's Republic of China. National interests and conflicts in international relations; liberty and authority; pluralism and power; administrative web; judicial institutions.

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 discussions. Lab free required. May be repeated for credit.

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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 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-speaking minorities of Puerto Rican and Mexican descent in United States compared with ethnic and racial counterparts in Puerto Rico, Cuba, and Brazil.

SS 179 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.

SS 180 Sociology and Urbanization* 3:0:3
Origins and history of urbanization, ecology of contemporary cities and urban-rural relations, urbanism, family patterns, personality development. Social-economic stratification, distribution of power, comparative analyses of urbanization in non-Western world. Student projects on urban problems.

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 183 History and Environment 3:0:3
Changing human evironmental support systems and societal and technological respohses at three critical historical junctures: the ancient world; the early modern period; and the twentieth century. Discussions focus on current environmental issues.

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 187 World Prehistory* 3:0:3
World history from emergence of humans to development of early civilizations; introduction to archaeology; early man in old and new world patterns of migration; trade; rise of farming and sedentary life; development of civilizations in Mesopotamia, Egypt, China, India, Africa, Peru, Mexico, Guatemala.

SS 188   Social Change and Evolution*   **3:0:3**
Theories of social change, "evolutionary" versus "functionalist" views. Evolution of social institutions through various stages of human history. Implications for solutions to contemporary social problems in both industrial societies and underdeveloped nations.

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 190   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 191   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 192   Experimental Psychology I*   **2:3:3**
Philosophy, theory and methods of measurement of functions of human and animal sensory and perceptual systems. Theoretical approaches to problems of sensory thesholds: classical psychophysical theory, neutral quantum theory and signal detection. Metric and nonmetric methods of scaling attitudes, preferences and judgments. Psychophysics of various sensory modalities. Prerequisite: SS 189.

SS 193   Experimental Psychology II*   **2:3:3**
Complex learning and verbal behavior. Students design, complete and analyze experiments dealing with learning verbal responses, concept formations, communication nets and perform original experiments designed with help of instructor. Laboratory reports required. Lectures on substance and methods of experiments. Prerequisite: SS 192.

SS 194   Drugs and Behavior   **3:0:3**
Mechanisms of action of various classes of drugs: tranquilizers, stimulants, analgesics, narcotics, hallucinogenics. Discussions on neurophysiological and pharmacological bases of drug action and behavioral effects of different drugs. Economic, historical, political, sociological, anthropological aspects of drug uses and abuses. Prerequisites: SS 189 and CM 105.

SS 195   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 196   Stress and Relaxation*   **2:3:3**
Behavioral, physiological and anatomical changes which result from stress and relationships between stress and disease. Techniques of reducing stress and anxiety: Jacobsen's relaxation technique, meditation, yoga and biofeedback. The laboratory gives students opportunities to measure the body's behavioral and physiological responses to stress and anxiety and to practice relaxation techniques including yoga and biofeedback training. Prerequisite: SS 189.

SS 197   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 198   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 199   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 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   Comparative Psychology*   **3:0:3**
Comparative studies of behavior of different species by ethological and behavioral approaches. Genetics of behavior, neural and hormonal controls of innate behavior, effects of early experience, generality of conditioning and learning. 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 211   Cultural Backgrounds of African Nations*   **3:0:3**
Precolonial history and cultures of Africa. Colonialism, changing forms of political, economic and social organization. Emergence of nationalism, Pan-Africansim, movement for independence. Contemporary sociopolitical and economic developments with case studies and student projects on selected areas.

SS 212   Cultural Backgrounds of Nations of Asia*   **3:0:3**
Ecological and cultural areas of Asia in relation to Asian history. Origin and development of urban society in Middle East and expansion into China and India. Classical cultures of China, India, Southeast Asia. Relations with surrounding tribesmen. Impact of Western imperialism. Contemporary social, economic, political developments with student projects on selected countries.

SS 213   History and Culture of Americans Called Indians   **3:0:3**
Peopling of North America and cultural adaptations to its various regions. Indian relations with Spanish, French, Dutch, English; mission activity, exploration, trade, war. Westward movements of settlers and struggles for land. Changing patterns of Indian societies. Contemporary Indian life and sociopolitical orientations — rural and urban.

ECONOMICS

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.

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. Evaulations 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.

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 252 or SS 254 or equivalent.

SS 258   Comparative Economic Systems*   3:0:3
Concepts of history of economic systems: capitalism, socialism, the market and planning. Income distribution, resource allocation and modes of economic decision-making under alternative socio-economic systems. Comparisons of centrally planned communist economies, such as in the Soviet Union or Cuba, and the market-socialism of Yugoslavia with the regulated capitalist economy of the United States.

SS 259   Economic Development*   3:0:3
Theories of development for both advanced and underdeveloped economies. Different historical paths to development. Problems of technological change. Capital accumulation. Economic planning.

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).

SS 263   Labor Economics*   3:0:3
Theoretical and empirical analyses of operations of labor markets in job-oriented cultures. Labor force composition and trends, nature of labor markets, significance of wages and income security, trade unionsim and collective bargaining, automation. Related issues, poverty, urban environments.

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.

SS 265   Money ann 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, inflation, business fluctuations. Domestic and international monetary policy.

SS 266   Libertarian Economics*   3:0:3
Libertarian, free-market analysis of economy and government policy. Contrasting nature and consequences of goverment operation and intervention into economy with workings of the market. Alternative free market solutions examined for problems now met by political intervention.

SS 267   The Market for Engineers and Scientists   3:0:3
Growth of the technological professions; social implications of technological 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.

INTERDISCIPLINARY

SS 300-301   Guided Readings in
Social Sciences   each 3:0:3
Selected problems in social sciences—history, economics, anthropology, sociology, psychology, politics, interdisciplinary studies. Individual or group projects under faculty supervision involving guided 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 department's permission.

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.

SS 357   Technology Transfer to Developing Countries
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 IE 357

SS 358   Human Resource Development in Advanced Developing Countries
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.
Also listed under IE 358

Special Topics

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 quantification, historiography of science, history of ecology, science and social thought. Main topic chosen by students and instructor. Training 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 615†   Guided Reading in History of Ideas   2½:0:3
Independent studies of leading interpretive works and sources in intellectual history of Western civilization. Regular tutorial sessions and periodic study-faculty colloquia. Course may be taken twice for credit with different topical emphases and instructors consent. Comprehensive written examination.

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 620†   History of Biology*   2½:0:3
Principal issues of biologists, solutions which they have offered, and relationships between these solutions and the technical capacities both of investigators and philosophical and other "sets" inherent in milieu of investigators.

**SS 621†   Development of Physical Theory
from Maxwell to Einstein*   2½:0:3**
Origins of knowledge which eventually led to criticism of Newtonian synthesis and attempts to find suitable, more general replacement.

SS 622†   Theory and History*   2½:0:3
Advanced studies of techniques and philosophies of historical writing with special reference to work of widely known historians: Burckhardt, Croce, Meinecke, Bloch, Namier, Beard, Toynbee, Huizinga, Sarton, Pirenne.

**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 interactions of science and technology. SS 625 prerequisite: SS 600 or equivalent. SS 626 prerequisite: SS 601 or equivalent.

SS 631   Seminar in Sociology of Science*   2½:0:3
Materials and sources from sociology and history of science dealing with mutual interactions between science and society, professionalization and specialization, growth of scientific institutions, models of scientific growth, problems associated with social organization of science.

SS 635†   History of Psychology*   2½:0:3
Survey of psychology against background of periods in which principal modern schools and issues emerged. Early psychology as speculative 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 environment studies or instructers consent.

SS 672   Technological Forecasting   2½:0:3
Problems of technological forecasting. Morphological analysis, extrapolations of trends, heuristic and intuitive forecasts. Consideration of rational directing of technological change. Students prepare forecasts on topics of choice.
Also listed under MG 672

**SS 675†   Technology Transfer to
Developing Countries   2½:0:3**
Levels of technology: village, intermediate, advanced. Mechanisms of technology transfer to less developed countries. National and international means to stimulate or block transfer. Ecological, social and economic factors in technology selection and utilization. Technology and political influence. Case studies of recently industrializing nations.
Also listed under IE 757

**SS 676†   Human Resource Development in
Developing Countries   2½:0:3**
Spectra of technology-related manpower needs in less developed countries. Education of engineers, technicians and skilled mechanics. Uses of foreign personnel, foreign schools, "brain-drain" problems. Economic consequences. Comparisons of educational systems of Western, Eastern and developing countries. Designs of curricula to suit national needs. Roles of technical assistance programs. Forecasting of human resource needs.
Also listed under IE 758

ECONOMICS

**SS 700†   Industrial Organization of
American Economy*   2½:0:3**
Monopoly and competition in America. Effects of industrial structure on business performance—profit rates, output, etc., and business behavior—collusive practices, price discriminations, etc. Other economic and political implications of concentration. Antitrust and other governmental attempts at social control. Alternative theories of industrial organization. Available to undergraduate majors in social science. Prerequisite: instructor's consent.

SS 711   Advanced Economic Theory*   2½:0:3
Advanced microtheory. Theory of utility and demand. Theory of prices and markets, profits, interest, capital, rent and wages. Monopoly and competition. Methodology of economics. Prerequisite: SS 251 or instructor's consent.

SS 713† Econometric Models and Methods* 2½:0:3
Econometric models with and without stochastic formulations. Supply and demand, elementary Keynesian model, consumption functions. Linear hypothesis and multiple regressions, linear models with errors in variables, time series anlaysis, autoregressive and distributed lag models. Simulataneous equation models. Prerequisites: SS 251 or SS 252 and MA 092 and MA 232, or equivalents.

SS 730 Mathematical Economics* 2½:0:3
Contributions of mathematical analysis to traditional economic problems. Basic mathematical tools. Capital theory, economic growth, static equilibrium, individual behavior, welfare economics. Subjects of special interest to students. Assumptions underlying (axiomatic to) models. Given these assumptions, necessary consequences deduced with some rigor.

PSYCHOLOGY

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 908† Experimental Psychology I* 2½:3:3
Research designs, evaluations and treatments of experimental data. Psychophysics and scaling techniques, signal detection, simple and complex learning in both humans and animals. Prerequisite: SS 189, equivalent or instructor's consent.

SS 909† Experimental Psychology II* 2½:3:3
Methods, paradigms and procedures for laboratory and field research with human subjects, including social and environmental psychology. Students perform research in laboratory and field settings using b oth experimental and quasi-experimental research designs. Development of research skills for a wide variety of situations. Prerequisite: SS 908†, equivalent or instructor's consent.

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 914 Comparative Psychology* 2½:0:3
Comparison of behavior of different species as function of ethological and psychological variables. Behavior genetics, neural and hormonal control of behavior, behavioral consequences of special sensory structures, species-specific behavior, development of behavior and concept of critical period, communication, and other social behavior and conditioning. Prerequisite: SS 189 or equivalent or instructor's consent.
Also listed under BE 676

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 majors. 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 935 Engineering Projects Related to Public Administration each 3 units

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, cognitive development, psycholinguistics and cognition.

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, contempo-
rary 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*

David Mermelstein, Professor of Economics
B.A., Amherst College; Ph.D., Columbia University
*Radical economics, current macroeconomic problems,
comparative economic systems, urban fiscal problems*

Murray N. Rothbard, Professor of Economics
A.B., M.A., Ph.D., Columbia University
Political and economic history; Austrian economics

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
B.A., M.A., Ph.D., Cornell University
History of science, Galilean studies, history of biology.

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, histo-
ry 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 thesse 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 envirionment, 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 enginering 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 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 enginering 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 deparmtental *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

John H. K. Kao, Professor of Industrial Engineering

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 Electric Engineering

Martin L. Shooman, Professor of Electric 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 Electric Engineering

Wen Yuan Xu, Visiting Professor of Electrical Engineering

TELECOMMUNICATIONS MANAGEMENT
(NEW OFFERING)

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.

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 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 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.

An all-inclusive fee covers tuition and fees, text books and other educational material, special tutorials and lectures, meals on class days, use of electronic mail system 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.

The courses in the curriculum are:

1st semester:
EL 635   Principles of Communication Networks
MG 600   Management Process
MG 650   Management of Information Systems

2nd semester:
MG 609   Managerial Accounting and Finance
MG 652   Telecommunications Regulation, Policy and Law
MG 820   Project Management

3rd semester:
EL 735   Communication Networks
MG 654   Economics of Information Systems
MG 970   Business Policy and Strategy I

4th semester:
CS 681   Information Privacy and Security
MG 607   Marketing Management
MG 971   Business Policy and Strategy II

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.

MS 650 Management of Information Systems
The structure of information processing, information storage, information transport, and user services within organizations. Centralized versus decentralized management. The relation of distributed processing, distributed databases, and telecommunication network topology to organizational structure. The management of voice and data acquisition; benchmarking; information system contracting; pricing of information services. Operations of information systems including site planning, design and preparation; maintenance; performance monitoring; training.

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 654   Economics of Information Systems
The concepts of market supply and demand as it applies to the market for information services and products; the rationales for, and nature of, emerging applications of infrmation systems; the availability and pricing of services; methods of economic decision making and justification of business information systems.

FACULTY

Richard Van Slyke, Professor of Electrical Engineering and Computer Science; Director of the Center for Advanced Technology in Telecommunications. B.S., Stanford University; Ph.D., University of California at Berkeley.
Computer communications; telecommunications

A. George Schillinger, Professor of Management
B.E.E., City College of New York; M.S. Eng., Sc.D., Columbia University
University general management, technology management, and corporate strategy

Aaron Kershenbaum, Associate Professor of Computer Science
B.S., M.S., Polytechnic Institute of Brooklyn; Ph.D., Polytechnic Institute of New York.
Computer communications, algorithms

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

Robert Flynn, Industry Professor of Computer Science
B.S., Manhattan College; M.S., Ph.D., Polytechnic Institute of Brooklyn
Computer architecture and operating systems

Byron David, Academic Director of Management Divsion
B.A., Queens College of the City University of New York; M.S., Polytechnic Institute of New York
Operations Management; project management

ADJUNCT FACULTY

Anne Wells Branscomb, Adjunct Professor
B.A., Georgia College; B.A., University of North Carolina; M.A., London School of Economics; J.D., George Washington University Law School

Dennis J. Dugan, Adjunct Professor
B.S., Creighton University; Ph.D., Brown University

E. Hart Rasmussen, Adjunct Professor of Management, Director, Management Programs, Westchester. B.S., M.S., Technical University of Denmark

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 transportation degree programs are in the Department of Transportation and Industrial Engineering. The Department also cooperate with the Department of Civil and Environmental Engineering to provide a program in Highway Engineering as part of master's degree programs in Civil Engineering.

Students and continuing professionals from a variety of disciplines undertake studies in transportation to lead to careers in transportation planning, operations, design, 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 a baccalaureate degree or its equivalent from an acceptable institution. The department admits students with undergraduate degrees in engineering, the sciences, social sciences, and the arts.

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. Those not meeting the mathematics requirement fully may be admitted, but must take TR 500 (Introduction to Transportation Analysis and Computations), which is not counted for graduate work.

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

There are no prerequisite requirments other than the computational requirements of TR 500. Students will be exposed, however, to uses of computers and computer packages in transportation integrated into the curricula. Emphasis is on personal computers. The Department has its own computer laboratory, using APPLE and IBM personal 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. The other 9 may be transferred or waived based upon acceptable graduate work taken in appropriate curricula.

Twelve units are in a common core shared by the two degrees. The M.S. (transportation planning and engineering) has another six required units, and the M.S. (transportation management) has another nine required units, for required totals of 18 and 21 units, respectively. The remainder is completed by electives as 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		Units
TR 601	Travel Demand Forecasting	3
TR 701	Traffic Enginering	3
		6

Other M.S.(TM) Requirements		Units
TR 751	Transportation Financial Control	3
TR 755	Legal and Regulatory Aspects of Transportation	3
TR 758	Transportation Management and Decision Making	3
		9

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 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 requirement 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 not included in computing grade point average. Validation credits by examination may not be used for any transportation degrees.

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.

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 704	Highway Capacity and Traffic Analysis	X	-
TR 705	Advanced Topics in Highway Capacity and Traffic Analysis	X	-
TR 710	Design of Traffic Facilities	X	-
TR 665	Design of Rail Facilities	X	-
TR 671	Airport Planning and Design	X	-
TR 672	Port Planning and Design	X	-
TR 720	Flexible Pavements: Design and Evaluation	X	-
TR 721	Rigid Pavements: Design and Evaluation	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	-
TR 715	Urban Goods Movement	X	X
TRAFFIC SAFETY			
TR 864	Transportation Safety Engineering	-	X
TR 865	Traffic Safety Engineering	X	-

	TRANSPORTATION MANAGEMENT: PRIVATE AND PUBLIC SECTORS		
TR 753	Management of Transportation and Distribution Operations	-	X
TR 754	Logistics Analysis	-	X
TR 760	Management of Transit Maintenance and Operations	-	X
IE 620	Project Planning and Control	-	X
IE 645	Productivity Management	-	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.

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 704	Traffic Capacity and Traffic Analysis	3
TR 998	Engineering Project in Transportation	6
		12

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 18 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 670	Planning and Design of Terminals	
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 Engineerings	
	Central Electives	18
	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. 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 once a year, usually in June, it consists of several written and oral portion. Copies of previous examinations are available on request from the Department 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.

Ph.D. candidates must also qualify in a foreign language, which entails translation of a part of a technical book or article with the aid of a dictionary. Students whose native language is not English may qualify in English if there is a body of related technical knowledge in their primary language.

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.

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 Department 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 | 3 |
| TR 704 | Highway Capacity and Traffic Analysis | 3 |

Plus three of:
TR 670	Planning and Design of Terminals
TR 705	Advanced Topics in Highway Capacity anf Traffic Analysis
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

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
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 720	Flexible Pavements: Design and Evaluation
TR 721	Rigid Pavements: Design and Evaluation

Public Transportation Certificate   Units
Required: 15
TR 660	Urban Public Transportation
TR 759	Transportation Policy and Decision Making
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 758	Transportation Management and Decision Making
TR 759	Transportation Policy and Decision Making

Plus one of:
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.

UNDERGRADUATE COURSES

The Department 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 three 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.

TR 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 Plánning 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 361 Transportation Demand Models 3:0:3
Modeling of transportation planning and engineering. Planning process and public transit. Modeling of travel demands, route selection and system evaluation. Analytical models and 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 500 Introduction to Transportation Analysis and Computations 2:1:3
Review of computational methods. Probability and statistics applications to transportation problems. Sampling and forecasting for transportation planning. Introduction to personal computer applications, and mainframe package use. Group projects performed in laboratory setting. (No graduate credit toward any transportation degree.)

TR 600 Characteristics of Transportation Demand and Systems 2½:0:3
Overview of fundamental relationships between transportation supply, land development, and travel in urban areas; characteristics of urban transportation systems and their usage by people and goods; introduction to theory and methods of forecasting urban activities.

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 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 701 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. Pre- or co-requisites for M.S. (TM) students: TR 758 and TR 751.

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 Urban 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 1:3:3
Traffic engineering and its role in person movement. Traffic demand and its generation and management. Capacity analysis concepts and basic study techniques. Substantial treatment of intersections, arterials, and arterial management. Laboratory emphasis on field procedures and on the use of analysis procedures, including personal computer applications.
Also listed under CE 805

TR 704 Highway Capacity and Traffic Analysis 1:3:3
Highway capacity techniques and traffic data collection and analysis. Capacity analysis techniques of the 1985 Highway Capacity Manual. Measurement, analysis and interpretation of traffic stream data is emphasized. Traffic safety studies. Use of personal computers in analysis, and workshop exercises. Prerequisite: TR 701.
Also listed under CE 806

TRANSPORTATION

TR 705 Advanced Topics in Highway Capacity and Traffic Analysis   2½:0:3
Basic research collection and use of traffic data. The importance of microscopic parameters and their use is emphasized. Calibration of highway capacity analysis techniques for uninterrupted flow, signalized intersections, and other facilities. Analysis of traffic breakdown and recovery characteristics. Coordination of various study techniques to analyze development impacts and related problems. Prerequisites: TR 701 and TR 704 or instructor's permission.

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 715 Urban Goods Movement   2½:0:3
Urban goods movement, primarily by truck, and its effect on urban mobility. Regulatory and institutional framework, freight demand modeling, spatial requirements at terminals and in the urban area, rail and marine terminals, and the terminal/street interface.

TR 720 Flexible Pavements: Design and Evaluation   2:1:3
Design and construction of flexible highway pavements, including road-mix, plant-mix and high-type bituminous pavements. Pavement performance and evaluation. Laboratory tests of bituminous materials and mixtures, including Marshall, Hubbard-Field and Hveem stability test. Viscosity of capillary viscosimeter. Prerequisite: CE 351 or equivalent.
Also listed under CE 801

TR 721 Rigid Pavements: Design and Evaluation   2:1:3
Design and construction of rigid highway and airport pavements. Pavement performance and evaluation. Laboratory tests of plain and reinforced concrete pavements. Nondestructive testing techniques. Prerequisites: CE 351 and CE 252 or equivalent.
Also listed under CE 802

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 751 Transportation Financial Control   2½:0:3
Analysis of financial performance and needs of private and public transportation companies and agencies. Balance sheet and income statement derived measures are used for comparative financial studies among various private modes. Financial needs of public transportation. Federal programs, state/local subsidies and dedicated taxes.

TR 753 Management of Transportation and Distribution Operations   2½:0:3
Management of transportation carriers, including passenger and freight operations; physical distribution management within these industries; basic organization; rate structure analysis; equipment management; marketing of services; labor issues; corporate policy in a changing regulatory environment; analyses of logistics costs and uses of logistic system models.

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 758 Transportation Management and Decision-Making   2½:0:3
Current multi-dimensional problems in financial management, organizational management, labor-management relations, ridership development and productivity which challenge top managers in the mass transportation and railroad industries. Case studies are used exclusively.

TR 759 Transportation Policy and Decision-Making   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. Recent topics presented are: decision-making in transportation; computer packages in transportation; transportation systems safety. Some have been added to regular curricula because of their popularity here. 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 888 Special Topics in Transportation for Developing Nations   2½:0:3
Possible topical issues include: transportation planning for economic development; financing international transportation projects; design and construction of low-type roadways; managemenmt of multinational project efforts.

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
of Doctor of Philosophy each 3 units**
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 and aerospace engineering, electrical engineering, civil engineering, metallurgy, and social sciences.

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 Transportation 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., Visiting 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

TRANSPORTATION

Philip A. Habib, P.E., Associate Professor of Transportation Engineering
B.E., City College of New York; M.S., Ph.D., Polytechnic Institute of Brooklyn
Goods movement; highway design; highway planning; transportation planning; terminal planning; traffic engineering

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

ASSOCIATED FACULTY

Luiz Gomes, Visiting Professor (1985); Professor, Catholic University of Rio de Janeiro (Brazil)

ADJUNCT FACULTY

Walter H. Kraft, Adjunct Professor
B.S., M.S., Newark College of Engineering; Dr. Eng. Sc., New Jersey Institute of Technology

Albert T. Rosselli, Adjunct Professor
B.C.E., City College of New York

Edmund Chalom, Lecturer
B.S.E.E., University of Maryland; M.B.A., Long Island University; M.S., Polytechnic Institute 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, 1986, are as follows:

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Parsons Brinckerhoff, Chairman of the Board

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First Deputy Commissioner of Transportation,
NYC Department of Transportation
New York City

Donald S. Berry,
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Ben Hackenberg, M.S., Assistant Director, Career Services and
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Michele E. Stewart, B.A., Coordinator, Part-Time Job
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Zena Jacobs, M.L.S., Manager, Reference and Circulation
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