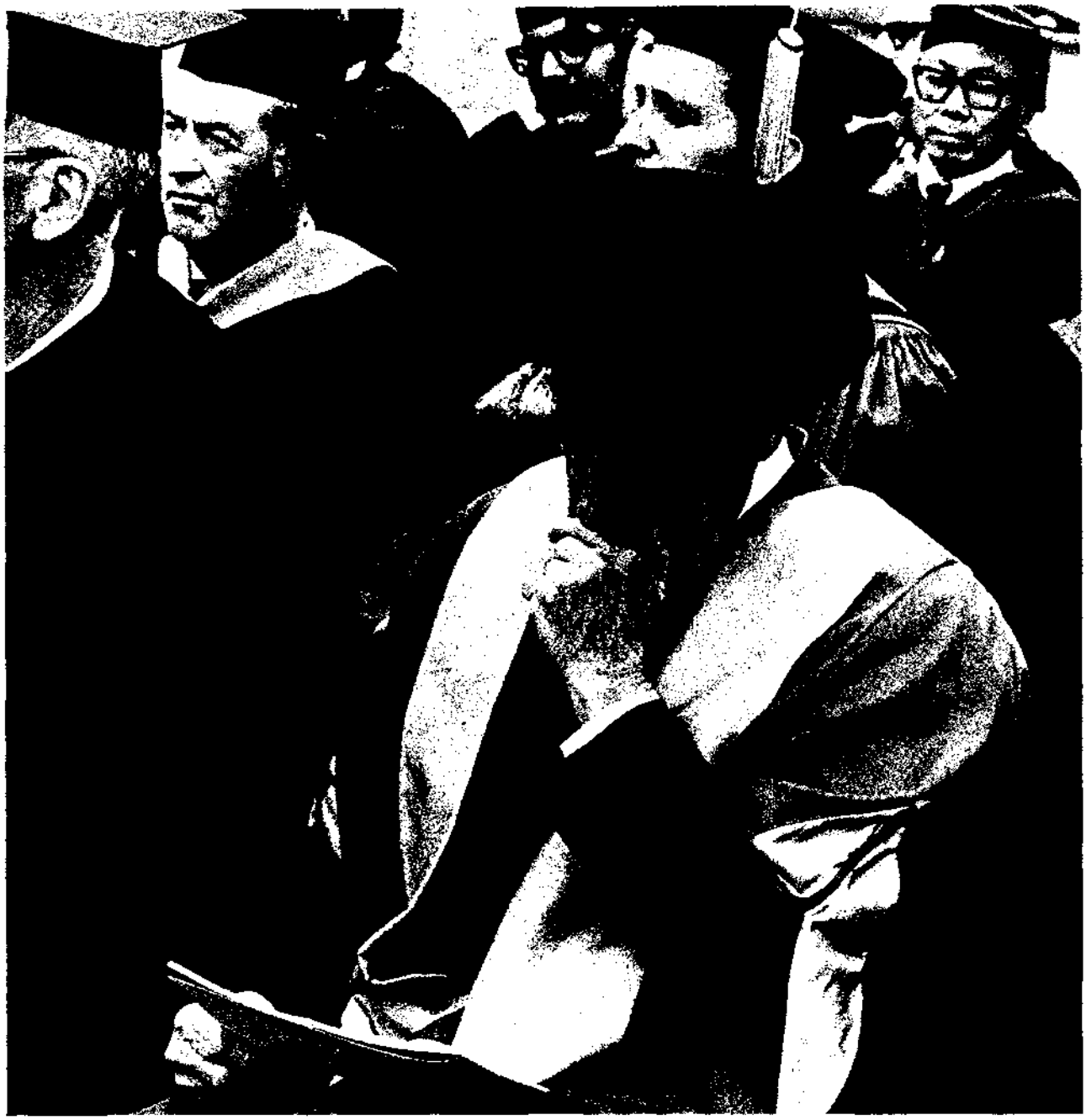
Polytechnic
INSTITUTE OF NEW YORK

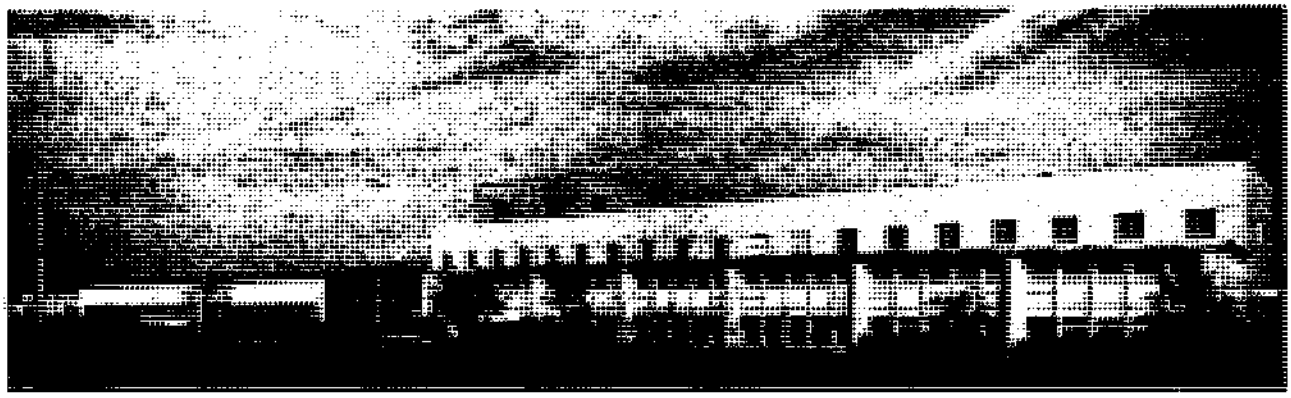
CATALOG 1981-1983

Brooklyn: 333 Jay Street, Brooklyn, N.Y. 11201 212/643-5000
Long Island: Route 110, Farmingdale, N.Y. 11735 516/694-5500
Westchester: 456 North Street, White Plains, N.Y. 914/949-1775

CONTENTS


POLYTECHNIC INSTITUTE
OF
NEW YORK





POLYTECHNIC INSTITUTE OF NEW YORK

Polytechnic Institute of New York is the largest and most extensive technological institution in Greater New York. The second oldest technological university in the nation, Polytechnic was founded in 1854. It was at Polytechnic that pioneering research was conducted in such important fields as x-ray scatterings, radar, microwaves, plastics and re-entry vehicles for the space program. Graduates have made important breakthroughs in such research areas as television broadcast technology, nuclear fission, bridge construction and dental anesthetics.

In 1973 Polytechnic absorbed New York University's School of Engineering and Science. Today, Polytechnic has campuses in Brooklyn and Farmingdale (Long Island), and a graduate center in White Plains.

A coeducational, independent university, Polytechnic has an enrollment of nearly 5,000 graduate and undergraduate students. The engineering enrollment (bachelor's, master's and doctoral) is first in New York State and one of the largest in the nation. About 11 percent of the student body are women, 37 percent are non-white and 11 percent are from abroad.

The undergraduate program includes courses leading to 16 degrees in engineering, science and the humanities. The graduate program in science, engineering and management offers 24 master of science degrees; 11 engineer degrees; and 22 Ph.D. degrees.

Traditionally, Polytechnic has been strong in chemistry, physics, mathematics and the major engineering disciplines—chemical, electrical, civil, mechanical and aerospace. It also has a number of specialized departments and programs such as computer science, metallurgy, nuclear engineering, and transportation engineering.

Many of Polytechnic's 225 faculty members are nationally and internationally recognized for their achievements as teachers, scholars and researchers. The Polytechnic faculty conducts over $6 million of research annually.

Conferring more than 400 baccalaureate degrees and more than 800 graduate degrees annually, Polytechnic now has nearly 30,000 alumni around the world. In 1981, more than 95 percent of Polytechnic graduates who sought employment found positions in their fields.

For detailed information, write the Office of Admissions or Office of Graduate Studies, Polytechnic Institute of New York, 333 Jay Street, Brooklyn, N.Y. 11201.

HISTORY

The two engineering colleges that merged in 1973 to become Polytechnic Institute of New York have roots in New York City going back to the same year. In 1854, the Brooklyn Collegiate and Polytechnic Institute received its charter from the New York State Board of Regents. That same year New York University established its school of civil engineering and architecture. Both schools began instruction in 1855. And in 1973, the inheritors of these traditions joined forces to form a single institution.

In 1869 the Board of Regents authorized Polytechnic's collegiate department to confer bachelor of science and bachelor of arts degrees, the first of which 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, and 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.

Dr. George Bugliarello, the first president of the merged institution, assumed office in 1973. Before his election as president of Polytechnic Institute of New York, Dr. Bugliarello had been Dean of Engineering at the University of Illinois at Chicago Circle, where he also served as Professor of Biotechnology and Civil Engineering. He received the degree of Dr. Ing. (summa cum laude) from the University of Padua, and the Sc.D. degree from the Massachusetts Institute of Technology in 1959. His books and research publications are concerned with bioengineering, fluid mechanics, computer languages and social technology.

PURPOSE

At Polytechnic, the scientific orientation of the curricula begins with a common freshman year. Here, new approaches in the teaching of mathematics, chemistry and physics provide the solid basis for the specialization that comes in varying degrees during the following three years.

No longer is it possible to isolate science and engineering, to teach engineering design primarily as an "art." Nevertheless, fundamental differences in attitude distinguish the professions of science and engineering.

Scientific exploration is directed toward accumulation of factual knowledge and the understanding of the basic forces and phenomena of the world. Engineering, on the other hand, has been defined by the Accreditation Board for Engineering and Technology as "the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize economically the materials and forces of nature for the progressive well-being of mankind."

The humanities and social sciences are well established at Polytechnic, partly because of the original nature of the Institute. A minimum of one-sixth of the total course work is devoted to literature, economics, history and modern languages. This area is specifically designed so the scientist and engineer will be prepared for the broader responsibilities that will come with career advancement. In addition, those who wish to do so may acquire a bachelor's degree in either humanities (with concentration in humanistic studies or communications) or in social sciences (history, economics or behavioral science).

The evening session at Polytechnic allows the student unusual latitude in adjusting a program to the realities of outside employment.

Polytechnic is accredited by the Middle States Association, the New York State Board of Regents and various professional organizations. While the undergraduate chemistry program is approved by the American Chemical Society, the Accreditation Board for Engineering and Technology accredits the undergraduate programs in aerospace, chemical, civil, electrical, industrial, mechanical and metallurgical engineering.

Although most undergraduate students live in New York City and surrounding communities, there are many who come from outside the state. The graduate programs draw students from all over the world, another indication of Polytechnic's reputation in engineering and science.

FACULTY

The faculty originates, organizes and approves all curricula taught at Polytechnic. Faculty members meet with students in lectures, seminars, laboratories and on field trips; they advise and examine students to determine established standards of achievement.

The faculty is also involved in non-teaching activities, conducting research. Many are also authors of textbooks used throughout the United States. Polytechnic students therefore have daily contact with recognized professionals who are making significant and continuing contributions to their professions.

ALUMNI

The Polytechnic Alumni Association promotes the welfare of Polytechnic and the individual alumna and alumnus. As the needs and interests of the alumni change, the responsibilities and objectives of the Alumni Association also change. It is today 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 sponsors the annual Freshman Round-up where incoming students meet recent graduates. Panel discussions, led by career alumni, highlight two yearly career conferences when students meet with alumni to discuss problems they may face when they enter the business world.

The Alumni Association has established a Student Auxiliary Committee within the structure of the Association. 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. Wherever 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. *Polygraphs* 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 at 333 Jay Street in downtown Brooklyn. This area is criss-crossed by public transportation lines and is accessible from any part 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 and the main library. *The Administration Building* contains administrative and faculty offices, the Office of Dean of Student Life and the Admissions, Bursar's and Registrar's Offices.

William H. Nichols Hall, Johnson and Bridge Streets, houses the placement office, research activities, laboratories, offices and classrooms.

The *Student Center,* located at 311 Bridge Street, housing cafeteria, lounges, game room and student offices, is the focal point for student extracurricular activities. The building is open Monday to Friday with facilities 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.

LONG ISLAND CAMPUS

The Long Island Campus, Route 110, Farmingdale was opened in the fall of 1961 for graduate study and research in response to the educational needs of Nassau and Suffolk Counties with their many technological industries. Located on 25 acres of land a half mile east of the Nassau-Suffolk border, the facility consists of four principal buildings and two ancillary research structures.

In 1974, full-time undergraduate programs in four engineering disciplines were introduced to the offerings of the campus. In 1980, two more undergraduate engineering programs were added.

The *Main Administration Building* contains classrooms, a cafeteria, an auditorium, conference and meeting rooms, a student lounge, faculty and administration offices and laboratories for research. 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. This building also includes a science-engineering library with a capacity of 25,000 volumes of periodicals and reference works specifically selected to support the courses and research conducted at the campus.

Preston R. Bassett Research Laboratory contains laboratories for research in gas dynamics, aerophysics, plasma physics and ultrahigh power microwaves, as well as teaching laboratories.

Grumman Hall, the student center, houses a lounge, the rathskellar, game room, locker rooms, a dark room, bookstore, student organization offices and exercise room.

The *Aerodynamics Test Building, Propulsion Research Laboratory* and a *Residence Hall* complete this complex.

WESTCHESTER GRADUATE CENTER

In response to the educational needs of graduate scientists, engineers and managers employed at the many high-technology companies on the Lower Hudson Valley and in Southern Connecticut, Polytechnic has established late afternoon and evening graduate programs at White Plains. It offers graduate degree programs in civil

POLYTECHNIC INSTITUTE OF NEW YORK CAMPUS LOCATIONS

Brooklyn Campus
333 Jay Street, Brooklyn, New York 11201
(212) 643-5000

Long Island Campus
Route 110, Farmingdale, New York 11735
(516) 694-5500

Westchester Center
456 North Street, White Plains, New York 10603
(914) 949-1775

engineering, computer science, economic systems, electrical engineering, and management. Other graduate courses offered include chemistry, energy policy, environmental engineering, industrial engineering and metallurgical engineering.

The Westchester Graduate Center at 456 North Street, White Plains, includes classrooms, computer terminal room and the Richard Laster Library Lounge.

FACILITIES

LIBRARIES

Acquiring, storing, retrieving and making available recorded knowledge, in all its forms and vast quantity, is the major function of the Polytechnic libraries. Its services are geared to assist all students to cope with our increasingly complex information/data environment.

Spicer Memorial Library, located on the first floor of Rogers Hall, is the center of Polytechnic's library system and contains one of the best collections of technical and scientific literature in the metropolitan area. The library also includes materials for research in the humanities, the social sciences and management. It contains more than 260,000 volumes, subscribes to 1,200 periodicals, has a half-million microforms and maintains a government document collection.

The Long Island Campus at Farmingdale is served by a library supporting its undergraduate, graduate and research programs.

The new *Richard Laster Library Lounge* was dedicated at the Westchester Graduate Center in the spring of 1979. Its collection reflects the areas of academic concentration at Westchester.

A highly trained and experienced staff of librarians and information specialists offers a wide range of reference assistance, classroom instruction, individual counseling, publications, referral, literature-searching and computerized information retrieval services. Through its participation in a number of cooperative arrangements and regional networks, access is available to the vast library resources of the metropolitan area, the state and the nation. Students are encouraged to visit the reference desk frequently to discuss their information needs.

COMPUTER CENTER

Polytechnic maintains a computer center responsive to its educational and administrative needs. Located in Rogers Hall, it is available to faculty and students for use in course work and research.

The main computing facility consists of an IBM 360/65 with 1,000,000 bytes of core memory, nine 3330 type disk drives holding upward of 900,000,000 bytes of information, four magnetic tape drives, two card readers, and two 1100-line-per-minute printers.

The Farmingdale campus computing facility consists of a Data 100-Model 74 remote batch terminal with one 450-line-per-minute printer and one 400-card-per-minute reader.

The Data 100 is connected to the IBM 360/65 via a high-speed data communications line.

Persons using the center's batch-processing capability may use languages such as FORTRAN IV, PL/1, WATFIV, PL/C, ICES, NASTRAN, SIMSCRIPT, GPSS, CSMP, ECAP and many others.

Time-sharing services for the academic and research users are provided at all three campus locations, utilizing a Digital PDP 11/70 computer running PWB/UNIX* located at Brooklyn.

In addition to the large 360/65 and PDP 11/70, a minicomputer laboratory housing various minicomputers and individual small computers, is also used on specific research and/or laboratory work and are used for interdisciplinary research carried out by the various centers within Polytechnic.

CENTER FOR URBAN ENVIRONMENTAL STUDIES

The *Center for Urban Environmental Studies (CUES),* established in 1967, initiates and coordinates programs of research and instruction relating to the interaction between man and his environment. It seeks to apply technology to the solution of complex problems common to metropolitan areas and acts as a focus for interdisciplinary studies related to the urban environment.

Current research programs at Polytechnic, sponsored by government, industry, and private foundations, are in housing, building codes, energy conservation, air and water pollution control, solid waste disposal, water resources, fire safety, flood control, building technology, delivery of health services, and urban planning.

Since Polytechnic offers degree programs not only in engineering and science, but also in management, premedicine, the humanities, and the social sciences, the scope of knowledge and capabilities which CUES can bring to bear upon urban environmental studies is unusually large. In addition, specially-developed short courses, symposia, and seminars are offered.

Advances in technology arising from CUES projects are often introduced into the curricula of the academic departments of Polytechnic. The environmental programs and projects of CUES are developed in cooperation with the user and are brought into use against real world problems.

*UNIX is a trademark of Bell Laboratories.

AEROSPACE RESEARCH LABORATORIES

For research in low-and high-speed fluid dynamics and aerophysics, Polytechnic has one of the world's most advanced and comprehensive university facilities, located in the Preston R. Bassett Aerospace Research Laboratory at Farmingdale. Here engineers and scientists are actively engaged in experimental and theoretical research on problems of aircraft and their flight environment, as well as contemporary problems with similar techniques. Some of these concern undersea vehicles, large scale atmospheric motions, flow processes in engines, the composition of exhaust pollutants, the development of new types of gas-dynamic lasers, and the application of lasers to flow problems.

A broad program which deals with advanced problems in the aerospace sciences, both theoretical and experimental, is carried on by the faculty, graduate students, honor undergraduates, and associated research staff. These efforts, and corresponding structural and propulsion programs, are aided substantially by the support of governmental agencies such as the Department of Defense, the individual armed services, the National Science Foundation, and the New York State Science and Technology Foundation.

Facilities are at hand for studies of jet mixing and chemically reacting flow (e.g., combustion) of heated and unheated gases and gas mixtures, including air hydrogen, and carbon dioxide. Sophisticated instruments and recording and data reduction equipment, including digital computers, are employed in connection with these facilities, while complete instrument and machine shops are important adjuncts.

MICROWAVE RESEARCH INSTITUTE

The internationally renowned *Microwave Research Institute (MRI)* was founded at Polytechnic in 1943 in response to wartime needs for new types of microwave components for radar applications. After World War II, the Institute continued to achieve stature under the leadership of its founder and first director, Dr. Ernst Weber. In collaboration with the academic departments, MRI has helped educate more microwave engineers than any other institute in the country.

In recent years, MRI has broadened the scope of its research activities to include the full range of topics encompassed by the broad term electronics. These activities include such seemingly diverse subjects as lasers, plasma physics, space radio-physics, x-rays, acoustics, wave propagation, microwave antennas, solid state materials, communication theory, control systems and image processing.

Through MRI, Polytechnic participates in the Joint Services Electronics Program, a basic research program sponsored by the federal government. This distinguished program involves only a few specially selected universities, and it places Polytechnic in the company of such schools as Harvard, M.I.T. and Stanford.

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 is 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 the Polytechnic, we may count among our graduates a large proportion of both academic and industrial scientists active in that field.

TRANSPORTATION TRAINING AND RESEARCH CENTER

The *Transportation Training and Research Center (TTRC)* is concerned with applied research, basic research and training in transportation and related areas. The Polytechnic established TTRC in 1975 to identify its mission in transportation and related areas, and to encourage the interdisciplinary and interdepartmental efforts so necessary in this field.

The TTRC is intended to be the Polytechnic's statement that

- it is committed to such interdisciplinary research, removed from internal departmental concerns
- it will provide the research sponsor with the experience, continuity and achievement record of depth and substance in a single identified internal entity, to the benefit of that sponsor
- it will provide the resources to accomplish the obligated work, in the clearly defined administration of TTRC.

The message is thus performance, responsibility and experience.

The TTRC experience includes

- Transportation Policy Studies
- Traffic Operations and Capacity
- Environmental Impact and Noise
- Transportation Planning and Management
- Transportation Finance

It is proud of its recent work on transportation energy, urban goods, travel training of the retarded, implications of fully accessible systems, minority faculty workshops, short courses and other activities. It has undertaken work for most relevant federal administrations, for state and local governments and with foundation fundings.

ADMISSIONS, FINANCIAL AID, REGISTRATION

GENERAL INFORMATION

Application materials and information on both undergraduate and graduate admission may be obtained by telephoning or writing the admissions offices at either of the following locations:

Brooklyn:
Admissions Office
Polytechnic Institute of New York
333 Jay Street
Brooklyn, N.Y. 11201
(212) 643-2150

Farmingdale:
Admissions Office
Polytechnic Institute of New York
Route 110
Farmingdale, N.Y. 11735
(516) 694-5500

Inquiries about graduate studies at the Westchester Center should be directed to the admissions office at the Brooklyn campus.

Polytechnic's admissions process operates on a rolling basis; preference, however, will be given to applicants who submit all of their documents according to the following timetable:

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

Part-time undergraduate (evening) and graduate study:
December 1—for the spring semester
August 1—for the fall semester

Polytechnic's rolling admissions procedure makes it possible for the admissions office to render a decision on all qualified freshmen and transfer applicants soon after all data have been received. Most candidates for freshman admission apply before February 1 for the fall semester and October 1 for the spring semester and are notified of a decision on admissions usually within four weeks of the receipt of their applications. 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 designed to help students who wish to accelerate or supplement their studies.

Because of the extra time required to process applications from abroad, consideration will not be able to be given to foreign applications received after November 1 for the spring semester, nor after May 1 for the fall semester. All official records along with notarized translations must also be received by these dates.

UNDERGRADUATE ADMISSION

ADMISSION AS A FRESHMAN: EXAMINATIONS

Applicants for admission as freshmen are required to take the Scholastic Aptitude Test of the College Entrance Examination Board. In addition, applicants for engineering, science and pre-medicine should take achievement tests in English composition, one laboratory science (physics, chemistry or biology) and level I or level II mathematics. 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 Entrance Examination Board's examinations.

SECONDARY SCHOOL RECORD

Since the course of studies at Polytechnic is academically rigorous and intellectually challenging, admission to the university is highly competitive. Candidates for admission will be judged primarily for their potential for success at Polytechnic.

The preferred course of studies on the secondary school level is as follows:
English—4 years
Foreign Language—2 years
Laboratory Science—2 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 pre-calculus, calculus, advanced laboratory science, computer science, etc. preferred)

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

EARLY ADMISSION

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

ADVANCED PLACEMENT

Students may receive college credit by scoring well on the Advanced Placement Examinations given by the College Entrance Examination Board. A student receiving a grade of 5 will receive degree credit for the specified Polytechnic course(s). If the grade is 3 or 4, the examination will be reviewed by the department concerned; the student may receive credit, advanced placement without credit, or neither.

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

ADMISSION AS A TRANSFER STUDENT

Polytechnic welcomes transfer students from accredited colleges and universities, provided that they have maintained a strong academic record. Students who have not completed two years of college work should forward to the admissions office a transcript of previous college grades plus the high school transcript and Scholastic Aptitute Test scores. Students who have completed two or more years of college need only submit a college transcript.

If accepted to the university, transfer students should meet with both a member of the admissions staff and a departmental adviser in order to determine which credits are transferable to Polytechnic. Students are required to submit copies of course content from their college catalog for all courses under consideration.

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

Transfer credit is awarded on the basis of current standards and curriculum; therefore, it is possible that credit which Polytechnic had previously awarded for courses taken at other universities may no longer be awarded at this time. All transfer credit evaluations are tentative and conditioned upon the student doing acceptable work at the Polytechnic. A substandard academic performance in a course at the Polytechnic may result in a requirement that the student enroll in, and pass, a course for which transfer credit was previously granted.

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

The grades for courses for which transfer credit is granted are not included in the computation of the Polytechnic grade point average.

ADMISSION AS AN INTERNATIONAL STUDENT

Proficiency in English is a prerequisite for admission and the Test of English as a Foreign Language (TOEFL) is required of all students whose native language is not English. In addition, international applicants must submit a statement of financial capability before being permitted to enroll. Students holding F-1 visas must enroll as full-time students.

If transfer credit is desired, the candidate 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 take into consideration family size, family members who are students and the family income.

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

Transfer students may enter HEOP; however, only students coming from similar programs approved by the HEOP central office are eligible as transfers into HEOP. For further information, contact the director of HEOP at the Brooklyn campus. HEOP is available at the Brooklyn campus only.

ADMISSION AS A PART-TIME STUDENT

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

New transfer students may be admitted on a part-time or full-time basis.

Regulations concerning subject matter requirements, and admissions procedures, are outlined under the section on *Admission As A Freshman.* However, part-time undergraduate applicants are not normally required to take the entrance examinations.

Following notification of acceptance, the student should contact the adviser in the student's major department. In some cases, the advising may be accomplished during the normal registration period.

Undergraduate students may also register for a *maximum of two courses* per semester on a non-degree basis. Applications for admission under this special status may normally be obtained during the week of registration. According to the student's individual interests and needs, 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.

GRADUATE ADMISSION

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, the American Chemical Society and the various regional accrediting associations. Applicants wishing to enter a graduate field different from the undergraduate field in which they hold a bachelor's degree, or its international equivalent, must anticipate the possibility of some make-up courses for which they may not receive graduate credit.

The previous program of studies must be acceptable, in quality and quantity, to the 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.

ADMISSIONS PROCEDURES

In addition to the application form and fee, applicants must have transcripts of any previous undergraduate record (and graduate record) sent directly to the admissions office. Applications for admission should be supported by letters of recommendation by persons who are well qualified to comment on the applicant's aptitude for graduate study and research. Action on applications will be taken as soon as possible after all supporting papers have been received.

In special instances, qualified admission is given to students who lack some of the prerequisites. These deficiencies must then be removed by prescribed undergraduate courses, which may be taken at Polytechnic or another acceptable institution.

EXAMINATIONS

Consideration is given to an applicant's attainment in the Graduate Record Examination established by the Carnegie Foundation for the Advancement of Teaching. Records of this examination may be presented with the application. Information about the examination may be obtained by contacting Educational Testing Service, 20 Nassau Street, Princeton, N.J. All applicants for studies in management are required to take the Graduate Management Admissions Test administered by the same Educational Testing Service.

INTERNATIONAL APPLICATIONS

International applicants applying from outside the United States are required to take the Graduate Record Examination (GRE aptitute tests) and the Test of English as a Foreign Language (TOEFL). Both examinations are administered by the Educational Testing Service (address above). No final action will be taken until the results of these examinations are received. At the discretion of the director of admissions or the dean of graduate studies, international applicants applying from within the United States may be required to take the examinations. Applicants may facilitate their admission by submitting an official document listing the contents of all undergraduate courses taken.

International applicants must submit a statement of financial capability before being permitted to enroll.

TUITION

Current information on tuition and fees is available in the course schedule bulletin available prior to the start of each semester. The registrar, bursar, and admissions offices also have up-to-date cost data available.

For fall 1981, full-time tuition for undergraduate students (12 to 20 credits) will be $2750 per semester. Students enrolled for fewer than 12 undergraduate credits will pay $175 per credit. Full-time tuition for graduate students will be $2850 per semester and for part-time graduate courses, $195 per unit.

Credits in excess of 20 must be paid for individually at the per credit rate.

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

Tuition covers the instruction costs, use of the libraries and the facilities of the department of student studies. Laboratory fees, ranging from $10 to $65 per semester are charged for various laboratory classes. Details of these charges are found in the *Course Bulletin,* since they may vary from semester to semester. Courses requiring lab fees are indicated in the course listings.

Other fees, also detailed in the *Course Bulletins,* include student activity fees, application and acceptance fees, transcript charges, diploma fees and fees for special examinations and dissertations. Housing charges vary according to the arrangements at Brooklyn and Farmingdale. For details, consult the Office of Dean of Student Life.

The bursar collects all payments that are due the Polytechnic Institute. Full tuition and fee payments are due from all students at the time of registration. Payments should be made by check or money order. Evidence of any financial aid should be presented at registration. (Visa and MasterCard are accepted.)

Deferred Payment

The college does not have a deferred tuition plan. However, outside agencies do provide independent tuition deferment arrangements. Information on these agencies may be obtained through the Polytechnic admissions office. Special education loan programs enabling the family or the student to repay over an extended period in monthly installments are available at many neighborhood banks. Also, any family can qualify for a New York State Higher Education Assistance Loan. Applications are available at local banks. Processing of these loans normally takes from six to eight weeks.

REFUND OF TUITION

Each student, upon registration, assumes obligation for the semester's tuition and other fees. In the event of withdrawal, the right to a refund must not be assumed. Whenever a student withdraws from a course or from all courses, the tuition charges are adjusted according to the schedule outlined below provided (1) the withdrawal notice is filed within the refund period, (2) it is submitted in writing to the registrar's office and (3) the withdrawal lowers the student's program to less than 12 credits. Forms for this purpose are available in the Office of the Registrar. The filing of a withdrawal form in the registrar's office is sufficient notification to the school 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.

A refund must be requested from the bursar's office. If no request is received, the refund amount will be credited to the student's account.

Refund Schedule:

The refund schedule is applicable only during the first four weeks of the semester. If the student makes official withdrawal from all courses at the Institute before the first day of classes, there is no charge; otherwise, the following is applicable.

Withdrawal during	*Per Cent Charge*
First week of semester	10%
Second week of semester	25%
Third week of semester	50%
Fourth week of semester	75%
After the fourth week of semester	100%

Two months after the start of classes must be allowed for the processing of credit and refunds.

Appeals to the refund schedule must be submitted in writing, with documentation of reasons that an exception should be made, to the registrar.

FINANCIAL AID

Polytechnic Institute 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 Institute and independent and government funds).

All financial aid is limited to the needs of the student as determined by the College Scholarship Service. Students receiving financial assistance from the Polytechnic Institute 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 a combination of academic ability and financial need which do not require repayment.
- *Loans*—specific sums awarded to students with repayment conditions. Education loans generally have a low interest with extended repayment terms.
- *Employment*—part-time and summer jobs either on or off campus.

About 80 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. First-time college students should file the complete Financial Aid Form (FAF), including the supplement, 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 March 1, and request a financial aid transcript from the transferring institution to be sent to the Financial Aid Office at Polytechnic Institute by March 15.

To Renew

1. Request the Financial Aid Form from the Director of Financial Aid in February.

2. File the FAF with the College Scholarship Service, Princeton, New Jersey, by April 1.

3. File the Polytechnic Institute Financial Aid Application with the Office of Financial Aid by April 15. A copy of the parents' 1040 or 1040A and/or the student's 1040 or 1040A tax form 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. The applicant must be (1) needy, and (2) enrolled at least half-time as an undergraduate student.

Award Schedule. The award ranges 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.

Rights and responsibilities. The student 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 an NDSL for the first two years of study.

Rights and responsibilities. The current interest rate, payable during the repayment period, is four 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 $30.00. Payment is not required for up to 3 years of active U.S. military service, or service in Peace Corps, VISTA, or similar national program.

College Work-Study Program (CWSP)

Application procedures. Awards are determined by Polytechnic's 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. The applicant 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 students in their freshman year.

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

Rights and 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. The application should be completed according to directions or a student should apply for the Pell Grant by checking the appropriate box on the FAF. A student eligibility report will be sent to the applicant from the Office of Education. Based on an eligibility index or the eligibility report, the amount of the applicant's Pell Grant is determined by the Financial Aid Office. Upon enrollment, funds are paid directly to the Institute in the student's name.

Selection and allocation. The Pell Grant program is an entitlement program. Scholastic accomplishment has no bearing on eligibility. The applicant must be enrolled as an undergraduate at least on a half-time basis. Financial need for the Pell Grant is determined by a formula developed by the U.S. Office 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 $200 to $1,800, but not more than one-half the total cost of attendance. The amount of the award will be affected by costs of attendance and full- or part-time enrollment status. The Pell Grant award does not duplicate state awards.

Rights and responsibilities. The student must continue to make satisfactory academic progress and must not owe refunds on Pell or other awards paid, or be in default on repayment of any student loan. Before receiving payment, the student must sign an affidavit that all money will be used for the costs of attendance only. Most Pell Grant payments are credited directly to the student's Institute account.

Social Security Payments

Application procedures. Application for Social Security payments to children of deceased or disabled parents may be made at any Social Security office. The applicant should present the Social Security card (if one has been issued), and provide the (1) name and address of the institution; (2) dates of past attendance; (3) student ID number; (4) number of credit hours carried; and (5) full- or part-time status planned for next academic period.

Selection and allocation. The applicant must be (1) single and between 18 and 22 years of age; (2) financially dependent and have a deceased or disabled or retired parent who worked long enough to qualify for Social Security; and (3) enrolled in a post-secondary institution as a full-time undergraduate.

Award schedule. The amount of Social Security benefits may be affected by earnings from employment or self-employment (if these are greater than $3,000 per year). Earnings of a parent may also affect the amount paid to the applicant, even if the applicant is not employed. Payment can continue until the end of the academic period in which the student becomes 22 years of age.

Rights and responsibilities. Several months before the applicant's 18th birthday, the Social Security Administration will contact those applicants already receiving benefits. So that benefits will continue, the applicant will be instructed on the procedures to follow upon becoming a full-time post-secondary student. Applicants who become eligible for benefits after reaching 18 must apply for benefits upon beginning full-time study. Eligible appliants who apply late may receive back payments for up to twelve months.

Veterans Administration (VA) Educational Benefits

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

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 for 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.

Rights and responsibilities. Institutions are required to report any interrupted attendance or termination of study on the part of students receiving benefits to the VA. Details of the Institute's requirements are given to each applicant. Eligible students must apply for certification each semester in the Office of the Registrar.

ARMY ROTC SCHOLARSHIPS

Army ROTC 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 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, lab fees, plus a living allowance of up to $1,000 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 1981-82 academic year is March 31, 1982. The HESC determines the applicant's eligibility with an award certificate indicating the amount of the grant. The applicant presents the Institutional copy of the certificate when tuition is paid. Polytechnic will defer payment upon receipt of the award certificate.

Selection and allocation. TAP is an entitlement program. The applicant must (1) be a New York State resident and a U.S. citizen or permanent resident; (2) be enrolled full-time at an approved New York State post-secondary institution; (3) have, if dependent, a family net taxable income below $20,001, or if independent and single with no tax dependents, a net taxable income below $5,667; and (4) be charged a tuition of at least $200 per year.

Undergraduate students may 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 1981-82 academic year, full-time dependent students can receive awards ranging from $200 to $1,800.

Regents College Scholarship

Application procedures. Applicants may obtain application forms from their high school principal.

Selection and allocation. Regents College Scholarships are awarded on a competitive basis. The applicant must (1) have been a legal resident of New York State for at least one year immediately preceding the first term for which application of an award is made; (2) be in attendance in a high school within six years in which 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 normal length of the program in which the recipient is enrolled.

Guaranteed Student Loan Program

Application procedures. The student should obtain a loan application from a participating state lending institution (bank, credit union, etc.) in the student's state of permanent residence. The completed application should be presented to the Polytechnic Financial Aid Office for certification. The application is then forwarded to the lending institution and the appropriate state agency.

Selection and allocation. To be eligible for a guaranteed state loan, a student must (1) be a U.S. citizen or permanent resident alien; and (2) be enrolled in or admitted at least half-time to an approved post-secondary institution.

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

Rights and responsibilities. A student may borrow at a relatively low interest rate (currently nine 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, service in the Armed Forces, or during full-time Peace Corps or Domestic Service service.

If a student applies for an additional loan, application must be made to 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.

SCHOLARSHIPS AND GRANTS

Polytechnic has a history of scholastic recognition to numerous applicants with outstanding academic credentials. The dollar value of such awards is based on need, academic achievement, recommendation, and outside awards.

Polytechnic Scholarships ranging from $250 to $2,500 are usually awarded students who have a strong academic background and demonstrated financial need. Normally a freshman student must have combined SAT scores of 1200 and a high school average of 90 to be considered for a Polytechnic Scholarship. Transfer students must have at least a 3.0 grade point average to be considered for a Polytechnic Scholarship.

Polytechnic matching grants are automatically awarded to a student receiving a Regents Scholarship, even if the student is ineligible for other financial aid. The matching grant is equal to $250.

Board of Trustee Scholarships are awarded to the most academically superior freshman applicants. The amount of the scholarship is equal to tuition, less any outside aid for which the student is eligible.

IMPORTANT FINANCIAL AID POLICIES

- To be eligible to receive financial aid, a student must be enrolled at least half-time. All Polytechnic Scholarships, TAP grants, and Regents Scholarships, however, require a student 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 office are combined, admissions decisions are not affected by financial aid decisions. Admissions officers do not have access to financial aid records. Their academic evaluation of a student's qualifications are made without knowledge of the applicant's financial need.

  Prospective students should, however, 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 then reviewed for financial aid.

- Financial aid is renewable annually, based on a student reapplying, continuing to demonstrate financial need where applicable, and fulfilling any other requirement stipulated by the award. To renew all Polytechnic Scholarships, a student must maintain a 2.5 cumulative grade point average.

- Since Financial Aid and Scholarship Funds *administered* by the Institute 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 a fixed amount of resources, the Institute does not deem it ethical to withdraw support from students who may have based their decision to attend Polytechnic on the financial aid they were awarded in order to free up money to assist new applicants later on. Funds from financial aid programs *not administered* by the Institute, such as the Pell Grant Program, TAP, and the

Guaranteed Student Loan Program, are available to eligible students regardless of whether a student received funds from these programs upon entry into the Institute.

SATISFACTORY ACADEMIC PROGRESS REQUIREMENT

During the academic terms in which a student is receiving financial aid from federal or state sources, he/she must be progressing toward their degree according to the standards set forth in the "Academic Policies" section of the Polytechnic catalog.

"Terms of eligibility" for financial aid are calculated as the total time of a student's enrollment at any institution. Students, therefore, can be making satisfactory progress toward their degree but potentially can exhaust their eligibility for financial aid by not completing their degree requirements within the eight semesters "terms of eligibility."

GRADUATE FELLOWSHIPS AND ASSISTANTSHIPS

Fellowships, traineeships, and assistantships are available for advanced study leading to the master's, engineer, or doctor's degree in engineering and science disciplines. Applicants must hold degrees in engineering or science from institutions of recognized standing.

Candidates should make application as early as possible but not later than February 1 on official forms available from the Office of Graduate Studies.

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 studies. Partial 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 departmental office concerned.

Graduate Assistantships

Opportunities are available to doctoral full-time graduate students for work on sponsored research projects. Stipends vary with the qualifications of the individual. Assistants serve 35 hours per week on research leading to the fulfillment of the doctoral research requirement of the graduate curriculum in which they matriculate.

National Science Foundation Graduate Fellowships

The National Science Foundation sponsors two fellowship programs for graduate study. They are listed below:

• Graduate Fellowship Program: fellowships are awarded for study leading to master's or doctoral degrees in the mathematical, physical, medical, biological, engineering and social sciences and in the history and philosophy of science. The program is open to applicants who are citizens or nationals of the United States as of the time of application.

• Minority Graduate Fellowship Program: fellowships are awarded for study leading to master's or doctoral degrees in fields described above. However, they are limited to citizens or nationals of the United States who are members of the ethnic minority group, i.e., American Indian, Alaskan Native (Eskimo or Aleut), Black, Mexican American/Chicano or Puerto Rican.

For details, contact the Commission on Human Resources, Washington, D.C. 20418.

Fannie and John Hertz Foundation Graduate Fellowships

The Polytechnic is one of 17 national schools to be selected for participation in the Fannie and John Hertz Foundation Graduate Fellowship program. Fellowships are awarded for study leading to master's or doctoral degrees to applicants who will have received a bachelor's degree by the time they propose to commence tenure of their fellowships. The objective is to aid the most capable students in the physical sciences and engineering.

Applications and further information may be obtained from the Fannie and John Hertz Foundation, P.O. Box 2230, Livermore, California 94550.

REGISTRATION

The institution endorses the concept of a close faculty-student relationship and as such the faculty advising system serves as the basis for a student selection of courses and registration. Each academic department identifies a group of faculty to serve as student advisers. In advance of registration, students should meet with their individual 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 Student Life.

Information on registration and registration appointments are mailed to new students and continuing students prior to the registration period.

PROCEDURE

All continuing full-time students (graduate and undergraduate) 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 a $25 late fee. Payment is due about one month before the next semester starts.

UNDERGRADUATE GRANTS AND SCHOLARSHIPS

American Bureau of Shipping Scholarship
American Society for Metals Scholarship
ARCO Corporation Scholarship
The J.B. Chittenden Scholarship
The Arthur Clapp Scholarship
The DeWitt Scholarship
The Aaron and Simcha Dupitzky Scholarship
The W.E. Duryea Scholarship
The A.S. Dwight Scholarship
EMCO Development Corporation Scholarship
The I.W. Fay Scholarship
Gemini Industries, Inc. Scholarship
The Alfred Helwig Scholarship
International Nickel Company, Inc. Scholarship
International Precious Metals Institute Scholarship
The Eugene R. Kulka Scholarship
The John F. Kunc Scholarship
The P.R. Mallory Memorial Scholarship
Raymond Mauro Scholarships
The NSC-Essie Mitchell Scholarship
The Colonel Frank Moll Scholarships
The William Nichols Scholarship
The Nippon Electric Scholarships
Lucius Pitkin Inc. Scholarship
Sperry Rand Scholarship
Myron Rosenthal Scholarship
Samuel Ruben Scholarships
The Frank R. and Emilie E. Stamer Scholarships
Institute Trustee Scholarships
The Ernst and Sonya Weber Grants

For the award of 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 registrar.

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

Adding and Dropping Courses

Students may elect to add or drop a course, or change a section of a course for another with the approval of their major adviser. Additions or changes may be made only until the end of the late registration period and only where class limits have not been reached.

If a student drops a course after this deadline, a grade of W (withdrawal) will be recorded.

It is each student's responsibility to register for a conflict-free schedule. In instances of student-scheduled conflicts that necessitate course changes after registration, the add-drop fee will not be waived.

A fee will be charged for adding or dropping courses or changing sections, except where schedule changes are necessitated by course cancellations, section adjustments and 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 the 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. This fee will be waived by the registrar only in clearly justifiable cases.

Course Prerequisites

To be eligible for admission to an advanced course, students should have passed all subjects prerequisite thereto as listed in the description of courses. If, however, they are deficient in but one such prerequisite course, they may apply to their adviser for admission to the advanced course. If these applications are approved by the adviser and by the teachers of the advanced and prerequisite courses, the student may be admitted to the advanced course.

Student Identification

Each student is required to carry and maintain at all times a photo-identification card issued by the registrar. This photo ID must be presented at each registration for validation and shown to a staff member of the Office of the Registrar when making changes in registration or requesting transcripts. ID must be presented and/or surrendered to any official of the college upon request.

A student ID number is used to identify individual records (billing payments, grades, etc.) for the student's entire stay at Polytechnic, from the time of admission to the completion of degree. The student ID number is sometimes a social security number, but not always. If a student does not have a social security number when admitted (as in the case of international students), the student is assigned a number by the admissions office. The assigned number will be permanent throughout the student's career at Polytechnic and it will not be changed should the student obtain a social security number.

Veterans Information

All veterans enrolled at the Polytechnic should notify the Veteran Affairs clerk in the Office of the Registrar of the credits to be attempted during a semester. Any questions concerning veteran's benefits or paperwork should be directed to the Veteran Affairs clerk, either in person or by telephone.

GRADUATE STUDENTS

Registration Status

Within the full-time and part-time classification of graduate students, there are five status groups: degree status, non-degree status, graduate probation status, provisional and special status. Changes from non-degree status to degree status must be approved by the dean of graduate studies. Graduate special and provisional students must apply for and be admitted to degree or non-degree status through the admissions office.

Degree Status. This status is assigned to applicants who apply for a degree program and whom Polytechnic considers adequately prepared for and capable of such study. Students are admitted to degree status upon the recommendation of their major department of study.

A student who applies without former graduate studies must have earned a bachelor's degree from a fully approved college or university (including professional accreditation). To attain degree status immediately at the time of acceptance into Polytechnic's graduate school, a student must have maintained an acceptable average in the major field of study.

Qualification for degree status of continuing students is reviewed yearly by the dean of graduate studies. If a cumulative B average is not maintained, the status is changed to non-degree status.

Non-Degree Status. This status is generally assigned to applicants who are asked to provide additional demonstration of the ability to pursue a graduate degree program—specifically by achieving A or B grades (minimum requirement of a B average) in at least 12 units of graduate courses. After satisfying the requirements specified at admission, the student will, upon written request and the approval of the major department, be transferred to degree status. Change of status forms are available in the Office of Graduate Studies. All of the courses successfully completed which are normally required of that degree program will apply toward satisfying the degree requirements.

This status is also awarded to applicants with advanced degrees who are entering a new professional area and desire extended education, but not for degree purposes. This includes students enrolling in Graduate Certificate Programs. However, should they so desire, students in this status may later request transfer with full credit to degree status.

Graduate Probation Status. The dean of graduate studies is authorized to place all graduate students whose average has fallen below 3.0 grade-points (B) on "academic probation." 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

Courses repeated will count only once in the grade-point average, with the highest grade included.

As soon as possible after the posting of spring grades, the dean will automatically notify all graduate students whose grade-point averages are below 3.0 that they are on academic probation. The data for such determination will be provided by the registrar and copies of all probation notices will go to the department, which will check the accuracy of the grade-point determination.

In addition, the department may, at its discretion, 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 is sent to the dean of 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 dean of graduate studies. When such a student is permitted to register, the department will provide the student with a written statement of the academic performance required for the next academic year or semester, in order to retain permission to register in future semesters. This statement will be kept on file in both the dean's office and the departmental office. Students may be denied permission to register by their department or the dean of graduate studies at any time while they are on academic probation. Students are cautioned that failure to maintain a 3.0 grade-point average may result in the loss of degree 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.

Special Status. Applicants requesting admission for study only in a particular course or group of courses are given this status, which permits registration, generally for a limited duration, in just those courses indicated in the approval of admission. If additional courses are desired, a new request must be filed through the admissions office. Registration is limited to two courses per semester.

Provisional Status. On occasion, a decision on a student's application may be delayed. Such a student may be temporarily accepted and allowed to register for one semester pending a decision. If the student is not accepted, he/she has the choice of withdrawing with a full refund or finishing the semester but will not be allowed to register again.

A student has six weeks after registration to get all necessary documents to the admissions office.

Transfer Credit

A limited amount of credit for graduate courses completed with honor grades (A or B) by students from acceptable institutions may be allowed toward meeting the requirements for either the master's or the doctor's degree provided these courses were acceptable at those institutions for similar degrees and usually after obtaining the bachelor's degree. Such transfer credit is deter-

mined by the department involved and by the dean of graduate studies. Transfer credit for the master's degree is limited to a maximum of nine units.

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 the undergraduate degree requirements. Such courses are considered to be transfer credits, subject to the nine unit limitation for master's degrees, since the student was not in residence as a graduate student when the courses were taken.

Transfer Credit While in Residence

To obtain credit for courses taken elsewhere while in residence at Polytechnic, written permission must be obtained from the academic adviser and the department head(s) of the course(s) for which credit is requested or from the dean of graduate studies before the start of the course (forms for such permission are available in these offices). The following requirements may apply:

- The other institution must be accredited.
- The grade earned must be at least C for undergraduate courses and B for graduate courses.
- Pass/fail courses are not acceptable.
- Only the credit will be granted (the grade is not computed in the cumulative average).

It should be noted that in most cases authorization to take courses at another school is required from the appropriate academic dean at Polytechnic.

Validation Credit

Graduate credit in a Polytechnic course may also be established by examination. In this case, application must be made to the dean of graduate studies and be accompanied by the fee specified for that course. The examination will be administered by the department.

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

DEGREE REQUIREMENTS

CREDITS AND UNITS

Undergraduate semester credits are based upon the number of 50-minute periods scheduled each week for one semester. Normally one credit signifies either one 50-minute period of class work or three hours of undergraduate laboratory, over a period of 15 weeks.

Graduate studies are expressed in terms of units. One 50-minute period of graduate class work for a semester carries 1⅕ graduate units. A standard course meeting 2½ academic periods a week would be equivalent to three units. Courses meeting more or less than 2½ academic periods a week carry a proportionate evaluation.

CREDIT FOR COURSES TAKEN ELSEWHERE

Undergraduate

Students entering Polytechnic with advanced standing will receive an appraisal of substitutions allowed based upon credit transferred from their former college. Senior subjects or their equivalent, determined in consultation with the departmental adviser, are to be taken at Polytechnic. The minimum residence requirement for the bachelor's degree is one continuous year of full-time study in the day session or the equivalent in the evening session. See page 13 for further details concerning undergraduate transfer credit policies.

Graduate

Graduate courses completed elsewhere with honor grades (A or B) may be allowed toward meeting the requirements for graduate degrees at Polytechnic to a maximum of nine units, provided these courses were acceptable at those institutions in qualifying for similar degrees.

Transfer credit will be awarded only upon recommendation by the student's major department of study and with the approval of the dean of graduate studies.

Requests for such transfer credit must be submitted in writing to the dean of graduate studies. Students are required to have official transcripts sent to the Institute describing the courses for which transfer credit is desired before such an evaluation can be made. Special questions regarding transfer credit will be referred by the dean of graduate studies to the Graduate Curriculum and Standards Committee.

Grades received in courses with acceptable transfer credits are not averaged in with grades earned at Polytechnic.

REQUIREMENTS FOR THE BACHELOR'S DEGREE

In each of the fields of concentration, a program of study (curriculum) is prescribed. The student is admitted to and registers in one of these programs. Subsequent transfer to another program requires approval by the new department. The changes become official only after the proper form has been received by the registrar. To qualify for the degree, the student must complete the program as outlined in each departmental section in this catalog.

Institute Degree Requirements. 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. 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 non-credit writing course before taking HU 101 (or HU 103). MA 101 and MA 102 are also Institute degree requirements.

Humanities and Social Science Requirements. In addition the student is strongly urged to select an area of concentration (such as literature, communications, the arts, or philosophy and comparative religion in the Department of Humanities and Communications, or political science, economics, history, anthropology or psychology in the Department of Social Sciences) and elect two or three courses in this concentration, in consultation with the departmental adviser. A modern language may be chosen as a suitable concentration but a student without prior knowledge of the language must plan to devote at least 12 credit hours to the subject.

For the remaining credits in the humanities/social sciences requirement, the student should select courses in areas other than that of the concentration. Additional courses in humanities and social sciences may be taken as free electives.

DEGREE REQUIREMENTS

A student is required to fulfill the following three conditions in order to be certified for a bachelor's degree:

- Fulfill all Institute and departmental course requirements.
- Earn the required number of credits for the major department.
- Have a 2.0 cumulative grade point average.

Graduation Check List

During the second semester of the student's junior year, a check list is sent to the student showing the courses passed as well as those required to satisfy graduation requirements. Because of curriculum and course changes from time to time, it is occasionally necessary for students to request course substitutions to meet their degree requirements. Variations from the required curriculum must be requested in writing and approved in advance. Such requests should be made to the adviser in the major department on a course substitution form available from the Office of the Registrar and approved by the dean of the academic division in which the student is majoring.

Evening students who complete their courses within eight years of continuous residence may qualify for their degrees under the requirements that prevailed at the time of their original registrations. In the case of transfer students, the eight-year period of residence is proportionately reduced. At the expiration of this residency, continuing students may be obliged to obtain revised lists of courses to include those that have been introduced into the curriculum during the eight-year period.

Whenever students interrupt the continuity of their residence by a period of one year or more, they must meet the requirements for degrees in effect at the time of their reregistration unless they have been granted a leave of absence for military service.

REQUIREMENTS FOR THE MASTER'S DEGREE

Each student qualifying for the master's degree must complete not less than 36 units of advanced study and research in the program elected. The student must establish an overall B average both for the project or thesis and for those courses submitted in partial fulfillment of the degree requirements.

A student may offer no more than 12 units of project or thesis toward the degree requirements. Registration for project or thesis must be continuous until a grade is recorded.

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

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

CONDITIONAL GRADUATE ADMISSION

A Polytechnic undergraduate entering the final semester of study may apply for conditional admission for graduate study in a department of the Polytechnic, for one semester. If accepted, the student will be simultaneously pursuing two degrees, taking both graduate and undergraduate courses. Graduate courses taken during that semester, and not used to satisfy undergraduate degree requirements, are not included in the nine credit transfer limit for master's programs.

REQUIREMENTS FOR THE ENGINEER DEGREE

Each candidate for the engineer degree must complete a minimum of 36 units of work beyond the master's degree. Part of this work will include a project or evidence of equivalent experience. A maximum of 12 units of project may be submitted toward fulfilling the degree requirements. At least 27 units of work must be completed at Polytechnic. Registration for project or thesis must be continuous until a grade is 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 dean of graduate studies.

The student must maintain an overall B average both for those courses submitted 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 upon a systematic program leading to the doctorate will confer with advisers 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 programs chosen.

Each candidate for the doctorate must complete three years of full-time study or its equivalent, namely, a minimum of 90 units of academic work beyond the bachelor's degree, including a minimum of 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, in addition, specific course requirements. A minimum of 30 units, including the dissertation units, must be taken at Polytechnic. Each student must maintain an overall B average both for those courses submitted and for the dissertation units completed for the doctoral degree.

All candidates are required to demonstrate a reading knowledge of at least one foreign language, as approved by their 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 student's Guidance Committee and the approval of the dean of graduate studies.

CANDIDACY FOR GRADUATE STUDIES

As soon as a student has completed enough work to be in a position to submit one-half of the degree requirements with a B (3.0) or better average, he or she is expected to apply to the dean of graduate studies for admission to candidacy for the degree. Approval of this application will require a satisfactory record of past academic progress toward the degree as well as the recommendation of the head of the department and the concurrence of the dean that the applicant continue studies toward the degree. Admission to candidacy is a formal recognition of the fact that the dean and the department find the applicant's credentials in order and that he or she is being encouraged to continue studies toward the degree. Students are cautioned not to delay filing for candidacy. An unsatisfactory overall academic record or an incomplete file, can result in a rejection of the application and bar graduation.

GRADUATE CERTIFICATE PROGRAMS

Many departments offer a variety of certificates in specific areas of knowledge for students interested in pursuing course work in these areas without enrolling in full degree programs.

Certificates are awarded for a minimum of 12 units of work in a concentrated area of study (some certificates require more than this—see departmental sections for specifics). Admission to a certificate program requires a bachelor's degree in a field related to the program. Students in certificate programs are generally admitted as *Non-Degree* students.

Admission to a certificate program *does not* imply admission to a degree-program, though appropriate courses taken toward a certificate could be applied to a graduate degree were the student to be admitted to the degree program.

To earn a certificate, a minimum of 12 units must be taken at the Polytechnic. A 'B' or better average in courses submitted for the certificate is required. No course applied to a certificate may be applied to another certificate. To qualify for a certificate, the student must be formally admitted as a nondegree or degree student in the program issuing the certificate, or have the approval of the department or program head if the student is enrolled in another program at the Polytechnic.

The requirement for a certificate must be completed within three years.

THESES AND DISSERTATIONS

Undergraduate Theses

The purpose of the thesis is to apply the knowledge gained in the field of the student's major interests and to familiarize the student with the methods of planning, conducting and reporting research.

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

The thesis may be a dissertation upon a subject included in the student's course of study, an account of original research, a report on a project or an original design accompanied by an explanatory statement. The 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.

Graduate Research (Projects, Theses, Dissertations)

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

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

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

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

All research should be characterized by accuracy of observation and measurement, by thoroughness of analysis and synthesis, and by clarity and completeness in presentation. The conclusions presented must be supported by adequate studies and investigations and supplemented by a complete bibliography.

Registration for Thesis and Dissertation

After a project or thesis adviser or guidance committee has been appointed, the candidate should register for a number of units to reflect realistically 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 dean of 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 reregistration will obligate the student for full tuition and laboratory fees. Registration for the last unit is required until a permanent grade is submitted to the registrar's office.

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 chemistry and in electrical engineering are required no later than nine weeks before commencement; in chemistry, four typewritten copies are required; in electrical engineering, a single copy.

Research Submission

The format of the bound dissertation is prescribed, and a brochure entitled "Regulations on Format, Duplication, and Publications of Project Report, Thesis, and Dissertations" is available from the Office of 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 300 to 600 words suitable for publication in "Dissertation Abstracts," as provided below.

The four finished copies are to be presented to the department for approval, and the original is to be filed in the Office of Graduate Studies before noon on the Monday four weeks before commencement in the year in which the degree is to be taken. This is the copy which is to be kept permanently in Spicer Library. 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 Graduate Studies.

Publication

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

The faculty regards publication of the major content of a doctoral dissertation in a recognized scientific journal as a necessary final step if the work performed is to achieve maximum usefulness. A deposit is assessed against each doctoral candidate to insure the necessary efforts will be made to secure such publication. This deposit will be returned if evidence of publication, in the form of ten reprints of the article judged satisfactory by the department, is deposited with the Office of Graduate Studies within six years of the awarding of the degree. To be satisfactory, the article must indicate, by footnote or otherwise, its basis in a Polytechnic dissertation.

APPLICATION FOR DEGREES

Formal application for the award of the degree must be filed by undergraduate and graduate students by the end of the first week of the semester in which they expect to complete the degree requirements, and by graduate students before February 4 of the year in which they expect to be awarded the degree. These application forms must include a diploma fee, to be paid in the bursar's office by the above dates. If award of the degree is delayed, the diploma fee need not be paid again. Each student enrolled for an advanced degree shall have been admitted to candidacy for at least one full semester before being eligible for the award of the degree.

Applications for graduate degrees are available in the Office of Graduate Studies.

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

Degrees are awarded at commencement in May or June of each year; completion of degree requirements are certified three times a year at the end of each semester.

CURRICULA

UNDERGRADUATE PROGRAMS

Students may work toward a bachelor's degree either in four years of full-time study in the day session or in a longer period of part-time study. The number of credits full-time students take each semester depends on the curriculum and ranges from 16 to 18.

Students are admitted as freshmen in September and February. Day students entering in September follow normal curricula outlined for fall and spring semesters. Those entering in February follow a program 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 desire to achieve competence in a limited branch of engineering, 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, engineer or doctor of philosophy—or take courses for personal or professional reasons. Not all graduate programs or courses are offered at all campuses; students are referred to the program descriptions under the various departments and to the Course Bulletin, available at the Office of the Registrar.

SUMMER COURSES

Polytechnic offers a wide variety of full-credit summer courses for both day and evening, 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. Also during the summer the military science department offers 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 experiences 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 the Cooperative Education Seminars CP 101-102. Freshmen, therefore, would be eligible for their first work experience during the summer following the completion of the 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 receive company benefits. In all cases the students will be given the opportunity to work at tasks directly related to career goals.

DEGREES OFFERED AT POLYTECHNIC**

Polytechnic's programs lead to the Bachelor of Science, Master of Science, Engineer and Doctor of Philosophy degrees. For convenience the following list of degrees offered includes not only those with departmental identifications but also the topics of some undesignated degrees and of some major options within degrees. For more information on degree titles, descriptions and requirements, please see departmental listings.

Numbers are HEGIS code numbers listed in the **Inventory of Registered Degree and Certificate Programs** of the New York State Department of Education.

	Brooklyn Campus				Farmingdale Campus				Westchester Campus
	B.S.	M.S.	Eng.	Ph.D.	B.S.	M.S.	Eng.	Ph.D.	M.S.
Aerospace Engineering (0902)	■				■				
Aeronautics & Astronautics (0902)		■	■	■		■	■	■	
Applied Mechanics (0921)		■	■	■					
Applied Statistics (0901)		■		■					
Bioengineering (0905)		■		■					
Chemical Engineering (0906)	■	■	■	■	■				
Chemical Physics (1906)		■		■					
Chemistry (1905)	■	■		■					
Civil Engineering (0908)	■	■	■	■	■	■	■	■	■
Computer Science (0701)	■	■		■	■	■		■	■
Economic Systems (0901)		■		■					■
Electrical Engineering (0909)	■	■	■	■	■	■	■	■	■
Electrophysics (0919)		■		■		■		■	
Environmental Health Science (0922)		■							
Environmental Psychology (0901)		■							
Fluid Mechanics Engineering (0901)		■				■			
History of Science (2205)		■							
Humanities (4903)	■								
Industrial & Applied Mathematics (1703)		■							
Industrial Chemistry (0906)		■							
Industrial Engineering (0913)	■	■	■	■					
Information Management (0702)	■								
Information Systems (0901)		■				■			■
Life Sciences (0401)	■								
Management (0913)		■				■			■
Mathematics (1701)	■	■		■					
Mathematics for Teachers (0901)		■							
Mechanical Engineering (0910)	■	■	■	■	■	■	■	■	
Metallurgical Engineering (0914)	■	■	■	■	†■				■
Metallurgy & Materials Science (0914)				■					
Nuclear Engineering (0920)	■	■	■	■		*■	■	■	
Operations Research (0913)	■	■		■					
Organizational Behavior (0901)		■				■			■
Physical Metallurgy (1920)				■					
Physics (1902)	■	■		■					
Polymer Science and Engineering (0906)		■		■					
Science, Technical, Financial Writing (0901)	■	■							
Social Sciences (2201)	■								
System Engineering (0901)		■	■	■		■	■	■	
Transportation Engineering (0908)			■				■		
Transportation Management (0901)		■							
Transportation Planning and Engineering (0908)		■		■		■		■	

*Brookhaven Labs.
†Attendance at Brooklyn Campus required during third and fourth years.
**In addition to the degree programs listed, courses are offered in other disciplines at both the Farmingdale and Westchester campuses. Check current bulletin for course listings.

ACADEMIC POLICIES

THE FAMILY RIGHTS AND PRIVACY ACT

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 Institute. Specifically: (1) Your educational records (with the exception of directory information) will be released to third parties outside the Institute only with your written consent, (2) You have the right to inspect your own individually identifiable educational records, (3) You have the right to have reviewed the information contained in your individually identifiable educational record.

The Family Educational Rights and Privacy Act permits the release of *directory type information* to third parties outside the institution without your written consent provided you have been given the opportunity to withhold such disclosure. The Institute 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 Institute of New York, degree. Currently registered undergraduate and graduate students may withhold directory information by requesting this in writing to the registrar each semester.

Additionally, Long Island campus students' names, addresses and telephone numbers may be released to other students for the purpose of arranging car pools. If you wish this information to be withheld, you must notify the dean of student affairs office 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 as of September 1 as follows:

Freshmen	fewer than 28
Sophomores	28.5-61
Juniors	61.5-95
Seniors	95 or more

CREDITS PERMITTED

Undergraduate

Full-time. A program of 12 credits or more categorizes a student as a full-time undergraduate student. The maximum course load for full-time undergraduate students is 19 credits. Students in special situations (such as graduating seniors or ROTC cadets) must receive permission from the designated person in their major academic department for any program above 19 credits. Students taking an excess of 20 credits will be charged the per credit rate for additional credits or half credits.

Part-time. Any student registered for less than 12 credit hours per semester (except summer) is considered a part-time student. Part-time students do not qualify for most financial assistance programs.

For evening attendance, a maximum program of 11 credits per semester is recommended under normal circumstances. The average program in the evening is six or seven credits. Registration for 12 or more credits will result in reclassification as a full-time student for that semester, and the student will be charged at the full-time rate.

Summer session. There is no distinction between day or evening status in the summer session. A student 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. Registration for six credits for a given summer term is considered full-time status, particularly for financial aid purposes.

Graduate

Full-time. Registration for 12 units or more categorizes a graduate student as full-time. The maximum course load per semester is 18 units. Students who desire to register for more than 18 units must obtain written permission from their department chairman and the dean of graduate studies prior to registration. Students who register for more than 20 units will be subject to an additional tuition fee based on the per-unit tuition for all units in excess of 20.

Part-time. Registration for less than 12 units comprises part-time status in the graduate school.

GENERAL INFORMATION

ADD/DROP

Additions may be made to a student's program only during the first five class days of the fall and spring or summer semesters. A course may be dropped without academic penalty through the 10th week of the semester in the spring and fall and according to a published schedule for the summer. Students may obtain an add/drop form from the registrar's office. To add or drop a course, the student must have the written approval of the major adviser.

There is a fee for adding or dropping a course or for changing one course or a section for another of equal or different credit value after classes have started.

If the total number of credits registered for increases, the student is subject to an additional tuition charge.

TOTAL WITHDRAWAL FROM THE INSTITUTE

Students having to withdraw completely from the semester in which they are registered must notify the dean of student life or the dean of graduate studies. No withdrawal is official unless a written form is approved and submitted to the registrar. Mere absence from class does not constitute official withdrawal. There is no charge for a complete withdrawal from all classes.

DROPPED COURSES

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 of withdrawal. Students who file a "drop" form with the registrar by the scheduled deadline will automatically receive a grade of W for any courses so dropped.

PASS/FAIL OPTION

Beginning in the sophomore year (after a student has earned 28 credits), and with the major adviser's approval, an undergraduate student may elect, during the first five class days of each semester to take one elective course on a pass/fail basis. No more than six courses in all may be chosen pass/fail by an undergraduate student. The student choosing this option need not inform the instructor. At the end of the semester the instructor will submit a letter grade which the registrar will automatically change to a P or U. A request for a letter grade other than P or U will not be honored once the pass/fail option has been chosen.

No course required by the student's major department or by the Institute may be taken on a pass/fail basis (e.g., SS104, HU101, MA101, MA102).

TUTORING PROGRAM

Freshmen showing failure or low grades at midterm are notified that tutoring would be helpful. 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 is a prearranged schedule for the student and tutor which stands for the entire semester which generally lasts for one hour a week per course. Students missing three sessions will be dropped from the program. Improvement is monitored by evaluating the grades of the student 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.

AUDITING COURSES (Graduate Students)

Students may choose the option of auditing a course instead of receiving credit and a grade for it. Regular tuition is charged, and the course is treated as part of a full-time load. The grade AU appears on the permanent record.

Interested graduate students should see their advisers and must notify the registrar's office within the first six weeks of the semester of their selection of audit status. Under no circumstances may an audit status be changed to credit status once elected.

CREDIT BY EXAMINATION (Undergraduate Students)

In order that capable undergraduate students may move more rapidly into graduate work, comprehensive examinations are available to establish credit in courses required for the baccalaureate degree to a maximum of 18 credits. Approval of the department of major study, the department giving each course and the dean of student life is required.

Students may not take examinations for credit for any course for which they have registered at the Institute.

A specified fee is paid to the bursar in advance of each examination. Credit for a subject not formally studied elsewhere or at Polytechnic is earned by achieving a grade of B+ or better in the examination. The grade is not posted to the permanent record.

When validation of transfer credit is the purpose of this examination, the passing grade is set by the department administering the test. In the area of foreign languages, those presenting their native tongue or the language in which they were schooled are excluded from credit by examination tests in lower-level language courses (i.e. courses for the first four semesters of that language).

VALIDATION CREDIT (Graduate Students)

Graduate credit in a course may be established if a more advanced course (course pairs to be specified by the department) has been passed with an honor grade. Prior arrangement must be made with the department. Credit is authorized by the dean of graduate studies, upon recommendation of the department.

Validation may also be established by examination, when recommended by the department. In this case, application must be made to the dean of graduate studies and be accompanied by a fee. The examination will be administered by the department.

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

TRANSCRIPTS

The Institute 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 the student.

Official transcripts of the scholastic record of any student or graduate will be issued only at the student's 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 any other properly authorized party. In no case, however, will a student receive an *official* copy 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.

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

COMPUTATION OF GRADE-POINT AVERAGE

Undergraduate Grading

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

Grade	Point Value	Grade	Point Value
A	4.0	C+	2.3
A–	3.7	C	2.0
B+	3.3	C–	1.7
B	3.0	D+	1.3
B–	2.7	D	1.0

A grade of F equals 0.

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

The grade-point average is 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.

A W grade does not replace a previously earned grade.

Course Repeats

When an undergraduate student repeats a course two or more times, only the second and subsequent earned 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. Undergraduate students taking graduate courses are subject to the graduate grading system.

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

Courses repeated will count only once in the grade-point average, with the highest grade included.

The AU grade is used for audited courses; it is not used in the grade point average. S or U grades are used for continuing research registration until the work is completed at which time the earned letter grade is entered on the student's permanent record. The grade point average is not shown on the graduate permanent record.

To obtain any graduate degree or certificate, the student must have a 3.0 grade-point ('B') average or better in courses submitted for the degree or certificate, and a B or better average in all guided studies (readings, project, thesis, dissertation) submitted.

INCOMPLETE GRADES

When, for valid reasons, such as sickness or some other emergency, a student has not completed the course work at the usual time, the following grades will be given in undergraduate courses: Inc(S) if the student has been performing satisfactorily; Inc(U) if the work has been unsatisfactory. In graduate courses an Inc grade will be assigned. The duration of these grades is one year for undergraduate students, one semester for graduate students. If at the end of this time the course work has not been completed, the grade of Inc(S) lapses into a grade of W; the grade of Inc(U) lapses into a grade of F. In all cases, an incomplete grade must be converted to a letter grade prior to graduation.

The W grade is the only grade not assigned to the student by an academic instructor; it is obtained by administrative action on the part of the student (dropping the course) or the Office of the Registrar (the lapse of an I-S grade).

If a student receives an Incomplete grade, he/she should not re-register for the course. Complete the work and make sure that the instructor submits a change of grade form to the Office of the Registrar, at which time it will be entered on the permanent record.

WITHDRAWAL GRADES

A student wishing to withdraw from a course must do so in writing. A grade of W will be entered on the student's transcript, provided the withdrawal occurs within the following authorized periods:

Fall and Spring Semesters: 5:00 P.M. of Friday of the tenth week of the semester

Six-Week Summer Session: 5:00 P.M. of Friday of the fourth week of the session

Nine-Week Summer Session: 5:00 P.M. of Friday of the sixth week of the session

Twelve-Week Summer Session: 5:00 P.M. of Friday of the eighth week of the session

The student's major adviser is required to approve the withdrawal on the appropriate form. Once entered on the student's record, the grade of W cannot be changed to any other grade.

CHANGE OF DEPARTMENT

Even though students voluntarily indicate on their applications their field of special interest, it is expected and understood that with the passage of time some will wish to make changes in department. Final approval for such action by undergraduates must be obtained from the adviser of the new department, and for graduate students, through the Office of Graduate Studies. Such departmental changes become official only when approval forms are filed with the registrar. (Forms are available from the registrar.)

LEAVE OF ABSENCE

Undergraduate

A student wishing a leave of absence should discuss this with the dean of student life. A student desiring to reenter 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 prior to 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 a request when approved by the dean of graduate studies, will constitute assurance of readmission to a degree program. Forms for requesting a leave of absence are available in the Office of Graduate Studies.

Once a graduate student has started the dissertation, registration must be continuous, and a leave of absence is required for semesters in which a student will not be registering for research credits.

ACADEMIC STANDING

In order to remain in good standing, an undergraduate student must maintain term and cumulative grade point averages of 2.0 or greater. In addition he/she 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. Intersession and summer courses are calculated separately. The minimum number 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

These requirements are not applied to part-time students.

In calculating the number of credits successfully completed:

1. Credits undertaken for which the grade of F is earned count in the calculation of total credits of enrollment. They do not however, figure into the number of credits successfully completed.
2. Credits assigned the grade of W do not appear in the calculation of credits undertaken, earned or successfully completed.
3. Credits originally bearing the grade of F and repeated within one academic year will be re-calculated with the second grade earned, thus potentially entering into the number of credits successfully completed.
4. Credits with the grade of incomplete will be counted toward successful enrollment for one term. At the end of that time any grade of IS or IU that has not been changed by the professor of record will go to the grade of W or F, respectively, and be deleted from the number of credits successfully completed.
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 good standing is the maintenance of a grade point average at 2.0 or above, or performance approaching 2.0 in a steady and realistic fashion. The grade point average is 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. "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.

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

PROBATION

Undergraduate students will be placed on academic probation when they cease to make minimal progress. Minimal progress is defined as the successful completion of an increasing number of credits and the achievement of a minimum term grade point average of 2.0. The academic standing for part-time undergraduates will be calculated at those points when they complete the equivalent of a full-term load, i.e. enrollment in 12 or more credits. The grade point requirements will be applied to these term equivalents.

RESTRICTIONS OF PROGRAMS AND ACTIVITIES

Undergraduate students on probation should limit their extracurricular activities and are limited to a 15-credit program. Evening students on probation are limited to seven credits per semester throughout the year, including the summer term.

DISQUALIFICATION

The Committee on Standing, comprised of the dean of student life and representatives of the student's major department, shall jointly disqualify from the Institute any student whose cumulative average falls below the appropriate minimum shown in the accompanying table:

TABLE III

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
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

Additionally, a student's major department may disqualify a student at or above the minima listed above, if indications exist 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 attend the Institute for at least one academic year.

EXCEPTIONS

Extenuating circumstances such as medical and serious personal disorders must be documented and can lead to the waiver of these criteria for *one* term. Performance in the subsequent term must return to the minimum standard. Such reckoning must be made in concert with the student's major department and the dean of student life.

READMISSION AFTER ACADEMIC DISQUALIFICATION

Students who have fallen below the minimum standard and are disqualified may be considered for readmission upon submitting a formal application and evidence of an increased interest and likelihood of satisfactory performance. Such applications will be considered by the dean of student life in consultation with the department to which a student is applying. A student will reenter in the standing at the time of disqualification. At the time of readmission a plan for regaining good academic standing must be recorded with the dean of student life. Conditions requisite to the pursuit of good standing must be followed by the readmitted student.

Questions regarding undergraduate academic standing should be directed to a student's departmental adviser and to the dean of student life.

FINANCIAL AID

The standards which prevail for determining a student's academic eligibility to re-enroll at the Institute also apply to a student's academic eligibility to receive all forms of government-sponsored financial aid. See the financial aid section for additional information.

ADMINISTRATIVE ACTIONS

DEAN'S LIST

Undergraduate students who achieve grade-point averages of 3.0 or better are commended by the dean and placed upon the honors list. This list will be posted semiannually for day students and annually for evening students. Only those who complete 12 semester hours or more of study during the interval and who have an overall cumulative grade-point average of 3.0 or better are eligible for the dean's list. Students who include project and thesis courses or pass-fail courses in their 12-credit-or-more programs are also eligible for the dean's list provided these courses comprise one half or less of the credit load for the semester and all the aforementioned requirements are met.

Senior Honor Students

Each spring, the departments may select those 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 when they are selected, and they are given special permission to make substitutions in their selection of senior year courses (e.g., substituting more advanced or graduate courses in place of the usual requirements).

To be eligible for this designation, transfer students must be scheduled to complete at the Polytechnic at least one-half of the credits used 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 will

PRIZES AND AWARDS GIVEN AT GRADUATION

Aerodynamics Laboratories Award
American Institute of Aeronautics and Astronautics Award
American Institute of Chemists Award
American Society of Mechanical Engineers Award
American Statistical Association Award
John W. Andrews Placement Award
Richard W. Block Award
John R. Brierley Alumni Award of Service
Daughters of the American Revolution Award
Dow-Jones Wall Street Journal Student Achievement Award
Mitchell Fein Award
Simeon Gang Award
Margaret Goldstone Memorial Fund Award
Harold Hertzberg Award
James H.J. Hughes, Jr. Award
Institute of Electrical and Electronics Engineers Award
Noah A. Kahn A.S.T.M. Committee E-7 Award
Raymond E. Kirk Award
Eugene R. Kulka Award (Eta Kappa Nu)
Eugene R. Kulka Award (Tau Beta Pi)
George C. Marshall ROTC Award
Mermaid Club Awards
New York Metropolitan Section of the American Nuclear Society Award
Omega Chi Epsilon Award
Outstanding Student Award
David B. Porter Award
Alfred Raymond Prize
Robert Ridgeway Student Chapter Prize
Myron M. Rosenthal Prize
Myron M. Rosenthal Scholarship Fund Award
George D. Schaefer Award
Seymour L. Shapiro Award
Sigma XI Senior Research Award
Joshua Sills Award
Albert E. Sobel Prize
Theodore Clinton Towl Award

be 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 to the total number of credits required for the particular degree.

CONCURRENT ATTENDANCE

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

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 the expressed and prior permission of the instructors involved. The following explanations are intended to clarify this statement for all students.

LABORATORY EXPERIMENTS

Although a student may be permitted or required to cooperate with one or more fellow students in a laboratory experiment, many experiments are to be done by the students independently, and all require some independent work. For a student to submit the results of another's work as the student's own or to accept unauthorized help in an experiment constitutes academic dishonesty.

WRITTEN WORK

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

EXAMINATIONS

A student using or receiving unauthorized assistance during an examination, as from notes or other students, is in violation of academic regulation and is subject to academic discipline, including forfeiture of credit for the course, probation and dismissal from Polytechnic.

STUDENT SERVICES AND ACTIVITIES

The Office of the Dean of Student Life is responsible for the operation and maintenance of the Institute's community and student-oriented programs and services. More specifically, the function of the office is to help students obtain the maximum benefit from their college training—academically, culturally and socially. To achieve this objective, the office supplements and reinforces the educational program by

- Providing services to guide the student in obtaining the most satisfactory results in scholarship and personal adjustment.
- Giving assistance to the student in matters such as health insurance, housing and community resources.
- Coordinating the extracurricular student activity groups and organizations.
- Representing student interests in the decision making processes of the Institute.
- Keeping the student aware of the rules and policies of the Institute.
- Administering the academic and disciplinary policies of the Institute.

PRE-COLLEGE GUIDANCE

Principally through its admissions office, Polytechnic conducts a career guidance program for secondary school students contemplating college training. Polytechnic personnel, including faculty members, frequently lecture before high school audiences on various phases of Polytechnic's programs. Students are interviewed by the admissions office and then directed to faculty members for a thorough briefing in a particular professional specialty. At its open houses in fall and spring, Polytechnic devotes several days to presenting its educational programs to potential students through lectures, demonstrations and conferences.

UNDERGRADUATE ORIENTATION

An orientation program is planned for the beginning of each semester. At this time, incoming students are introduced to the academic and social environment of Polytechnic. Informative sessions and advisement as well as activities relative to student life are offered. The Ambassador Society conducts tours and welcomes new students to assist them to make the transition from their former academic environment to that of Polytechnic a bit more comfortable.

UNDERGRADUATE ADVISERS

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

GRADUATE ADVISERS

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

COUNSELING SERVICES

Often students require counseling in dealing with matters concerning 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 a student is in need of academic assistance, the Office of Special Services provides tutoring on an individual or group basis. Qualified upperclassmen serve as mathematics, physics, computer science and chemistry tutors.

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

In addition to academic guidance, the special services staff 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.

Special services coordinates a special summer program designed to assist pre-freshmen with deficient academic backgrounds. Through summer courses in mathematics, English and academic skill building, incoming students are able to accelerate and enter Polytechnic in the fall ready to meet the academic challenge.

Addressing the varied needs of the Polytechnic student is the primary goal of the special services office. Therefore, all tutorial, educative and counseling support services are provided at no charge to the student.

WOMEN'S PROGRAMS

The Women's Programs Office was established to reaffirm Polytechnic's commitment to equal opportunity in technical and scientific education for women and minorities. This office coordinates our special programs for women students and serves as a clearinghouse for information about scholarship opportunities, career options and other activities of particular interest to women.

Women's Programs sponsors a special program for minority women who are graduates of two-year colleges and wish to transfer to Polytechnic to pursue careers in management and other technical fields. This program, which has doubled its enrollment within the past two years, offers counseling and tutoring support for participants as well as other transfer students.

Women's Programs also coordinates a special summer mathematics program designed to provide an intensive review of high school mathematics and geared to those students who are deficient in math and/or who are changing fields.

In addition to programs for undergraduates, the Women's Programs Office offers educational and career counseling for female college graduates who are returning to the classroom to prepare for a career in the technical fields. Re-entry programs for women are currently available at Polytechnic in many graduate engineering and scientific disciplines.

INTERNATIONAL STUDENTS

The Polytechnic Institute of New York has been enrolling international students for many years. Over the years, thousands of students have graduated and returned to their countries. International students are an integral part of the Polytechnic. Advisers and administrative personnel are sensitive to the needs of international students and strive to meet them. International Student Services is centralized in the Office of Student Life. A full-time adviser is on hand to coordinate services and provide assistance to students. Students are urged to contact the office upon arrival and are welcome to drop by anytime. (See also the "Admissions Section" for further information.)

PHYSICALLY HANDICAPPED

Every effort is made by the Institute staff to provide assistance to physically handicapped persons so they may participate fully in the life of the college community.

Polytechnic fully supports Section 504 of the Rehabilitation Act of 1973 making accommodation of disabled students mandatory. The physically handicapped student may be assured that on our small and easily accessible campus individualized supportive services are available as needed. To further attract the physically handicapped, renovations are planned which will eliminate existing architectural impediments from the facility.

CAREER SERVICES

The placement service for students functions as part of the educational system 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 the responsibility for deciding what, how, when and where they will provide for their future needs.

Accordingly, the primary function of Career Services is to help students learn how to locate suitable positions, decide whether to work or pursue graduate studies, or 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 a career or job change.

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 fully utilize its services.

HOUSING

Resident students on the Brooklyn campus are housed on two floors of the Richard L. Connolly Residence Hall of the Long Island University located at Flatbush Extension in Brooklyn, just four blocks from the Polytechnic.

Residents are assigned to either 2-person rooms or 4-person suites. *There are no facilities for children. There are no cooking facilities.* There is an optional meal plan available.

Further information can be obtained from the Office of Student Life at the Brooklyn campus.

The Residence Hall at the Long Island campus houses a limited number of students in apartment-style suites. Each suite contains 4 private bedrooms, a common room complete with kitchenette, a shower room and a bathroom.

Private housing in the area surrounding Polytechnic's Long Island Campus is scarce. Often it is necessary to pay a fee (usually equal to one month's rent) to a real estate broker. Additional information about housing at the Long Island Campus is available from the Campus' Student Services Office.

CAMPUS LIFE

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

I. RULES OF CONDUCT

A. All members of the Institute 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 Institute premises.

1. Conduct that is violative of such laws and ordinances occurring on Institute premises may be subject to Institute discipline and public sanctions as circumstances may warrant or dictate.

2. Conduct that is violative of such laws and ordinances occurring off Institute premises will ordinarily not be subject to Institute discipline, unless such conduct:

a. seriously affects the interests of the Institute or the position of the member within the Institute community, or

b. occurs in close proximity to Institute premises and is connected with violative conduct on Institute premises.

B. All members of the Institute 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 the Institute.

2. Denial of, or unreasonable interference with the rights of others—including persons not members of the Institute community who are present as invitees or licensees—on Institute premises. These rights include the right of academic freedom as well as constitutionally protected rights.

3. Injury to Institute property, real or personal.

4. Unauthorized access to or occupation of nonpublic areas on Institute 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 and records.

6. Any action or situation which recklessly or intentionally endangers mental or physical health or involves the forced consumption of liquor or drugs, for the purpose of initiation into or affiliation with any organization.

C. Visitors, including invitees and licensees, shall at all times conduct themselves in a manner that is consistent with the maintenance of order on Institute premises, and their privilege to remain on Institute property shall terminate upon breach of this regulation. The Institute in addition reserves the right at its discretion to withdraw at any time the privilege of an invitee or licensee to be on Institute premises. A trespasser has no privilege of any kind to be on Institute property but is nevertheless subject to these regulations governing the maintenance of 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 and Trespassers). When administrative officers or members of the protection service of the Institute in their discretion determine that the privilege of an invitee or licensee to be on Institute premises should be withdrawn, they shall ask the invitee or licensee to leave the premises, and the invitation or license shall hereby be terminated. If any person, whether initially a trespasser, licensee or invitee, fails to leave Institute premises promptly upon request, the Institute will use all reasonable means, including calling for assistance of the police, to effect removal.

B. Disciplinary Action. A member of the Institute community who is charged with a violation of the Institute rules set forth in Section I above shall be subject to appropriate disciplinary action as follows:

1. Students

a. Disciplinary action shall be carried out by the Student Affairs Committee of the Faculty and the Office of the Dean of Student Life. Academic performance falls within the purview of the instructor who may seek the assistance of the department chairman. In instances of broader consideration, the services of the dean of student life are requested. That person will contact all parties involved, collect facts and request the advice of the monitoring bodies within the academic community. In order to initiate this process written complaints are submitted to the dean of student life.

Matters of sufficient gravity that affect the general operation and policies of the Institute will be addressed at an administrative hearing. At that time a person may introduce personally relevant information in support of a particular position. The person may also have an adviser present.

2. Faculty Members

a. When a faculty member is charged with a violation of these rules, an effort shall be made to resolve the matter 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 the matter cannot be resolved as provided in the preceding paragraph, disciplinary action shall 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 shall apply.

ii. If the faculty member does not have continuous or permanent tenure, his case shall be referred to a special committee of the faculty designated for that purpose. The special committee shall adopt its own rules of procedure consistent with procedures recommended by the American Association of University Professors. It shall have the authority to impose any of the penalties, other than dismissal listed in Section II-C and to recommend the penalty of dismissal.

3. Institute Staff: Administrative Officers and Other Employees

When a member of the Institute staff, other than a faculty member, has been charged with a violation of Institute rules, the charges shall be considered and determined administratively in accordance with established practices of the Institute. If the person against whom the charge has been made is both an administrative officer and a faculty member, the case shall be governed by this section unless the violative conduct was of such a nature as to call into question the person's continued qualification for service on the faculty; in the latter event, disciplinary action will proceed in accordance with Section II-B-2, above.

4. Student Organizations: If a student organization is charged with a violation of Institute rules, the charges shall be considered and determined administratively in accordance with the established practices of the Institute.

C. Penalties. Penalties for violation of Institute rules that may be imposed upon members of the Institute community include the following:

1. Reprimand
2. Censure
3. Removal of privileges
4. Suspension
5. Dismissal or expulsion
6. Recision of permission for student organization to operate on campus
7. Other sanctions deemed appropriate

DRUG ABUSE

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

HAZING

The Institute complies with Section 6450 of the Education Law of the State of New York (as amended in 1980). Accordingly, any action or situation which recklessly or intentionally endangers mental or physical health or involves the forced consumption of liquor or drugs for the purpose of initiation into or affiliation with any organization is prohibited.

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 the Institute 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

There are approximately 45 student organizations on campus working under Institute goals which give the student freedom of expression in setting organizational guidelines, in assuming responsibility for performance and in developing independence and awareness leading to social, cultural and educational growth. Some of the main activities are:

Student Council: The members of the Student Council are elected by popular vote as are the officers of other student organizations which govern student activities at Polytechnic. Each class elects its own officers with the student council president and treasurer elected by all campus elections. The Student Council directs the extracurricular activities of the undergraduate student body and administers funds received from the student activity fee and allocates these to publications, organizations and other student activities. The Council is also responsible for presenting a campus-wide film, lecture and music series which are open to all students.

Publications: Engineers and scientists require writing ability for their professional duties. Polytechnic publications offer a practical medium for students to develop their writing talents. The *Reporter* is the newspaper of Polytechnic. *Polywog* is the yearbook which works closely with Focus, the photography club, in capturing moments for reminiscence. The Polytechnic Engineer is a magazine devoted to technical and engineering articles. *Phoenix* is the literary publication of the student body produced in cooperation with the humanities and communications department.

Radio Station: WPIV is the student-operated radio station located in the Student Center. The station offers a cross section of musical interests with student disc jockeys presenting shows during the hours the Student Center is open. Participation is open to any student with technical facilities and record library available to scheduled announcers.

Athletics: For students who seek intercollegiate competition, Polytechnic fields teams in which junior varsity and varsity competition is actively pursued: baseball, basketball, wrestling, rifle, tennis, swimming, cross-country, fencing and soccer.

Polytechnic also encourages intramural competition in touch football, volleyball, basketball, hockey, tennis, handball, softball and badminton.

PROFESSIONAL AND DEPARTMENTAL SOCIETIES

Professional and technical societies are established in conjunction with the various departments in order 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: Six national fraternities are represented at Polytechnic. Most own or rent property in the Brooklyn area, with three offering live-in accommodations. The social fraternities contribute to the student community of Polytechnic. Not only do they administer an impressive array of social functions for their own members, but they also serve the student body in many activities. These include the organization of blood donation drives, dances, an annual charity drive and handball, basketball and bowling tournaments.

Clubs: At Polytechnic, there are clubs to suit every interest, whether intellectual, religious, musical, cultural or athletic. The range is quite broad. Many have had a long and distinguished history. Some of these are the Chess Club, Radio club, Railroad Club and the Pershing Rifle Drill Team.

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

RECOGNIZED COCURRICULAR ORGANIZATIONS

Professional Societies
American Institute of Chemical Engineers
American Institute of Industrial Engineers
American Chemical Society
American Institute of Mining and Metallurgical Engineers
American Institute of Physics
American Nuclear Society
Institute of Electrical and Electronic Engineers
Association of Computing Machinery
Operations Research and Systems Analysis Society
Operations Research Society of America
Society of American Military Engineers
Society of Women Engineers
American Institute of Aeronautics and Astronautics
American Society of Civil Engineers
Pre-Med Society
Society for Experimental Stress Analysis
Physics Math Society
Society of Physics Students
American Society for Metals
American Society for Mechanical Engineers
Society of Automotive Engineers
Nuclear Engineer Society
Space Technology and Resources Association

Student Organizations
Pershing Rifles
Capers
Sappers
Chinese Students Association
Demokritos
Association of Latin American Students
NARTU
Jewish Student Union
Society of Chinese Engineers
Radio Club
Astronomical Society
Chess Club
Resident Student Organization
Ambassador Society
Iranian Student Association
International Students Association
Korean Students Association
National Association of Black Engineers

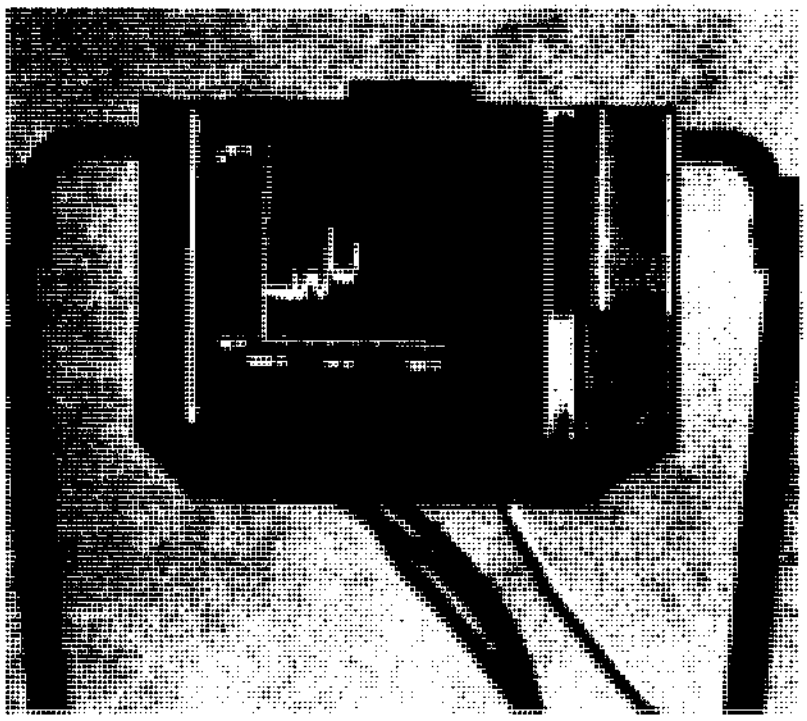
Fraternities
Alpha Phi Delta
Alpha Phi Omega
Lambda Chi Alpha
Phi Kappa Phi
Tau Delta Phi
Tau Epsilon Phi

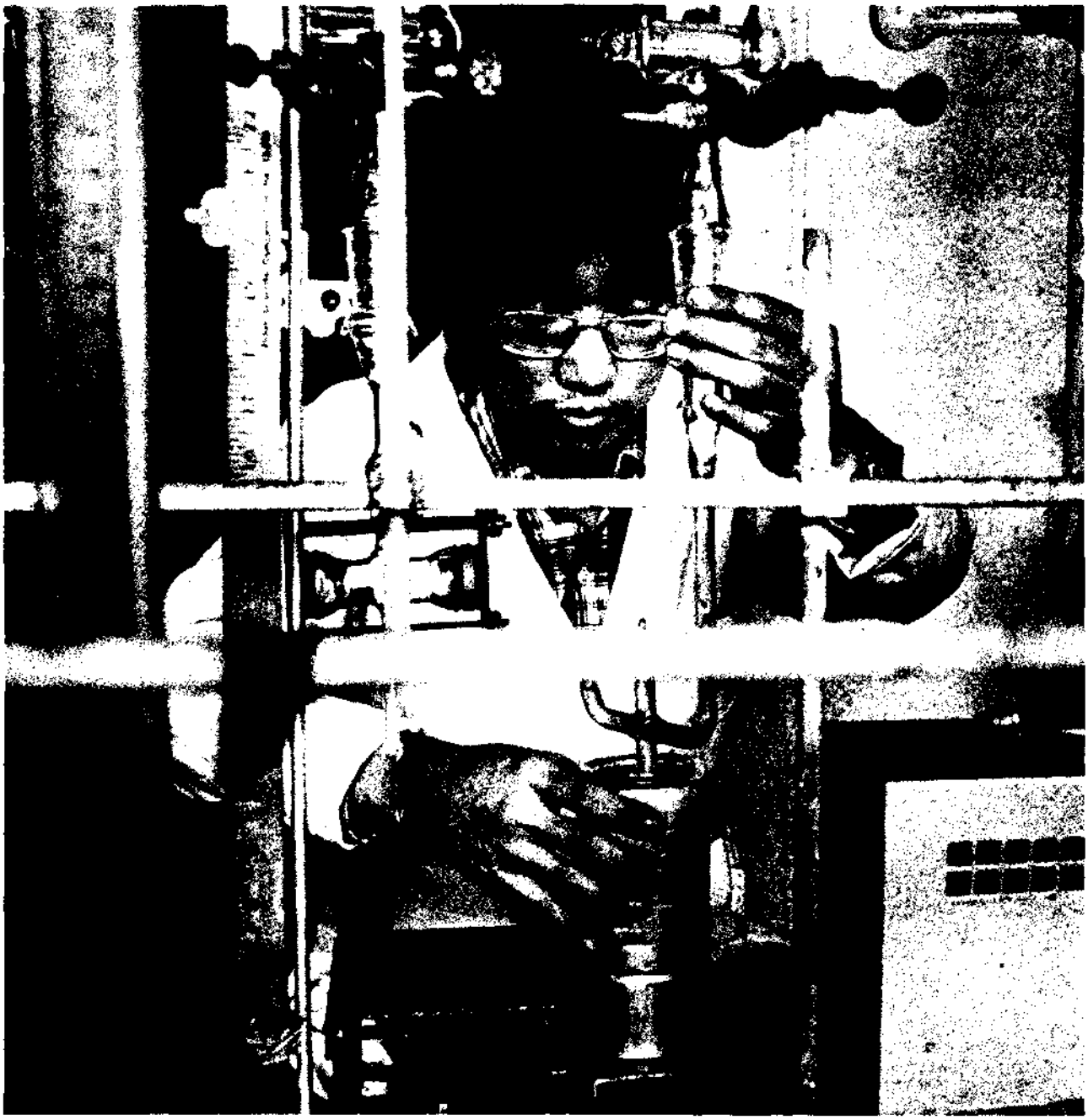
Honor Societies
Alpha Pi, industrial engineering
Alpha Sigma Mu, metallurgy
Chi Epsilon, civil engineering
Eta Kappa Nu, electrical engineering
Omega Chi Epsilon, chemical engineering
Omega Rho, operations research
Phi Lambda Upsilon, chemistry, chemical, and metallurgical engineering
Pi Mu Epsilon, mathematics
Pi Tau Sigma, mechanical engineering
Sigma Gamma Tau, aerospace engineering
Sigma Pi Sigma, physics
Sigma Xi, research
Tau Beta Pi, engineering

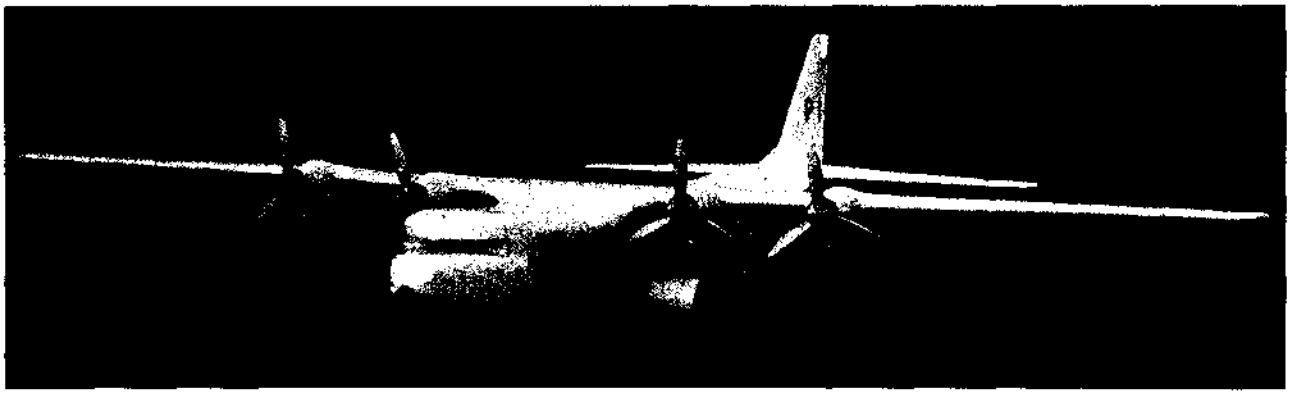
POLY-MENU

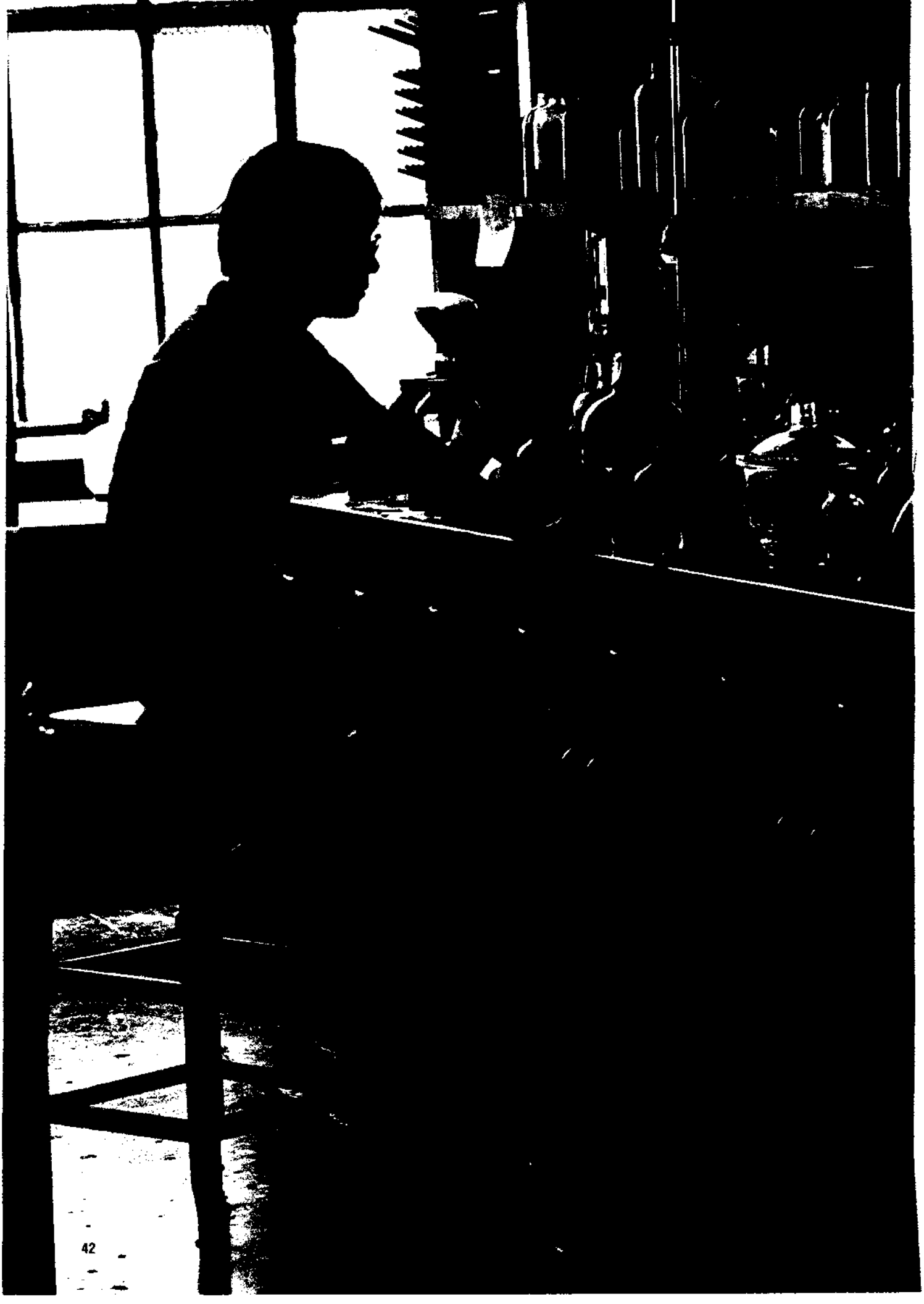
ITEM	
ACCELERFURTERS	17¢
BETA-BURGERS	24¢
HOT SCALARS ON A BUN	78¢
VECTOR SOUP	32¢
2 DIMENSIONAL MOTION CRACKERS	-11
VELOCITY A LA CARTE	2.00
SCRAMBLED OMEGA	34¢
EGG McCOSINES (ON AN AXIS)	-11¢
FRICTIONLESS COFFEE	69¢

INTEGRALS PERMITTED








41
42

A BRIEF GUIDE TO THE 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 all 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. Prerequisites: MA 224, **MA 153.**
Also listed under OR 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 at 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. Following "Prerequisites," you will notice that one course number appears in ordinary Roman Types (MA 224) while one number (**MA 153**) is in **boldface** type. If a prerequisite is in Roman type, that course must have been successfully completed *before* you may register for the course being described (in this case, the fictional MA 563). If the course is in **boldface** type, you may take that course *concurrently* (during the same semester) with the course being described, if you have not already taken it.

"Also listed under OR 899" 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

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 coverage includes the instrumentation to acquire physiologic data and the techniques to analyze and process such data.

Bioengineers bring a new viewpoint 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 system. 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, bioengineers provide the intellectual link between engineering and the life sciences, a role that is 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 equivalent) must be completed before the student is permitted to register for graduate level courses in bioengineering. 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 senior year. Students from other schools take these courses or show equivalent preparation.

The master's program consists of 36 units: 6 in mathematics, 18 in bioengineering, 6 in research and 6 in electives. The 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	Physical Properties of Biological Structures	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 996	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 hospital environment and equipment used in clinical 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 as 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 some research program he has elected. 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 dean of graduate studies.

Required Subject Areas	Units
Advanced Laboratory or Internship (as arranged with adviser)	5
Transport Phenomena or Equivalents	6
Graduate Biochemistry	3
Bioengineering Electives or Equivalents	9
Research and dissertation (BE999)	36
	59

UNDERGRADUATE COURSES

BE 201-202 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 departmentel 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. 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. Prerequisites: LS 105 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. Prerequisites: LS 105 and CM 164 or equivalent.
Also listed under PH 635

BE 604 Biophysics II* **2½:0:3**
Transport processes 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 of radionuclides, radiation safety levels, effects of acoustical, microwaves, and thermal radiation. Prerequisite: PH 335 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; cells, tissue, organs, structure, fluids. Properties and transportation of body fluids; renal function, cardio-pulmonary system, nervous system, gastrointestinal system. 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 620 Instruments and Measurements in Physiological Systems I* **2½:0:3**
BE 621 Instruments and Measurements in Physiological Systems II **2½:0:3**
Theoretical and practical aspects of measurement problems in physiological systems. Volume conductors; microelectrodes; technique for acquiring body-generated signals. Multiphasic screening systems. EMG, EEG, EKG. Readout devices and computer interface; digital instrumentation; telemetry. Analog and digital computer simulation of biological systems. BE 620 prerequisites: LS 105 and BE 201-202 or equivalent. BE 621 prerequisite: BE 620 or equivalent.

BE 622 Research Instrumentation* **1:6:6**
Laboratory course in electronics for students who find it necessary to use electronic instrumentation in research programs. Malmstadt/Enke Instrumentation Laboratory used. Power supplied, vacuum-tube and solid state amplifiers, oscillators, servo-systems, operational amplifiers, digital instrumentation. Prerequisite: adviser's approval.
Also listed under CH 841, CM 712 and SA 605

BE 623 Minicomputer Instrumentation for Scientific Research* **1:2:3**
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. Prerequisite: instructor's permission.
Also listed under PH 612 and CM 760

BE 650 Biomechanics* **2½:0:3**
Fundamental bases 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 instructor. Prerequisites: SS 189 or equivalent or instructor's permission.
Also listed under SS 912

BE 676 Comparative Psychology **2½:0:3**
Comparison 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 the 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 control nervous system disorders, etc. Topics will vary from semester to semester and course may be taken for repeated credit. Prerequisites: 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**
Design 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 205 for details.

THESIS, COLLOQUIUM 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**
Assignment of graduate students as members of selected hospital teams to observe hospital practice and participate where appropriate. Work directed by adviser from Polytechnic and leader of hospital team. Normally limited to students who have completed one full year of graduate study. Prerequisites: BE 602, BE 611, adviser's permission.

BE 996 Project **each 3 units**
Bioengineering project under guidance of qualified faculty member subject to approval of program adviser. Project 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. Candidate required to take oral examination on subject of thesis and related topics. Minimum registration of 24 credits required. Prerequisites: degree status and successful performance on qualifying examination. Registration fee, any part: 3-credit charge.

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 Padua (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
Chemical instrumentation

Carl P. Mason, Adjunct Lecturer in Bioengineering
B.S.M.E., M.S. Bio.E., Polytechnic Institute of New York
Rehabilitation engineering

PARTICIPATING FACULTY

Robert C. Ackerberg, Professor of Chemical Engineering

Patrick T. Cahill, Professor of Chemical Physics

Herbert Morawetz, Professor of Polymer Chemistry and Director of Polymer Research Institute

Shirley M. Motzkin, Professor of Biology and Director of Life Sciences Program

Kurt Salzinger, Professor of Psychology

William R. Allen, Associate Professor of Mathematics

Barry M. Wolf, Associate Professor of Mechanical and Aerospace Engineering

SUPPORTING AND ADVISORY STAFF

Doris Escher (Montefiore Hospital and Medical Center)
M.D., New York University
Pacemakers, cardiovascular studies

Henry Freedman (Long Island College Hospital)
M.D., New York University
Obstetrics and gynecology

Paul Fried (Veterans Administration—Brooklyn)
M.S., Polytechnic Institute of Brooklyn
Biomedical engineering

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

George Kelen (Veterans Administration— Brooklyn)
M.B., B.S., University of Sydney (Australia)
Cardiology, noninvasive testing

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

Chemical engineering is, in a broad sense, a professional endeavor that bridges the gap between scientific knowledge and man-made products. The chemical engineer relies heavily on science, the engineering method, experience and ingenuity to create the equipment and processes that affect the efficient and economical production of energy or substances.

Virtually everything of material concern to mankind today has, at some point, been nurtured by chemical engineers. They engage in the production of petroleum products, plastics, pharmaceuticals, foodstuffs, synthetic rubber, rocket propellants and a host of other substances. Their influence has been felt in the development of nuclear reactors, fuel cells, automatic controls, sea water desalting plants, missiles and artificial kidney machines. In their daily work they may be behind a desk, at a computer, in the laboratory or in an industrial plant. The challenges they face today are the realities of tomorrow.

The profession of chemical engineering embraces a broad spectrum of activities, including research, process and product development, design and supervision of the construction and operation of the industrial plants that use chemical and physical processes, technical sales and services, consulting, management and teaching. It is a dynamic profession in which the opportunities for a stimulating and rewarding career in the technological era of the future are truly 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 cover 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.

Dealing as it does with both physical and chemical transformation, the chemical engineering curriculum provides a background that enables the graduate to select a professional career from an extremely broad spectrum of opportunities. Graduates will be prepared to take employment in any one of 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 its undergraduate degree program at two campuses, Brooklyn and Farmingdale, with identical curricula and courses.

In addition to the regular program in chemical engineering, the department also gives students the opportunity to concentrate in one of three particular areas of wide current interest: biosystems, environmental studies and management. All are within the chemical engineering degree program.

The undergraduate program leads to the degree of bachelor of science in chemical engineering and is accredited by the Accreditation Board for Engineering and Technology.

In addition to the requirement of a 2.0 minimum average for graduation, students also are obliged to maintain at least a 2.0 average in chemical engineering courses to qualify for the degree.

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 131, 142, 143, 146, for six credits of technical electives.

Students in the management concentration option may count SS 251 and SS 252 (6 credits) as part of their humanities and social sciences requirements.

b. A total of 17 credits of technical electives (minimum) is necessary. In fulfilling this requirement the student should choose at least 3 credit hours of mathematics, plus 3 credit hours of chemical engineering elective courses and an additional 6 credit hours of physics, chemistry or life sciences. The remaining technical electives (5 credits) may be taken in any technical area in consultation with the departmental adviser. Students electing the biosystems, environmental studies or management concentration options may choose their electives in any technical area in consultation with their adviser.

c. Junior transfer students should take CH 123 and CH 124 in junior year in place of electives.

d. To be taken only with permission of undergraduate adviser. A 3.0 average is recommended.

GRADUATE PROGRAM

The graduate programs in chemical engineering are designed to introduce students to advanced design, research and development. The Department of Chemical Engineering offers graduate programs leading to the degrees of master of science, engineer and doctor of philosophy in chemical engineering.

In addition, the Departments of Chemical Engineering and Chemistry jointly offer programs leading to the degrees of master of science and doctor of philosophy in polymer science and engineering. See page 231.

A degree in chemical engineering is generally required for admission to graduate study. The student 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 either as 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 chemical engineering program is oriented toward those chemical engineers who wish to achieve a level of education in advanced process design beyond that normally possible for the master's degree.

The doctor of philosophy in chemical engineering degree program provides advanced graduate study and research for the qualified student 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, a student may not obtain a grade of C (or lower) in more than three of the required subjects listed above, including required courses retaken for purposes of improving a grade. This requirement is in addition to the Institute requirements for the master's degree.

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 the 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 will be obliged to satisfy these requirements as deficiencies prior to enrollment in the engineer's program.

Candidates for the degree of engineer in chemical engineering are to plan their programs in accordance 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.

On completion of the design project, the candidate is obliged to submit to an oral examination before a faculty committee. While the examination will focus on the subject of the project, its scope will not be limited thereto; the candidate could expect to be examined on his design competence in a broader 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 the direction of a guidance committee appointed by the dean of graduate studies for each candidate. The program is planned to give the student a thorough chemical engineering background accompanied by study in a minor field chosen by the candidate. The student must pass a comprehensive qualifying examination in chemical engineering, exhibit a reading knowledge in a 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 the summer session, 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 will be 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 seminars for at least four semesters. Each student must maintain an overall B average in those courses submitted for the doctoral degree.

For a degree in chemical engineering, the following courses are required and may be used to complete the 48 graduate units required in chemical engineering subjects:

No.	Required Subjects	Units
CH 631-632	Transport Phenomena I, II	6
CH 771-772	Chemical Engineering Thermodynamics I, II	6
CH 781	Chemical Process Kinetics	3
CH 782	Chemical Reactor Design, Simulation and Control	3
CH 821	Process Dynamics and Control	3
		21

Students interested in the Ph.D. program should obtain a brochure 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 the chemical processes and process 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 study 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.

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 multistage model and mass and energy balances, e.g., absorption, extraction, distillation. The equilibrium stage, 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 potential and its use in phase and chemical reaction equilibria. Prerequisites: CM 161 and CM 162, CH 123 and CH 124, or adviser's approval.

CH 271 Engineering Materials **3:0:3**
Structure, properties and uses of polymers and metals as engineering materials. Crystal structure, defects, heat treatment, corrosion and its prevention. Manufacture and processing of polymers. Mechanical behavior of polymers and their thermal and electrical properties. Prerequisites: CM 161, CM 162, CM 123 and CM 124.
Also listed under MT 420

CH 301-302 Chemical Engineering Laboratory I, II **each 0:6:2**
Experimental study of operations in chemical engineering. Laboratory projects on the unit operations, transport processes, thermodynamics, reaction kinetics, process instrumentation, process dynamics and control. Design and conduct of experiments, interpretation of results, preparation of engineering reports. Data analysis done with aid of computer. CH 301 prerequisites: CH 241 and CH 221. CH 302 prerequisites: CH 301, CH 322 and CH 351.

CH 322 Chemical Reactor Engineering 3:0:3
Application of thermodynamics and chemical kinetics to analysis and design of chemical reactors and reactor systems. Homogeneous and heterogeneous reactors of various types, uncatalyzed and catalyzed. Design of single and cascaded industrial reactors. Prerequisites: CH 221, CH 251 or inetructor'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 theory. Process systems analysis via transient and frequency response methods; control systems design. Analog computer simulation. Prerequisites: MA 104 and CH 241.

CH 361 Process Design I 3:0:3
Synthesis and design of chemical processes, with consideration of site and process selection, process economics, materials of construction, data requirements and acquisition, flow-sheeting and subsystems. Computer utilized. Case studies. Prerequisites: CH 241 and CH 251.

CH 362 Process Design II 3:0:3
Design of large chemical process systems, with special emphasis on more complex, integrated process schemes and systems optimization. Prerequisites: CH 322, CH 351 and CH 361.

CH 380-381 Chemical Engineering Project each 2 credits
Independent work in an area of interest in chemical engineering selected by the student and faculty supervisor. 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 391-394 Bachelor's Thesis in Chemical Engineering each 2 credits
Original investigation of a problem in chemical engineering. A thorough search of the literature required. Special apparatus constructed as required for experimental work.

CH 396 Chemical Engineering Internship 2 credits
A supervised, creative engineering experience of at least two months' duration, typically taken during the summer, culminating in a written and oral report presented to the industrial and faculty supervisors. Faculty visitations and conferences during the internship 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
Study of the more important chemical industries, their processes and products. Effects of process variables on end products and needs for variation in properties of products as determined by market demands. Interlocking chemical industries. Product planning and marketing. Prerequisite: instructor's permission.

CH 612† Chemical Process and Project Evaluation 2½:0:3
Analysis of the design and operation 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 the design 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 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 analysis; 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. Analysis of particle size distribution and concentration. Fluid-solid reaction kinetics and design. Prerequisite: MA 531 or equivalent.

CH 721 Mass Transfer Operations* 2½:0:3
Unified treatment 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 742 Design of Solid Waste Processing Systems* 2½:0:3
An evaluation of advanced solid waste processing technology with particular emphasis on processes still under development. Incinerator and pyrolysis design for heating value recovery and effluent recovery. Separation for recovery of valuable raw materials. Other modern techniques. Prerequisite: adviser'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 753 Dispersion of Pollutants* 2½:0:3
Introduction to theory of diffusion of pollutants and methods for estimation of dispersion in atmosphere. Nature of mean and turbulent motions in various urban, rural, valley environments; effects of these on dispersion of pollutants. Mean and turbulent motions in oceanic and coastal waters and fresh-water bodies. Dispersion of pollutants in sea, lakes, rivers.
Also listed under CE 753

CH 755 Air Pollution Chemistry* 2½:0:3
Significant chemical reactions occurring in lower atmosphere and basic chemistry required to understand problems peculiar to air pollution field. Also, chemistry applicable to fuels combustion and other sources of atmospheric pollution.
Also listed under CE 755

CH 756 Air Pollution Analysis* 2:3:3
Principles of reaction or physical measurement used for variety of analytical equipment employed in air pollution studies Analysis of various atmospheres and evaluation of results.
Also listed under CE 756

CH 757 Air Pollution Effects* **2½:0:3**
Effects of atmospheric pollution on various forms of life, including both direct and secondary effects. Corrosion or contamination of inert matter by pollutants in the atmosphere. Legal aspects and community organization for control of atmospheric pollution.
Also listed under CE 757

CH 760 Energy Resources, Conversion Technology, Distribution Utilization* **2½:0:3**
Comprehensive study of the energy problem in terms of available and potential resources of primary energy, conversion technology, distribution and utilization, with emphasis on both economic and technical factors. Present and possible future environmental impact. Prerequisite: instructor's permission.

CH 766 Process Heat Transfer* **2½:0:3**
Thermal design of industrial heat exchangers, including condensers and forced and natural circulation reboilere; process design of fired heaters; optimum use of extended surface; heat transfer and power requirements of agitated jacketed veesels. Prerequisite: instructor's permission.

CH 771 Chemical Engineering Thermodynamics I **2½:0:3**
Laws of thermodynamics; conditions for thermodynamic equilibria; use of equations of state and the principle of corresponding states to determine changes in thermodynamic properties for pure substances and mixtures. Chemical potential, 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 rule, Gibbs-Duham equation, non-ideal solutions; stability of thermodynamic systems, osmotic pressure, surface teneion, thermodynamic equilibria in potential fields; introduction to irreversible thermodynamics. Prerequisite: CH 771 or equivalent.

CH 781 Chemical Process Kinetics **2½:0:3**
Reactor analysis and design; segregation and maximum-mixedness, selectivity in laminar and dispersed flows, variable density flows; numerical and statistical analysis of nonlinear systems; multistage reactors, shemisorption and pore diffusion; steady-state multiplicity; packed bed momentum transport; solid-gas flow reactors. Prerequisite: CH 322.

CH 782 Chemical Reactor Design, Simulation Control* **2½:0:3**
Design of industrial reactors, optimization of reactors, dynamic behavior of reactors, modeling of reaction rates, computer simulation of reactors, stability and control of reactors. Case studies. Prerequisite: CH 781 or equivalent.

CH 784 Catalysis* **2½:0:3**
Catalytic processes and engineering problems associated with each process. Review of catalytic chemistry, relationships between chemistry and choice of processing conditions with choice of catalyst composition and structure. Experimental methods in catalytic research; relation of processing conditions to chemistry and transport effect. Prerequisite: CH 781 or equivalent.

CH 791 Electrochemical Engineering* **2½:0:3**
Theory and measurement of reversible and irreversible electrochemical processes at metal-electrolyte interfaces. Thermodynamics, kinetics, mass transport, mixed potential theory, passivation. Modern experimental techniques. Electrochemical energy conversion devices (batteries and fuel cells). Prerequisite: CM 162 or equivalent.

CH 815 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 819 Machine Computation 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 techniquea using GPSS. Applications to material and energy balances, design and optimize distillation processes, heat transfer apparatus, process flow sheets, use of matrix methods in formulating and solving chemical engineering problems. Prerequisite: CS 100 or equivalent.

CH 821 Process Dynamics and Control **2½:0:3**
Instrumentation and control of chemical processes from viewpoint of system engineering. Unsteady state behavior of chemical engineering systems. Analysis of closed-loop feedback systems for control of variables of chemical process equipment. Prerequisite: CH 351 or equivalent.

CH 841 Research Instrumentation* **2½:5:6**
Laboratory course in electronics for students who find it necessary to use electronic instrumentation in research programs. Malmstadt/Enke Instrumentation Laboratory used. Topics include power supplies, vacuum-tube and solid-state amplifiers, oscillators, servo-systems, operational amplifiers and digital instrumentation. Prerequisite: adviser's approval.
Also listed under CM 712, BE 622 and SA 605

CH 851-852 Process Design and Synthesis I, II* **each 2½:0:3**
Design of complex chemical process plants. Use of optimization techniques in design. Selection of design techniques and process alternates. Evaluation and design of projects in the light of uncertainty. Factors affecting design and erection of plants such as market, plant location, raw materials availability. CH 851 prerequisite: CH 781 or equivalent. CH 852 prerequisite: CH 851.

CH 862 Rheology of Non-Newtonian Fluids* **2½:0:3**
Classification of non-Newtonian viscoelastic fluids. Derivation of rheological equations of state from continuum mechanics point of view. Molecular viscoelastic theories: random-coil theory and network theory. Experimental characterization 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 872 Fundamentals of Biochemical Engineering **2½:0:3**
Kinetics of enzymatic reactions. Transport phenomena in microbial systems. Design and analysis of biochemical reactors. Principles of natural product isolations. Genetic engineering and chemical processes. Prerequisite: CH 631.

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 will be 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. Study of non-Newtonian polymeric systems. Extrusion theory and applications. Discussions and problem-solving in compression, transfer and injection molding, thermoforming and plasticization, as well as other polymer engineering processes. Prerequisites: CH 220 and CH 221 or instructor's permission.

CH 922 Polymer Processing Laboratory 0:4:3
Laboratory study of engineering principles and processes involved in polymer processing and analysis. Experiments involved in polymer processing and analysis. Experiments include injection molding, extrusion, thermoforming, mixing and compounding, melt rheology, flat- and blown-film extrusion, blow molding, etc. Prerequisite: CH 921.

CH 923 Industrial Polymerization Processes* 2½:0:3
Analytical study of principal processes used to synthesize polymers, including polymer engineering operations, equipment, polymerization control, instrumentation, process economics. Emphasis on development and solution of polymer plant engineering problems. Prerequisite: CM 771.

CH 926 Engineering Properties of Polymers 2½:0:3
Study of mechanical properties and structure of solid polymers. Viscoelastic theory and response of amorphous, crystalline and composite materials in stress-strain tests, creep, stress relaxation and dynamic tests. Effects of orientation, and previous history on mechanical behavior. Prerequisites: CH 915, CM 771.

CH 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 polymeric materials as announced in advance of particular semester offering. Prerequisite: adviser's approval.

PROJECT, THESIS AND SEMINAR

CH 902 Guided Studies in Chemical Engineering 6 units, each 2 units
Selection, analysis, solution and presentation of an engineering report of some problem in process or equipment design, thermodynamic study or correlation, or another field of chemical engineering practice under supervision of staff member. Conferences scheduled. Candidates for master's degree required to submit three unbound copies of typewritten report 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
Selection, analysis, solution and presentation of a comprehensive report of some problem involving polymeric materials, such as polymer synthesis, processing, evaluation, equipment design, etc. Conducted under supervision of staff member. Conferences scheduled. Candidates for master's degree 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 investigation of a problem in the chemistry and chemical engineering of polymeric materials. Thesis may involve experimental research, theoretical analysis, or process design, and possibly a combination thereof. Candidates for master's degree 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 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 Seminar in Chemical Engineering nc
Recent developments in the field of chemical engineering 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
Thesis for master's degree in chemical engineering should give results of original investigation of a problem in chemical engineering or application of physical, chemical or other scientific principles to chemical engineering. Thesis may involve experimental research, theoretical analysis or process design, and possibly a combination thereof. Candidates for master's degree 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 Project 9 units, each 3 units
Engineering analysis, synthesis, optimization and design of a process or novel equipment. Project requires original individual work. Evaluation of results, use of engineering judgment and excellence in reporting emphasized. Conducted under supervision of staff member. Conferences scheduled. Candidates for engineer degree required to submit four unbound copies of typewritten project report 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
Dissertation must give results of independent investigation of a problem in chemical engineering and may involve experimental and/or theoretical work. Thesis must show ability to do creative work and that an original contribution has been made to chemical engineering, which is worthy of publication in recognized journals. Candidate required to take an oral examination on subject of thesis and on related topics. Candidates for doctor's degree 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 chemical engineering.

FACULTY

Chang Dae Han, Professor and Head of Chemical Engineering
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

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

William H. Kapfer, Professor of Chemical Engineering
B.Ch.E., M.Ch.E., Eng.Sc.D., New York University
Polymeric materials, plant design economics

Eli M. Pearce, Professor and Head of Chemistry
B.S., Brooklyn College; M.S., New York University; Ph.D., Polytechnic Institute of Brooklyn
Polymer synthesis and degradation

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

Jovan Mijovic, Assistant 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

Paul F. Schubert, Assistant Professor of Chemical Engineering
B.S., University of Notre Dame; Ph.D., Cornell University
Transport processes, separation sciences, biochemical engineering

ADJUNCT FACULTY

Herbert W. Cooper, Adjunct Professor of Chemical Engineering
B.Ch.E., M.Ch.E., CCNY; Eng. Sc.D., Columbia University
Process equipment design, high temperature processes, heat transfer

W. Lincoln Hawkins, Adjunct Professor of Chemical Engineering
Chem. Eng., Rensselaer Polytechnic Institute; M.S., Howard University; Ph.D., McGill University; LL.D (Hon.), Montclair State College
Degradation and stabilization of polymers, recycling of plastics

Joseph W. Prane, Adjunct Professor of Chemical Engineering
B.Ch.E., CCNY; M.S., Columbia University
Polyurethanes, polyesters—alkyd resins, surface coatings

EMERITUS FACULTY

Paul F. Bruins, Professor Emeritus of Chemical Engineering
B.S., Central College, Iowa; M.S., Ph.D., Iowa State University; D.Sc. (Hon.) Polytechnic Institute of New York
Plastics technology, electrochemistry, materials science

Warren L. McCabe, Dean of Faculty Emeritus
B.S., M.S., Ph.D., University of Michigan

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 process, thermodynamics of phase equilibria

W. Fred Schurig, Professor Emeritus of Chemical Engineering
B.Ch.E., M.Ch.E., D.Ch.E., Polytechnic Institute of Brooklyn

CHEMICAL PHYSICS

GRADUATE DEGREE PROGRAMS

The chemical physics program at Polytechnic is designed to train students for careers in those 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. Typical areas of interest include aspects of quantum and theoretical chemistry, statistical mechanics, solid-state physics and chemistry, molecular structure, x-ray crystallography, nuclear and electron resonance, the structure of liquids, the study of surfaces, and biophysics.

Students normally enter the program with undergraduate degrees in chemistry, physics or mathematics. All applicants should take the Graduate Record Examination. 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 given below.

Representative Program for First-Year Students

No.	Required Subjects	Units
CM 705	Introduction to Chemical Physics	6
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		11-14

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. Satisfactory passing is required.

No.	Required Subjects	Units
CM 971-972	Chemistry Colloquium	0
or		
PH 901-902	Physics Colloquium	0
CM/PH 995-996	Seminar in Chemical Physics (to be taken with either colloquium)	
and one of the following:		
CM 998/ PH 999	Thesis in Chemical Physics	12
Electives*		at least 21
or		
CM 998/ PH 999	Project in Chemical Physics†	6
Electives*		at least 27
or‡		
Electives*		at least 33
		at least 36

A reading knowledge of French, German, Japanese or Russian is required; students whose native language is not English will be required to demonstrate adequate mastery of English.

* To be chosen from approved courses in chemistry, mathematics and physics in consultation with adviser.

† Under special circumstances, CM 951-2, Experiment Design I, II, may be substituted for the project.

‡ 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. The student is expected to pass examinations which form part of those regularly given to graduate students in the Departments of Chemistry and Physics. The candidate must also demonstrate a reading knowledge of scientific French, German, Japanese or Russian. Students whose native language is not English will be required to demonstrate adequate competence in English.

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 simultaneously with their application for admission to the graduate school or at some later time. Special application forms, as well as additional information, are available from the Office of the Dean of Arts and Sciences.

FACULTY INTERDEPARTMENTAL COMMITTEE

*__Bernard J. Bulkin,__ Professor of Chemistry and Dean of Arts and Sciences; Chairman, Chemical Physics Committee

*__Ronald D. Parks,__ Professor and Head of Physics

__Ernest M. Loebl,__ Professor of Chemistry

*__Eli M. Pearce,__ Professor and Head of Chemistry

__Benjamin Post,__ Professor of Physics and Chemistry

PARTICIPATING FACULTY

__Ephraim Banks,__ Professor of Chemistry

__Patrick T. Cahill,__ Professor of Physics

__Hellmut J. Juretschke,__ Professor of Physics

__Norman C. Peterson,__ Professor of Chemistry

__Stephen Arnold,__ Associate Professor of Physics

__Bruce A. Garetz,__ Assistant Professor of Chemistry

__Sophia Merajver,__ Assistant Professor of Chemistry

*Ex officio

CHEMISTRY

Chemistry is concerned with our ever-expanding knowledge of the structure, properties and reactions of matter and our evolving theories to explain our observations, predict chemical behavior and suggest experiments.

The 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 and quantitative determinations of composition; and physical chemistry, which seeks to provide an understanding of the properties of matter, including chemical bonds and molecular interactions. These classical fields have overlapped increasingly, however, and several inter-disciplinary fields of study are now of great importance. Examples are biochemistry, electrochemistry, photochemistry, polymer chemistry and chemical physics. Thus, biochemistry integrates the biological sicences with classical chemistry and polymer chemistry.

Polytechnic's Department of Chemistry offers a full complement of undergraduate and graduate courses in important aspects of modern chemistry. Graduates are prepared for meaningful positions with educational institutions, research institutes, industrial organizations and government laboratories.

The department is active in research, with staff members conducting and supervising research at both undergraduate and graduate 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.

The participation of undergraduates in a variety of research activities provides them with both stimulus and exceptionally good preparation for graduate school or a professional position.

The department offers programs leading to the 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 programs jointly with the Department of Physics and the Department of Chemical Engineering as described below.

CHEMICAL PHYSICS PROGRAM

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, a flexible course of study in both departments. The program leads to the degrees of master of science and doctor of philosophy. (For details, see special listing on page 57.)

POLYMER SCIENCE AND ENGINEERING

Polymer science and engineering is an interdisciplinary program, administered jointly by the Departments of Chemistry and Chemical Engineering, leading to the degrees of master of science and doctor of philosophy. (For details, see special listing on page 231.)

UNDERGRADUATE PROGRAM

For the student majoring in chemistry, the Department of Chemistry provides a curriculum that goes beyond the educational requirements of the American Chemical Society for professional training. The courses offered are professional courses designed to prepare the candidate for graduate study or for work in industry.

Bachelor of science degrees are certified by the ACS, and graduates are immediately eligible for membership in the American Chemical Society.

Requirements for the Degree of Bachelor of Science in Chemistry

	Credits
CM 101, 102, 108, 109, 111, 112, 118-120, 122-125, 161, 162, 175, 177, 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/social sciences.

Curriculum for Bachelor of Science 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

CM 122	Organic Chemistry I	3	0	3	CM 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

CM 108	Inorganic Chemistry	3	0	3	CM 119	Analytical Chemistry	3	0	3
CM 109	Inorganic Chemistry Lab.	0	3	1	CM 120	Analytical Chemistry Lab.	0	6	2
CM 118	Chemical Equilibria	2 9/10	5	4	CM 177	Physical Chemistry Lab.	3/10	5	2
CM 162	Physical Chemistry II	3	0	3	CM 504	Chemical Lab. Safety	1	0	1
CM 501	Chemical Literature	1	0	1		Hum./Soc. Sci. electives	3	0	3
	Hum./Soc. Sci. electives	3	0	3		Technical electives			3
	Electives			2		Electives			3
				17					17

Senior Year

CM 175	Adv. Physical Chemistry	4	0	4		Advanced Chemistry	3	0	3
CM 390-391	Bachelor's Thesis			4	CM 392-394	Thesis			6
	Hum./Soc. Sci. electives	3	0	3		Electives			5
	Electives			3					14
				14					

Total credits required for graduation: 128

BIOCHEMISTRY OPTION

Freshman and sophomore courses as above.

Junior Year

First Semester		Hours/Week			Second Semester		Hours/Week		
No.	Subject	Cl.	Lab.	Cr.	No.	Subject	Cl.	Lab.	Cr.
LS 105	Biology I	3	0	3	LS 106	Biology II	3	0	3
LS 115	General Biology Lab. I	1	3	2	LS 116	General Biology Lab. II	1	3	2
CM 118	Chemical Equilibria	2 9/10	5	4	CM 177	Physical Chemistry Lab.	3/10	5	2
CM 162	Physical Chemistry II	3	0	3	CM 202	Biochemistry II	3	0	3
CM 201	Biochemistry I	3	0	3	CM 204	Biochemistry Lab.	3/10	5	2
CM 501	Chemical Literature	1	0	1	CM 504	Chemical Lab Safety	1	0	1
				16		Hum./Soc. Sci. electives			3
									16

Senior Year

CM 108	Inorganic Chemistry	3	0	3	CM 119	Analytical Chemistry	3	0	3
CM 109	Inorganic Chemistry Lab.	0	3	1	CM 120	Analytical Chemistry Lab.	0	6	2
CM 390-391	Bachelor's Thesis			4	CM 392-394	Thesis			6
	Hum./Soc. Sci. electives			3		Hum./Soc. Sci. electives			3
	Electives			3		Electives			2
				14					16

Total credits required for graduation: 128

HU 101, 200 or 201, SS 104	9
Technical elective	3
Humanities/Social Science Electives*	21
Free Electives*	12
PE 101-104	—
	128

In humanities and social sciences, the student 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).

In addition, the student is strongly urged to select an area 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 this concentration, in consultation with the departmental adviser. A modern language may be chosen as a suitable concentration, but a student without prior knowledge of the language must plan to devote at least 12 credit hours to the subject.

For the remaining credits in the humanities/social sciences requirement, the student should select courses in areas other than that of the concentration. Additional courses in the humanities and social sciences may be taken as free electives.

CM 201, CM 502 or a graduate course may be used as the advanced chemistry course. Students with a strong interest in mathematics may substitute MA 111-114 for MA 101-104.

Students with a special interest 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. The requirement for an advanced chemistry course is waived for students taking the biochemistry option.

All laboratory courses in chemistry require a breakage deposit.

The department does not usually grant transfer credits for students who, while registered at Polytechnic, take chemistry courses at other schools.

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

TEACHING CERTIFICATION

Students wishing to obtain certification for teaching in the public schools of the New York City area may take education courses off campus and receive credit at Polytechnic for these courses as free electives. Approval for courses to be taken at another college must be obtained in advance from the major department and the academic dean.

GRADUATE STUDY

Admission to graduate study 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 a student to have had differential equations, atomic and nuclear physics, and two years of German, Russian or French. Chemistry graduate students cannot take CM 500† courses for graduate credit.

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 the master's degree. Programs must include four courses from among the following:

No.	Subject	Units
CM 601	Inorganic Chemistry	4½
CM 705	Chemical Physics	6
CM 771	Introductory Polymer Chemistry	3
CM 801	Theory of Analytical Processes	4½
CM 903	Advanced Organic Chemistry	4½
CM 941	Biochemistry I	3

Students may elect research and a thesis (12 units). An 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 the thesis are required to take 3-6 units of guided studies with submission of a written report (CM 871-872).

Students in the master's program must participate in seminar for two semesters (CM 973-974); those electing no thesis must present at least one lecture to the seminar group.

All master's students must take CM 504†, Chemical Laboratory Safety.

Additional requirements not measured in units are:

Demonstration of competence in one acceptable foreign language: in general, German, Russian or French. Students whose native language is not English must also demonstrate competence in English.

Continuous attendance at departmental colloquia.

Industrial Chemistry

The Department of Chemistry offers a master of science in industrial chemistry. Students electing this program are required to take the following courses:

No.	Subject	Units
CM 950-951	Industrial and Engineering Chemistry I, II	6
MG 600	Management Process	3
MG 865	Management of Innovation, Technological Change, Research and Development	3
CM 760	Minicomputer Instrumentation for Scientific Research	3
or		
MA 531	Applied Mathematics for Engineers	
CM 955	Project in Industrial Chemistry	3-6
CM 504†	Chemical Laboratory Safety	0
		18-21

At least 12-15 units must be taken from graduate courses in chemistry numbered above 600.

The remaining units are to be 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	3 each
CH 921	Polymer Processing	3
HU 605	Technical Writing	3
CM 502	Environmental Chemistry	3

REQUIREMENTS FOR THE DOCTOR'S DEGREE

Formal admission to the doctoral program 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. The program includes the following courses, the first four in which the student must have at least a B average:

	Course	Subject	Units
1.	CM 601	Inorganic Chemistry	4½
	CM 705	Chemical Physics	6
	CM 801	Theory of Analytical Processes	4½
	CM 903	Advanced Organic Chemistry	4½
	CM 504†	Chemical Lab Safety	0
2.	A major		12
3.	A minor		7½
4.	Participation in seminar for four semesters, twice as a lecturer.		6
5.	Research presented in a dissertation.		45

6. Demonstration of competence, at a level higher than that required for the master's degree, in an acceptable foreign language: in general, German, Russian or French. Students whose native language is not English must also demonstrate competence in English.
7. By the end of the second year, the student is required to pass a preliminary examination, administered by the Guidance Committee, which may consist of written and oral portions.
8. Attendance at seminars and colloquia for the duration of research.
9. Passage of a final oral examination. The final oral examination will take place after the members of the Guidance Committee have read the dissertation in typed, unbound form.

All students in the doctoral program will be awarded the master of science degree upon satisfactory completion with a grade of A or B in course requirements equivalent to the above in addition to 12 units of research toward the doctoral dissertation, as certified by the chairman of the Guidance Committee. On proper application to the dean of the graduate studies and after completion of the preliminary examinations, the student will be certified as having earned the 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 091 Principles of Chemistry I* **2½:1½:3**
Basic principles of chemistry with emphasis on historical origins. States of matter, modern concepts of atomic and molecular behavior in relation to chemical processes. Introduction to chemical equilibrium and kinetics. Selected laboratory experiments. For students majoring in humanities or social sciences. Lab fee required.

CM 092 Principles of Chemistry II* **2½:1½:3**
Basic principles of descriptive inorganic and organic chemistry with applications to electrochemistry, polymer chemistry, biochemistry. Selected laboratory experiments and introduction to quantitative laboratory techniques. For students majoring in humanities or social sciences. Lab fee required. Prerequisite: CM 091.

CM 101 General Chemistry I **2½:0:2½**
Chemical conservation laws, states of matter, acid-base and oxidation-reduction theory, introduction to chemical thermodynamics and chemical equilibrium, electro-chemistry, 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 structure of elements as baeis for periodic classification. Descriptive chemistry of elements and their compounds. Theory 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. Prerequisites: CM 102, CM 112 and CM 161.

CM 111 General Chemistry Laboratory I 0:1½:½
Introduction to chemical laboratory procedures. Laboratory associated with the lecture course, CM 101. Lab fee required.

CM 112 General Chemistry Laboratory II 0:1½:½
Laboratory experiments in qualitative analysis to be taken in conjunction with CM 102. Lab fee required. Prerequisites: CM 101, CM 111.

CM 118 Chemical Equilibria 2⅓:5:4
Equilibria in homogeneous and heterogeneous chemical processes. Applications of equilibrium concepts and data to analytical and physical chemistry. Theory of titrations and other analytical processes. Thermodynamic and chemical interpretations of equilibrium data. Separation, techniques. Lab fee required. Prerequisites: CM 161-162.

CM 119 Instrumental Methods in Analytical Chemistry 3:0:3
Theory and application 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, **CM 119** and CM 161-162.

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, stereochemistry, spectroscopic methods. Prerequisites: CM 102 and CM 112.

CM 123 Organic Chemistry II 3:0:3
Continuation of CM 122 with emphasis on 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. Prerequisite: **CM 122.**

CM 125 Organic Chemistry Laboratory II ⅓:5:2
Laboratory methods for preparation, purification, characterization and identification of organic compounds by chemical and physical means. Introduction to use instrumental methods of analysis and identification. Lab fee required. Prerequisites: **CM 123** and CM 124.

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 164 Physical Chemistry of Living Systems 3:0:3
Basic concepts of physical chemistry illustrated by examples of physiological significance. Thermochemistry, chemical equilibria, equilibria in coupled processes, electrochemistry, diffusion, determination of molecular weight of macromolecules, spectroscopy, reaction kinetics and use of isotopes. This course may not be used in fulfillment of physical chemistry requirements for the B.S. in chemistry. Strong students may, with an instructor's permission, present this course as a prerequisite for CM 201. Prerequisites: CM 102, CM 112, MA 103 and PH 103.

CM 175 Physical Chemistry III* 4:0:4
Atomic and molecular aspects of physical chemistry. Quantum chemical and statistical description of matter with applications to molecular spectroscopy, binding and structure. Prerequisites: MA 104 and **CM 162.**

CM 177 Physical Chemistry Laboratory ⅓:5:2
Experimental methods of physical chemistry. Chemical kinetics, thermodynamics, electrochemistry, molecular spectroscopy, high vacuum, instrumental techniques. Computer analysis of experimental data. Report writing. Lab fee required. Prerequisites: CM 118 and CM 162.

CM 201 Biochemistry I 3:0:3
Survey of modern biochemistry with emphasis on currently active areas of research. Structure-function relationships in proteins and nucleic acids. Enzymes and their mechanisms of action; bioenergetic principles and energy production. Biochemical theory 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 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. Prerequisite: **CM 201.**

CM 390-394 Bachelor's Thesis in Chemistry each 2 credits
Original investigation by student under guidance of a departmental staff member. 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. Student required to give oral resume of work before at least two members of chemistry faculty. Full-time students 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. Prerequisites: **CM 501** and **CM 504.**

CM 501† Chemical Literature 1:0:1
Program of lectures, exercises and discussion designed to familiarize students with the chemical literature. Students may emphasize topics related to bechelor'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. Genesis analysis and removal of pollutants. Effects of chemical pollutants on health of industrial workers and the general population. Prerequisites: CM 122, CM 124 and CM 161 or CM 164 or instructor's permission.

CM 503† Organic Chemistry for Bioengineers 2:0:2
Introductory course in organic chemistry for engineering students entering bioengineering program. Structure and reactions of organic compounds; organic molecules of biological significance. Prerequisites: CM 102 and CM 112 or equivalent.

CM 504† Chemical Laboratory Safety 1:0:1
A discussion 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.*

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 theory. 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 solid state, chemistry of coordination compounds, mechanisms of inorganic reactions, chemistry of non-metals, inorganic polymers, chemistry of representative elements, bonding theory. Prerequisite: CM 601 and adviser's approval.

PHYSICAL CHEMISTRY

CM 705† Chemical Physics 5:0:6
Fundamental ideas of quantum and statistical mechanics; application to elucidation of atomic structure and chemical bonding and to interpretation of spectra of atoms and molecules. Development of relationships of various bulk properties of matter to molecular structures and interactions. *Required of all candidates for Ph.D. degrees in chemistry.* Prerequisites: CM 162 and PH 103.

CM 706 Chemical Thermodynamics* 3¾:0:4½
Principles of equilibrium and nonequilibrium thermodynamics from both statistical and classical points of view. Application to chemical and physical problems, including solutions, chemical equilibria, electrochemistry, surface and transport phenomena. Development of quantitative relationships between molecular scale behavior and bulk thermodynamic properties. Prerequisite: **CM 705** or permission of instructor.

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 supplied, 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 Kinetics of Chemical Reactions* 2½:0:3
Methods and results of investigation of rates and mechanisms of reaction in gases and in solution. Collision and transition state theories of reaction rates. Prerequisite: CM 705.

CM 716 Valence and Molecular Structure* 2½:0:3
Descriptive exposition of application of quantum mechanics to problems of chemical bonding and molecular structure. Various quantum mechanical theories of valence, their applicability and limitations. Prerequisite: CM 705.

CM 717 Electrochemistry* 2½:0:3
Theory of equilibrium and mass transport properties of electrolyte solutions and fused salts. Chemical potential, diffusion, viscosity, electrical conductance. Theories of molecular relaxation processes in electrolyte solutions and techniques employed in their investigation (transient and forced oscillatory methods, NMR). Prerequisite: CM 162.

CM 721 Quantum Mechanics for Chemists* 3¾:0:4½
Principles of quantum mechanics quantitatively developed. Comparison of various approaches. Most important approximation methods useful for application of theory to many problems in chemistry and physics. Detailed discussion of several applications to some basic problems. *Required of all Ph.D. candidates with major in physical chemistry.* Prerequisite: CM 705, PH 601 and PH 602.

CM 722 Statistical Mechanics for Chemists* 3¾:0:4½
Classical and quantum statistical mechanics systematically developed and applied to calculation 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 applications 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 theory, energy band theory 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
Synthesis 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 formation. Modern mechanistic analysis of reactions. Stereochemistry of polymer structure and forces of stereoregulation. Condensation, free radical (bulk, suspension, emulsion, solution), ionic, ring-opening and nonclassical polymerization reactions.

CM 781 Solution Properties of High Polymers 2½:0:3
Application of osmometry, light scattering, equilibrium ultracentrifugation, electrophoresis, viscosity, diffusion, 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 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 in 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.

ANALYTICAL CHEMISTRY

CM 801 Analytical Chemistry 3¾:0:4½
Principles of analytical chemistry, with emphasis on modern techniques. Chromatography, including GC and HPLC, spectroscopy (atomic absorption, luminescence circular dichroism, mass), electroanalytical chemistry, voltammetry, laser methods. Other instrumental applications are discussed in CM 119 and CM 905. *Required of all candidates for the Ph.D. degree in chemistry.* Prerequisite: CM 162.

CM 850 Special Topics in Analytical Chemistry* 2½:0:3
Advanced or specialized topics in analytical chemistry. PH 671-672 and PH 673-674 may be offered to satisfy minor requirements in analytical chemistry.

ORGANIC CHEMISTRY

CM 903† Advanced Organic Chemistry 3¾:0:4½
Advanced organic chemistry, with emphasis on structural and mechanistic concepts. Molecular reactions, homolysis, heterolysis, displacement on hydrogen and on carbon, addition to unsaturated systems, elimination reactions and electrocyclic reactions. *Required of all candidates for Ph.D. degree in chemistry.* Prerequisites: CM 123, CM 125 and CM 162.

CM 905† Spectroscopy of Organic Molecules 2½:0:3
Application of spectroscopy to organic chemistry with emphasis on interpretation of vibrational, electronic, mass and magnetic resonance spectra of organic molecules. Prerequisites: CM 123 and CM 125, or equivalent.

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.

CM 920 Current Aspects of Organic Synthesis* 2½:0:3
Approaches to synthesis of organic molecules. Stereoselective and stereospecific reactions. Examples drawn from naturally occurring and theoretically interesting molecules. Prerequisite: CM 903.

CM 921-33 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.

CM 940 Special Topics in Organic Chemistry* 2½:0:0
Selected topics of current importance in organic chemistry. Prerequisite: CM 903.

BIOCHEMISTRY

CM 941-942 Biochemistry I, II each 2½:0:3
In-depth study of biochemistry. Properties of biological macromolecules: proteins and nucleic acids. Enzyme kinetics, mechanism and control. Energy production, transformation and utilization. Regulation of biochemical systems. Replication, transcription and translation of DNA. Protein synthesis. Membrane structure and function. Prerequisites: LS 106, LS 116 and CM 202, or consent of instructor.

CM 943-948 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 and characterization of biological macromolecules. Enzyme kinetics. Biochemical application of tracer techniques. Lab fee required. Prerequisites: CM 123, CM 125, CM 202, CM 162, LS 106, LS 116 and **CM 941-942.**

CM 948 Epidemiology of Environmental Health 3:0:3
An introductory course on methodology, meaning and scope of epidemiology. Elements of biostatistics, study design, data collection. Emphasis on the scientific appraisal of the patterns of health and disease in environmental and occupational exposure to toxic chemicals.

INDUSTRIAL CHEMISTRY

CM 950-951 Industrial and Engineering Chemistry I, II each 3:0:3
Discussion of the chemical process industries, emphasizing basic chemical and physical principles, as well as the economic feasibility of individual processes, to provide a chemical engineering background 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 analysis and recycling. Stagewise and continuous contact equipment and flow sheet analysis. 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 Project in Industrial Chemistry **as arranged**
Directed study or supervised reading and/or experimental work in advanced area of chemistry and chemical technology. Conferences scheduled. Candidates for this M.S. degree program are required to submit four unbound copies of a typewritten project report and present an oral summary to advisers before or on the seventh Wednesday prior to commencement. Prerequisite: B.S. in chemistry or allied field or permission of instructor.

GENERAL COURSES

CM 971-972 Guided Studies in Chemistry **as arranged**
Directed study or supervised readings in advanced areas of chemistry. Registration by consent of department head.

CM 971-972 Chemical Colloquium **0**
Meetings of the members of the department staff, invited guests and qualified students to study recent developments in chemistry. Required each year of all students in graduate degree status majoring in chemistry and for two years of doctoral matriculants in other departments with minor in any field of chemistry. Seminar fee required.

CM 973-978 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 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 may serve as the basis for the master's degree. Also to be taken by Ph.D. candidates prior to completion of the Ph.D. preliminary examination in chemistry. Minimum research registration requirements for the master's degree: 12 units. Registration for research required each semester consecutively until student has completed adequate research project and acceptable thesis and has passed required oral examination. Number of research credits registered for each semester shall reflect realistically time to be devoted to research. A maximum of 6 units may be counted toward the 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 physica major with thesis advisers in Department of Physics should register for PH 791-798 and PH 981-993. Minimum research registration requirements for the 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 student has completed adequate research project and acceptable thesis and has passed required oral examination. Number of research credits registered for each semester shall reflect realistically time to be devoted to research. Research fee required. Prerequisites: completion of Ph.D. preliminary examination in chemistry and consent of thesis director and CM 504†.

FACULTY

Eli M. Pearce, Professor of Polymer Chemistry and Head of Chemistry Department
B.S., Brooklyn College; M.S., New York University; Ph.D., Polytechnic Institute of Brooklyn
Polymer synthesis and degradation

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

Judith S. Bellin, Professor of Biochemistry
B.S., Hunter College; M.S., Ph.D., Polytechnic Institute of Brooklyn
Environmental chemistry, environmental/occupational health

F. Marshall Beringer, Professor of Organic Chemistry
B.S., Harvard University; M.S., Ph.D., Columbia University
Organocopper compounds, organic derivatives of polyvalent iodine, reactive intermediates

Bernard J. Bulkin, Professor of Chemistry; Chairman of Chemical Physics Program and Dean of Arts and Sciences
B.S., Polytechnic Institute of Brooklyn; Ph.D., Purdue University
Infrared and Raman spectroscopy, cell membranes, liquid crystals

Frederick Eirich, Distinguished Professor of Polymer Chemistry
Ph.D., University of Vienna
Mechanical behavior of polymers, rheology, colloid chemistry, chemical evolution, biopolymers

Ernest M. Loebl, Professor of Physical Chemistry
M.S., Hebrew University; Ph.D., Columbia University
Theoretical chemistry, quantum and statistical mechanics

Herman F. Mark, Professor Emeritus of Polymer Chemistry and Dean Emeritus
B.S., Ph.D., University of Vienna
Synthesis, characterization, and properties of natural and synthetic polymers

Herbert Morawetz, Institute Professor, Professor of Polymer Chemistry and Director of Polymer Research Institute
B.A.Sc., M.S.Sc., University of Toronto; Ph.D., Polytechnic Institute of Brooklyn
Polymer reactions, hindered rotation in polymer systems, properties of polymer gels, polymer compatibility

Yoshiyuki Okamoto, Professor of Organic Chemistry
B.S., Osaka University of Science and Engineering (Japan); Ph.D., Purdue University
Organic and polymer chemistry

Ronald Parks, Professor of Physics and Chemistry
B.S., Kansas State University; M.S., Ph.D., Stanford University
Surface physics and chemistry

Norman C. Peterson, Professor of Physical Chemistry
S.B., 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

Benjamin Post, Professor Emeritus of Physics and Chemistry
B.S., CCNY; M.S., Ph.D., Polytechnic Institute of Brooklyn
Crystal structure analysis, x-ray instrumentation and diffraction theory

Mark M. Green, Associate Professor of Organic Chemistry
B.S., CCNY; Ph.D., Princeton University
Dynamic stereochemistry, isotope effects, polymer-organic chemistry, mass spectrometry

Nancy Tooney, Associate Professor of Biochemistry
B.S., M.S., SUNY (Albany); Ph.D., Brandeis University
Structure and function of proteins and other biopolymers, the blood clotting system.

Martel Zeldin, Associate Professor of Inorganic Chemistry
B.S., Queens College; M.A., Brooklyn College; Ph.D., Pennsylvania State University
Chemistry of elements in Groups IIIA and IVA

Bruce A. Garetz, Assistant Professor of Physical Chemistry
A.B., Harvard College; Ph.D., Massachusetts Institute of Technology
Laser spectroscopy, nonlinear optics and multiphoton processes, molecular dynamics

Patrick Hoggard, Assistant Professor of Inorganic Chemistry
B.S., University of California (Berkeley); Ph.D., Washington State University
Spectroscopy of transition metal complexes

Sophia Merajver, Assistant Professor of Physical Chemistry
B.S., Ph.D., University of Maryland
Conformational studies of chain molecules, laser spectroscopy, theoretical studies

Subhash C. Narang, Assistant Professor of Organic Chemistry
B.Sc., M.Sc., Panjab University; D.Sc., Flinder University
New synthetic methods and reagents, reaction mechanisms

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

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

CIVIL AND ENVIRONMENTAL ENGINEERING

Civil engineering, the oldest branch of applied science, covers the entire range of environmental control. It includes the planning, design, construction and maintenance of such diverse elements as subterranean and subaqueous tunnels for vehicular traffic and fluid flow, bridges, buildings, dams, works for water and air purification, structures and vehicles for space probes.

Today the ingenuity and imagination of civil and environmental engineers are engaged intensively in coping with the complexities of public health, sanitation, traffic flow in urbanized areas and city planning. Civil engineers plan and construct the superhighways, airports and other means of transportation required to satisfy the needs of our industrialized civilization. They also harness, control and utilize our water resources for irrigation, power production and human consumption, all of which are basic to our very existence. The needs for civil and environmental engineers and the challenges they must face for many decades in the future dwarf any previous experience.

The Department of Civil and Environmental Engineering offers courses leading to the bachelor of science, master of science, engineer and doctor of philosophy degrees. The undergraduate program is accredited by the Accreditation Board of Engineering and Technology.

UNDERGRADUATE PROGRAM

The fundamental sciences of mathematics, physics and chemistry are presented first, together with additional subjects such as English, history, language and economics designed to broaden the student's intellectual horizons. The program then introduces the basic engineering sciences including properties of materials, fluids, soils, electricity, thermodynamics and stress analysis. In the last phase of the program, professional applications such as highways, environmental engineering and detailed design of structures are studied. The emphasis is on preparing students broadly in all of the major areas of civil and environmental engineering.

ELECTIVES

In order to allow the students to broaden their knowledge, elective subjects are provided. Senior courses in other departments may be selected as well as some courses in the graduate program. Approved technical electives are indicated below; other courses may be chosen with the approval of the department adviser.

No.	Technical Electives	Credits
CE 272	Construction Engineering	3
CE 306	Introduction to Geophysical Sciences I	3
CE 307	Introduction to Geophysical Sciences II	3
CE 315	Soils Engineering	3
CE 335	Advanced Structural Design	3
CE 336	Timber and Masonry Structures	3
CE 345	Hydraulic Engineering	3
CE 375	Hydraulic Design Laboratory	2
CE 521	Oceanography	3
IE 300	Engineering Economic Analysis	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
PH 230	Introduction to Atomic and Nuclear Physics	2
PH 232	Introduction to Modern Physics	3
PH 240	Optics	3

ROTC students should note that freshmen and sophomores may substitute zero-credit military science courses for PE 101-104 (physical education); junior and seniors may substitute three of the following two-credit courses, MS 131, 142, 143, 146, for six credits of technical electives.

EVENING SESSION

Most civil engineering courses in the undergraduate listing will be offered only on an alternate-year basis. Exceptions to this plan are courses CE 202, CE 150, CE 214, CE 222, CE 391, CE 392, which will be offered each year.

Students enrolled in the evening session should contact the evening adviser or departmental office for details about this plan. A suggested eight year evening program leading to the B.S. in civil engineering degree is given on the following page.

Typical Course of Study for the Bachelor of Science Degree in Civil 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
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
PH 101	Introductory Physics I	3	0	3	PH 102	Introductory Physics II	3½	1½	4
HU 101	College Comp.	3	0	3	SS 104	Cont. World History	3	0	3
AM 101	Graphics	1	3	2	CS 100	Intro. to Programming	2	0	2
PE 101	Physical Education	0	2	0	PE 102	Physical Education	0	2	0
				15					16
					Summer camp (2-week session)				
					CE 150	Surveying Fieldwork			2

Sophomore Year

MA 103	Calculus III	3	0	3	MA 104	Applied Ord. Diff. Eqs.	3	0	3
PH 103	Introductory Physics III	2½	1½	3	AM 117	Eng. Mech. II	2	0	2
AM 116	Eng. Mech. I	2	0	2	CE 202	Mechanics of Materials	3	0	3
CE 151	Surveying	3	3	4	CE 303	Nat. & Prop. Struct. Mat.	1	3	2
HU 200	Intro. to Literature	3	0	3	EE 370	Principles of E.E.	3	0	3
PE 103	Physical Education	0	2	0		Hum./Soc. Sci. elective	3	0	3
				15	PE 104	Physical Education	0	2	0
									16

Junior Year

CE 222	Fluid Mechanics	3	3	4	CE 214**	Computer Techniques in Eng.	3	0	3
CE 322	Theory of Struct. I	3	0	3	CE 232	Soil Mechanics	2	3	3
CE 351*	Highway & Transp. Eng.	2	3	3	CE 323	Theory of Struct. II	3	0	3
AM 201	Thermodynamics	3	0	3	CE 331	Steel Structures	3	0	3
	Mathematics elective	3	0	3	CE 340	Water Res. & Hydr. Eng.	3	0	3
	Hum./Soc. Sci. elective	3	0	3		Hum./Soc. Sci. elective	3	0	3
				19					18

Senior Year

CE 252	Reinforced Concrete Struct.	3	0	3	CE 305	Eng. Contr. & Specs.	2	0	2
CE 317	Foundations	2	3	3	CE 332	Design of Struct. Sys.	2	3	3
CE 341	Environ. Eng. I	2	3	3	CE 342	Environ. Eng. II	2	3	3
	Hum./Soc. Sci. elective	3	0	3		Hum./Soc. Sci. elective	3	0	3
	Technical electives			6		Technical electives			6
				18					17

Minimum total credits required for graduation: 136

*Offered in the second semester at Farmingdale.
**Offered in the first semester at Farmingdale.

Suggested Eight-Year Program Leading to the Bachelor of Science Degree in Civil Engineering

First Year

First Semester			Hours/Week		Second Semester			Hours/Week	
No.	Subject	Cl.	Lab.	Cr.	No.	Subject	Cl.	Lab.	Cr.
MA 101	Calculus I	4	0	4	MA 102	Calculus II	4	0	4
HU 101	College Composition	3	0	3	PH 101	Introductory Physics I	3	0	3
				7	SS 104	Contemp. World History	3	0	3
									10

Second Year

MA 103	Calculus III	3	0	3	MA 104	Appl. Ord. Diff. Equations	3	0	3
PH 102	Introductory Physics II	3½	1½	4	PH 103	Introductory Physics III	2½	1½	3
HU 200	Intro. to Literature	3	0	3	AM 101	Graphics (1981-1982, 1983-1984) or	1	3	
				10	CS 100	Intro. to Programming (1982-1983, 1984-1985)	2	0	2
									8

Third Year

AM 116	Eng. Mechanics I	2	0	2	AM 117	Eng. Mechanics II	2	0	2
CM 101	General Chemistry I	2½	0	2½	CM 102	General Chemistry II	2½	0	2½
CM 111	General Chemistry Lab. I	0	1½	½	CM 112	General Chemistry Lab. II	0	1½	½
	Mathematics elective	3	0	3	AM 101	Graphics (1981-1982, 1983-1984) or	1	3	
				8	CS 100	Intro. to Programming (1982-1983, 1984-1985)	2	0	2
									7
					CE 150*	Surveying Fieldwork			2

Fourth Year

CE 202	Mech. of Materials	3	0	3	CE 214	Computer Tech. in Eng.	3	0	3
AM 201	Thermodynamics	3	0	3	CE 222	Fluid Mechanics	3	3	4
	Hum./Soc. Sci. elective	3	0	3					7
				9					

Fifth Year†

CE 340	Water Res./Hyd. Eng.	3	0	3	CE 151	Surveying	3	3	4
EE 370	Principles of E.E.	3	0	3		Hum./Soc. Sci. elective	3	0	3
CE 303	Nature & Prop. of Struct. Materials	1	3	2					7
				8					

Sixth Year**

CE 322	Theory of Struct. I	3	0	3	CE 323	Theory of Struct. II	3	0	3
CE 232	Soil Mechanics	2	3	3	CE 331	Steel Structures	3	0	3
	Hum./Soc. Sci. elective	3	0	3		Hum./Soc. Sci. elective	3	0	3
				9					9

Seventh Year†

CE 252	Reinforced Concrete	3	0	3	CE 332	Design of Struct. Syst.	2	3	3
CE 351	Hwy. & Transp. Eng.	2	3	3	CE 317	Foundations	2	3	3
	Technical elective			3		Technical elective			3
				9					9

Eighth Year**

CE 341	Environ. Eng. I	2	3	3	CE 342	Environ. Eng. II	2	3	3
CE 305	Eng. Contr. & Specs.	2	0	2		Hum./Soc. Sci. elective	3	0	3
	Technical elective			3		Technical elective			3
				8					9

Minimum total credits required for graduation: 136

* *This 2-week course will be offered every May during the day. Normal credit completion by end of third year* = 52 credits

† Offered in alternate *odd* years, i.e. 1981-1982, 1983-1984. (The fifth and sixth years are interchangeable.)

** Offered in alternate *even* years, i.e., 1982-1983, 1984-1985. (The seventh and eighth years are interchangeable.)

GRADUATE STUDY

Programs of study are offered leading to the degrees of master of science in civil engineering, master of engineering in civil engineering, master of science in environmental health science, engineer in civil engineering, doctor of philosophy in civil engineering and the undesignated doctor of philosophy.

The requirements for the master's degree include prescribed courses and approved elective courses. A thesis or a project may be substituted for elective courses. A minimum of 36 units is required for the degree.

The engineer degree is 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.

The Ph.D. degree requires advanced study beyond the master's degree level in the field of civil engineering. Evidence of reading knowledge of modern language other than English is required. 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 the master's degree 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. The student should consult with the department head to determine the expected scheduling of such courses.

AREAS OF SPECIALIZATION

Structural Engineering Program

No.	Required Subjects	Units
CE 601	Theory of Structural Analysis and Design I	3
CE 602	Theory of Structural Analysis and Design II	3
Minimum of nine units from the courses listed immediately below:		
CE 609	Matrix Methods of Structural Analysis I	9
CE 611	Limit Design of Metal and Concrete Structures I	
CE 614	Metal Structures I	
CE 641	Reinforced Concrete Structures I	
	Required units	15
	Minimum elective units	21
	Minimum total units	36

Water Resources and Hydraulic Engineering Program

CE 715	Open Channel Hydraulics	3
CE 716	Hydraulic Problems	3
CE 722	Hydrology I	3
CE 724	Water Resources Planning	3
and either		
CE 723	Hydrology II	3
or		
CE 732	Coastal Engineering	
	Required Units	15
	Minimum elective units	21
	Minimum total units	36

Environmental Engineering and Planning Program

a. Water Quality Engineering

No.	Required Subjects	Units
CE 738	Sanitary Chemistry	3
CE 740	Sanitary Microbiology	3
CE 742	Water and Wastewater Treatment I	3
CE 743	Water and Wastewater Treatment II	3
CE 747	Analysis of Stream and Estuary Pollution	3
	Required units	15
	Minimum elective units	21
	Minimum total units	36

b. Air Resources Engineering

CE 753	Dispersion of Pollutants in the Atmosphere	3
CE 755	Air Pollution Chemistry	3
CE 756	Air Pollution Analysis	3
CE 757	Air Pollution Effects	3
CE 758	Air Pollution Engineering Control	3
	Required units	15
	Minimum elective units	21
	Minimum total units	36

c. Environmental Health Science

CE 738	Sanitary Chemistry	3
CE 740	Sanitary Microbiology	3
CE 741	Analysis of Water Quality Systems	3
CE 751	Environmental Health Engineering	3
CE 752	Air Pollution	3
CE 770	Solid Waste Management	3
	Required units	18
	Minimum elective units	18
	Minimum total units	36

d. Environmental Planning

CE 751	Environmental Health Engineering	3
CE 759	Engineering Aspects of Regional and Master Planning	3
CE 760	Planning and Engineering of Urban Environmental Systems I	3
CE 761	Planning and Engineering of Urban Environmental Systems II	3

CE 762	Urban Environmental Systems Workshop	3
	Required units	15
	Minimum elective units	21
	Minimum total units	36

Ocean Engineering Program

CE 717	Hydrodynamics for Civil Engineers	3
CE 732	Coastal Engineering	3
CE 733	Forces on Marine Structures	3
CE 734	Design of Marine Structures	3
MA 551	Applied Statistics I	3
	Required units	15
	Minimum elective units	21
	Minimum total units	36

Highway Engineering Program

CE 801	Flexible Pavements—Design and Evaluation	3
CE 802	Rigid Pavements—Design and Evaluation	3
CE 805	Traffic Studies	3
CE 821 and either	Design of Traffic Facilities	6
CE 759	Engineering Aspects of Regional and Master Planning	
	or	
CE 812	Transportation Economics	
	Required units	15
	Minimum elective units	21
	Minimum total units	36

Geotechnical Engineering Program

CE 881	Special Topics in Soil Mechanics and Foundation Engineering I	3
	or	
CE 882	Special Topics in Soil Mechanics and Foundation Engineering II	
CE 861	Soil Mechanics I	3
CE 862	Soil Mechanics II	3
CE 863	Experimental Soil Mechanics	3
	Required units	12
	Minimum elective units	24
	Minimum total units	36

REQUIREMENTS FOR THE ENGINEER DEGREE

A master's degree in civil engineering meeting the specialization area 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. The engineer degree may be earned in any area of specialization except environmental health science. The program for this degree follows:

No.	Required Subjects	Units
CE 998	Project for the Degree of Engineer	12
	Applied Mathematics or Operations Research and Systems Analysis	3
	Nine units of courses in area 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 pursuing the doctorate in civil engineering must hold a master's degree in civil engineering. For the 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 the departmental graduate adviser.

Each candidate for the doctorate must complete a minimum of 66 units of academic work beyond the master's degree, of which at least 57 units must be completed at Polytechnic. In any case the candidate must complete not less than 90 units of work past the bachelor's degree. Of the units taken at Polytechnic, at least 27 must be formal course work (not including guided readings, seminar or project.) Registration for a minimum of 30 units of dissertation research is required at the rate of a minimum of six units per term, continuously, until the dissertation has been completed and accepted.

All candidates must demonstrate a reading knowledge of one modern language other than English, as approved by the department head. Students interested in the Ph.D. program are advised to refer to the *Civil Engineering Graduate Study Guide*, available from the department head, for information on qualifying examinations and other regulations.

UNDERGRADUATE COURSES

CE 150 Surveying Fieldwork **2 credits**
Field exercises involving the rudiments 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
Course devoted to use of higher-level computer languages and techniques in engineering. Use of digital computer 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 equations 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 323.

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
Structure of solid materials related to interatomic bonding and states of aggregation. Amorphous, crystalline, polymeric and composite materials. Physical and mechanical properties of concrete, metals, plastics and asphaltic materials. Experimental investigation of mechanical properties of select structural materials and physical properties of cement and concrete mixes. Prerequisites: CM 101, CM 111 and CE 202.
Also listed under MT 303

CE 305 Engineering Contracts and Specifications 2:0:2
Detailed analysis of engineer's part in preparation of engineering contracts and specifications. Prerequisite: CE 202.

CE 306 Introduction to Geophysical Sciences I 3:0:3
The earth as a planet. Time. Tides. Map projections. Planet earth in the sun's rays. The earth as a magnet. The moon and man-made satellites. The atmosphere and oceans. The earth's figure and gravity.

CE 307 Introduction to Geophysical Sciences II 3:0:3
Atmospheric and oceanic circulation. Ocean waves and sea ice. Air masses, fronts and storms. The earth's interior. The crust of the continents and ocean basins. Origin and early history of the earth. Weathering and soils. Water at the surface and in the subsurface zone. Work of moving water. Floods. Shoreline processes. Glacial processes. The Pleistocene Epoch and man.

CE 315 Soil Engineering 3:0:3
Seepage, flow net studies and pore pressures. Filter criteria and applications. Capillarity, sorption and frost problems; permafrost. Shear strength theory and laboratory measurements. Stability of slopes and landslides. Additional topics in consolidation and settlement. Lateral earth pressures. Loads on underground conduits. Laboratory demonstrations.
Prerequisite: CE 232, **CE 317.**

CE 317 Foundations 2:3:3
Site exploration and soil sampling; planning boring programs and interpretation of boring logs. Bearing capacity of footings and mats for granular soils and clays. Settlements of structures. Lateral earth pressures and proportions of retaining walls. Pile foundations. Prerequisites: CE 232 and **CE 252.**

CE 322 Theory of Structures I 3:0:3
Analysis of statically determinate structures including beams, frames, arches, trusses, three-dimensional structures. Influence lines and the effects of moving loads. Deflections of structures. Prerequisite: CE 202.

CE 323 Theory of Structures II 3:0:3
Analysis of statically indeterminate structures including continuous beams, trusses, rigid frames, arches. Classical, numerical and matrix methods of analysis. Effects of temperature and movement of supports. Influence lines and relation of design to analysis. 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 323.**

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 252, CE 323, CE 331.

CE 335 Advanced Structural Design 3:0:3
Elastic and inelastic design of structural steel members and frames. Yield-line theory of reinforced concrete slabs. Principles and techniques of prestressed concrete construction. Stability, stress intensification and secondary stresses in structural components. Prerequisites: CE 323, CE 331 and **CE 252.**

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 323.**

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 multiple purposes. Prerequisite: CE 222.

CE 341 Environmental Engineering I 2:3:3
Water and wastewater quantities. Water quality. Water and wastewater treatment. Laboratory analyses of water and wastewater samples, treatment process tests, measurements of air and solid wastes. 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 plant for a small community. Introduction to air quality and solid waste problems. Prerequisite: CE 341.

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 375 Hydraulic Design Laboratory 0:6:2
Comprehensive investigation into areas of hydraulic design for which rational solutions are not readily available or for which present design criteria are inadequate. Course culminates in detailed study of area chosen by student from topics that may include, among others, open channel manifolds, drop inlets, energy dissipators. Prerequisite: CE 222.

CE 391-392 Bachelor's Thesis in Civil Engineering each 2 credits
Original research, design or plan for approved engineering project. Thesis gives student opportunity to apply knowledge and training gained in course of study by approaching and successfully solving a comprehensive problem. Conferences held regularly with appointed members of staff. Thesis registration required each semester. Students must reregister for thesis until completed. Prerequisite: senior status.

CE 396 Civil Engineering Internship 2:0:2
A supervised, creative civil engineering experience of at least two months' performance judged on the basis of written and oral reports presented to the industrial and faculty supervisors. Regular faculty visitations and conferences arranged during the internship. Open to students who have completed the junior year and have departmental approval prior to beginning the internship experience. Prerequisite: department's permission.

CE 398 Project in Civil Engineering 2 or 3 credits as arranged
Solution to civil engineering problem or detailed study of advanced area of civil engineering under close supervision of adviser. Prior to undertaking the project, interested students must submit to course director detailed written proposals of the problem they intend to investigate, along with number of credits for which they decide to register. Results of project must be submitted to course director in acceptable written form. Prerequisite: course director's permission.

CE 521 Oceanography 3:0:3
Plate tectonics. Ocean sediments. Composition and physical properties of sea water. Equations of motion. Effects of friction. Wave properties and theory. The tide. Survey of marine biology. Open for graduate credit. Prerequisites: MA 104 and PH 103.

GRADUATE COURSES

STRUCTURAL ENGINEERING

Prerequisites for all courses: MA 104, CE 323.

CE 601 Theory of Structural Analysis and Design I 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. Prerequisites: CE 252 and CE 331.

CE 602 Theory of Structural Analysis and Design II 2½:0:3
Analysis of arches, rings and continuous arches on slender piers. Frames and continuous curved members subjected to lateral and out-of-plane loading. Space frameworks, secondary and participation stresses, buckling of frames, trusses, arches. Prerequisite: CE 601.

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 adviser 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 structure. Complete solution of structural problems by chain matrix operations. 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 I* 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. Prerequisite: **CE 601.**

CE 612 Limit Design of Metal and Concrete Structures II* 2½:0:3
Application of plastic theory to multistory steel frames. Creep effect on concrete structures. Inelastic behavior of members with open cross sections. Yield line theory of reinforced concrete slabs. Prerequisite: CE 611.

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 602.

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. 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 604 and CE 610.
Also listed under AM 621

CE 621 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.
Also listed under AM 611

CE 623 Experimental Mechanics* **1:2½:3**
Application of experimental stress analysis techniques to aerospace, civil and mechanical engineering structures. Mechanical strain gauges, Begg's deformeters, the use of electrical strain gauges and associated instrumentation, brittle coating, photoelasticity and photostress, moire fringes. Stetic and dynamic loading; creep and fatigue of structural elements.
Also listed under AM 625

CE 624 Numerical Methods in Civil Engineering **2½:0:3**
Formulation of numerical techniques for solution of various problems in civil engineering. Topics include finite difference, numerical integration and relaxation methods. Critical path method in construction management. Elements of linear programming.

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. Effect of wind on bridges, suspension systems and tall buildings using random vibration theory. Earthquake analysis of structures responding inelastically. Application to problems in material behavior such as fatigue in cables, hysterisis 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 601-602 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. Prerequisites: CE 252 and **CE 601.**

CE 642 Reinforced Concrete Structures II **2½:0:3**
Biaxial bending of columns. Stability of reinforced concrete columns. Designs of two-way and flat slabs, arches and horizontally curved members. Shear wall design and design problems of tall structures. Prerequisitee: CE 641 and **CE 602.**

WATER RESOURCES AND HYDRAULIC ENGINEERING

Prerequisite for all courses: MA 104, CE 222, except as indicated.

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 transition in subcritical and supercritical flow, culverts, lateral spillway channels. 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 nonprismatic 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. Sediment trensport. Cavitation. Prerequisite: **CE 715.**

CE 717 Hydrodynamics for Civil Engineers* **2½:0:3**
Application of basic concepts of fluid kinetics and dynamics to problems in turbulent diffusion, density current, stratified flows and other problems of special interest to civil engineers.

CE 722 Hydrology I **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 analyses of floods and droughts. Prerequisite: undergraduate degree in engineering or science.

CE 723 Hydrology II **2½:0:3**
Studies of duration curves, reservoir operation, urban drainage, temperature and snowmelt, erosion, sedimentation. Statisticel methods in hydrology, including analysis of floods and droughts and other hydrologic events; steamflow simulation.

CE 724 Water Resources Planning **2½:0:3**
Water resources investigations, comparison of elternatives, screening and formulation of projects, economic enelysis of single and multipurpose projects. Financial management, legal and other considerations. Applications of system analysis. Prerequisite: undergraduate degree in engineering or science.

CE 725 Water Resources Mathematical Modeling* **2½:0:3**
The study 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 conditons and problems of calibration and verification. One-, two- and three-dimensional models considered. Stormwater models and water resource systems modeling also covered. Prerequisites: course in computer programming and **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 ehoreline protection. Water-wave dynamics as applied to coastal structures, including effects 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. Application of wave forecasting

and spectra. Description of interaction between wave forces and structural response.

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 as affected by hydrodynamic and other loads.

CE 735-738 Special Topics in Water Resources and Hydraulic Engineering I*, II* **2½:0:3**
Topics of special interest in water resources and hydraulic engineering. Such topics may include hydroeconomic models; finite difference and finite element models; synthetic hydrology; conjuctive use of surface water, groundwater, desalinized and recycled water; thermohydrologic and hydrometeorological problems; flushing of estuaries; hydrodynamics of oil pollution, sludge dumping, and sediment movements; environmental design of hydraulic structures: problems of macro projects. Prerequisite: permission of instructor.

ENVIRONMENTAL ENGINEERING

CE 738 Sanitary Chemistry **1:2:3**
Lectures and laboratory work. Review and application of principles of chemistry to waters and wastewaters. Laboratory analyses of representative waters and wastewaters for most commonly determined parametere as related to applications in water environment. Evaluation of methods and procedures used.

CE 739 Chemistry for Sanitary Engineers* **2½:0:3**
The study of physical chemistry, organic chemistry, biochemistry involved in water and wastewater treatment. Course provides advanced study of principles illustrated in CE 738. Prerequisite: CE 738.

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

CE 741 Analysis of Water Quality Systems* **2½:0:3**
Fundamental study of chemistry, biochemistry, microbiology and application of these principles to water and wastewater treatment. Study of natural water-courses in relation to natural and man-made pollution. Techniques of evaluating self-purification capacity of streams, lakes, estuaries.

CE 742 Water and Wastewater Treatment I **2½:0:3**
Study of 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. 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 744 Unit Operations in Water and Wastewater Treatment* **2½:0:3**
Advanced study of various biological, physical and chemical principles involved in water and wastewater treatment. A rational approach and theoretical development of design relationships commonly used in the design of unit processes. Prerequisites: CE 742 and CE 743.

CE 745 Water and Wastewater Treatment Laboratory* **1:2:3**
Laboratory process course 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 a waste. Prerequisite: **CE 743.**

CE 748 Industrial Waste Treatment **2½:0:3**
Study of sources of industrial wastewaters and their treatability of 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**
Analysis of 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 **1:2:2**
Design of water supply and wastewater treatment systems. Topics of special interest. 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**
Study of the causes and effects of air pollution. Methods of sampling. Interpretation of data. Meteorological aspects. Methods of air pollution control.

CE 753 Dispersion of Pollutants* **2½:0:3**
Introduction to theory of diffusion of pollutants and methods for estimation of dispersion in atmosphere. Nature of mean and turbulent motions in various urban, rurel, valley environments; effects of these on dispersion of pollutants. Mean and turbulent motions in oceanic and coastal waters and fresh-water bodies. Dispersion of pollutants in sea, lakes, rivers.
Also listed under CH 753

CE 755 Air Pollution Chemistry* **2½:0:3**
Significant chemical reactions occurring in lower atmosphere and basic chemistry required to understand problems peculiar to air pollution field. Chemistry applicable to fuel combustion and other sources of atmospheric pollution.
Also listed under CH 755

CE 756 Air Pollution Analysis* **2½:0:3**
Principles of reaction or physical measurement used for variety of analytical equipment employed in air pollution studies. Analysis of various atmospheres and evaluation of results. Prerequisite: CE 755.
Also listed under CH 756

CE 757 Air Pollution Effects* **2½:0:3**
Effects of atmospheric pollution on various forms of life, including both direct and secondary effects. Corrosion or contamination of inert matter by pollutants.

CE 758 Air Pollutant Engineering Control **2½:0:3**
Fundamentals of adsorptive, absorptive, and reactive recovery and control; removal of gaseous oxides of nitrogen, carbon and sulfur; removal of particulates from moving and stationary sources; removal of fluorides, complex oxidants and mercury vapors. Taught in the Department of Chemical Engineering.
Also listed under CH 752

CE 759 Engineering Aspects of Regional and Master Planning 2½:0:3
Stresses influence and especially constraints imposed on population levels and land use by various engineering systems required to service the plan region. Current concepts and methodology dealing with conservation of resources and evaluation of environmental impact of engineering systems and techniques for decision-making for selecting engineering alternatives in regional planning. Prerequisite: engineering degree.

CE 760 Planning and Engineering of Urban Environmental Systems I 2½:0:3
Consideration of sociological, political and economic values in planning and engineering of urban communities. Recent techniques for collection, processing and application of demographic, geographic and physical data in design of housing, water supply, solid and liquid waste disposal, other urban environmental subsystems. Zoning regulation and building codes in urban renewal. Prerequisites: B.S. in C.E. (or other engineering degree and equivalent experience).

CE 761 Planning and Engineering of Urban Environmental Systems II* 2½:0:3
Continuation of CE 760. Technology associated with production of housing through conventional and industrialized operations. Influence of building codes, techniques for assessment of quantity and condition of housing stock in urban communities, costs and financial systems for delivery. New town design and renewal of urban communities in context of residential housing and supportive service systems. Assessment of energy needs and delivery systems for urban communities. Prerequisite: engineering degree.

CE 762 Urban Environmental Systems Workshop* 2½:0:3
Application of principles, methodology and techniques developed in CE 760 to planning and engineering of urban communities. Team approach to comprehensive planning of an urban community including housing, water supply, waste disposal, and consideration of physical needs and other implications of service systems such as police, fire protection, hospitals. Prerequisite: **CE 760.**

CE 763 Aerodynamics of the Urban Environment I* 2½:0:3
Aerodynamic forces and pressures on nonaeronautical shapes —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.
Also listed under AM 751

CE 764 Aerodynamics of the Urban Environment II* 2½:0:3
Travel and dispersal of atmospheric pollutants. Plume rise and dispersion theories with applications to uniform and nonuniform atmospheres. Effects of boundary configurations of various scales—buildings, urban regions, bodies of water, mountains, valleys. Multiple source urban dispersion. Scale model experimentation.
Also listed under AM 752

CE 765 The Planet Earth* 2½:0:3
Survey of major disciplines of geophysics, with emphasis on general meteorology and oceanography.

CE 766 Industrial Environmental Health Engineering* 2½:0:3
Pertains to field of industrial hygiene, occupational health and workroom safety. Study of causes and effects leading to stresses that may cause sickness, impaired health and well-being, or discomfort among workers and indirectly, affect community health. Discussion includes consideration of chemical, biological, ergonomic and physical stresses; engineering controls designed to alleviate or eliminate such stresses, and the organizations and administrative regulations pertaining to federal, state and local control of the environmental hazards found within industrial establishments. Prerequisite: CE 751.

CE 767 Environmental Impact Evaluation* 2½:0:3
An examination of legal and technical requirements in the preparation of environmental impacts. 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 the 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 include nitrification in natural and treated waters, organic removal from water supplies, water reuse, specialized aspects of biological wastewater treatment, environmental health, solids disposal, and modeling natural waters and treatment systems. Prerequisite: permission of the instructor.

HIGHWAY ENGINEERING

Prerequisites for all courses: MA 104, CE 351.

CE 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 mixturas, 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 applications of travel forecasting methods to predict the amount and nature of travel on transportation systems. Emphasis on UMTA Transportation Planning System models. Prerequisite: **MA 551** or equivalent.
Also listed under TR 601

CE 805 Traffic Studies 2½:0:3
Techniques for collection of traffic data and information: speed, travel time, volume, origin-destination, parking, accidents, etc. Analysis and interpretation of results. Corrective actions and program formulation based on study results. Prerequisites: MA 551 and TR 701, or equivalents.
Also listed under TR 703

CE 806 Traffic Capacity and Design 2½:0:3
The use of highway capacity analysis techniques in design, planning and operational analysis treated. Highway Capacity Manual methods as well as foreign techniques and recent research developments are discussed and illustrated. Functional design of freeways, arterials, streets and rural highways covered.
Also listed under TR 704

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

CE 812 Transportation Economics 2½:0:3
A brief review of the principles and concepts of engineering economic analysis and a thorough application of these principles to decision-making in the transportation sector; methods for estimation of capital, operating and direct-user costs in transportation; benefit concepts and estimation of benefits; indirect effects; transportation finance and taxation; concepts of public finance and equity in taxation.
Also listed under TR 750

CE 821 Design of Traffic Facilities 2½:0:3
Presents 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
Introductory course in passenger and freight terminals with emphasis on the system description of these facilities. Land, marine and air terminals discussed. Methods discussed for determining the level of service for pedestrian flows, service times for passengers boarding and alighting, transit vehicles and simulation methods for transit terminals.
Also listed under TR 670

CE 841 Airport Planning and Design 2½:0:3
Techniques for forecasting air passenger traffic, aircraft operations at commercial and general aviation facilities. Principles and practices for the planning and design of terminal facilities, ground transportation systems, parking facilities, runways and navigational aids. Airport site selection, configuration and economics.
Also listed under TR 671

CE 848 Analytical Photogrammetry* 2½:0:3
Detailed presentation of various modern methods for determination of relative and absolute orientation of single photographs and stero-pairs by analytical methods utilizing data from comparator measurements. Discussion of strip and block adjustments in aerial triangulation.

CE 849 Geodesy* 2½:0:3
Computation of geodetic positions. Properties of earth's figure, theories of astronomical, magnetic and gravity observations, application of least squares to adjustment of surveys. Position determination through satellite observations.

GEOTECHNICAL ENGINEERING

Prerequisites for all courses: MA 104, CE 232, CE 317.

CE 851 Earth Pressures and Retaining Structures I* 2½:0:3
Conjugate stress relationships in infinite slopes in granular and cohesive soils. Study of classical works of Rankine, Coulomb, Kerisel and others for determining pressure distributions on rigid-type structures retaining soil masses. Effects of ground water, seepage, surcharge loadings. Shallow and deep sliding failures on retaining structures.

CE 852 Earth Pressures and Retaining Structures II* 2½:0:3
Modern earth pressure theories. Evaluation of realms of validity of classical and modern theories. Classical methods for determining pressure distributions on flexible-type retaining structures. Critical evaluation of recent large-scale model tests of sheet-pile bulkheads and their value in supplying design criteria. Treatment of silos, bins, other containers of granular material. Prerequisite: CE 851.

CE 861 Soil Mechanics I* 2½:0:3
Study 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-spaces 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.

CE 862 Soil Mechanics II* 2½:0:3
Classical consolidation theory and recent modifications and extensions; application to problem of settlement of structures. Detailed study of stress-strain-strength relationships in granular and cohesive soils; application to theoretical study of bearing capacity and lateral earth pressure. Stability of slopes and landslide phenomena. Prerequisite: CE 861.

CE 863 Experimental Soil Mechanics* 1:2¼:3
Critical evaluation of standard testing procedures for identification and classification tests. Detailed examination of permeability, capillarity and seepage phenomenon using both soil samples and electric analogs. One-dimensional consolidation test. Treatment of shear strength and the static triaxial compression test and its several varieties. Special tests. Prerequisite: CE 861.

CE 871 Foundation Engineering I* 2½:0:3
Soil sampling and exploration procedures; emphasis on standard penetration test. Analytical procedures for determining bearing capacity as function of stability and settlements. Plate-loading test. Application to 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. Study of behavior of single piles, pile driving and pile groups from viewpoint of load capacity and settlement. Negative skin friction. Analysis and design of cofferdams and caissons. Prerequisite: CE 871.

CE 881-882 Special Topics in Soil Mechanics and Foundation Engineering I, II 2½:0:3
Current topics of interest including theoretical determination of pile capacities, sheet pile bulkhead and trench problems, stresses on tunnels, theoretical approach to soil stability, refinements in settlement analysis and digital computer solution of problems in foundation engineering. Soil-structure interaction problems. Prerequisite: CE 851 or CE 861 or CE 871.

CE 890 Earthquake Engineering I* 2½:0:3
Basic concept of seismology as applied to design of civil engineering structures. Geologic considerations related to earthquakes. Earthquake distribution, type, magnitude, intensity, energy and seismic regionalization. Instrumentation and spectrum theory. Effects of earthquakes on soil and response of structures to earthquakes as influenced by underlying rock and/or soil formations.

CE 891 Earthquake Engineering II* **2½:0:3**
Effects of earthquakes on coastal structures. Soil-structure interaction problems. Slope stability problems developed by earthquake activity. Emphasis on rational design criteria for underground and elevated structures constructed of steel or reinforced concrete. Prerequisite: CE 890.

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. Prerequisite: CE 861.

CE 894 Marine Geotechnology* **2½:0:3**
Geological nature of marine sediments and comparison with terrestrial soil deposits. Sampling techniques and problems of obtaining undisturbed samples and cores; in situ measurements of physical and mechanical properties of marine soils. Comparison of stress-strain, strength and consolidation characteristics of terrestrial and marine soils. Stability of submerged slopes and slumping, bearing capacity, breakout resistance, marine anchors.

CE 927 Energy Policy Issues **2½:0:3**
See Energy Program for details.

CE 928 Energy Resource Distribution and Conversion Technology **2½:0:3**
See Energy Program for details.

PUBLIC ADMINISTRATION

CE 932 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.

CONSTRUCTION MANAGEMENT

CE 825 Construction Administration* **2½:0:3**
Management problems unique to construction business including licensing, bonding, insurance, short-term financing, employee relations. Prerequisite: MG 600.
Also listed under MG 825

CE 826 Construction Estimates and Costs* **2½:0:3**
Estimates, costs from viewpoint of contractor or construction engineer, details of estimating, emphasis on labor, material, equipment, overhead costs. Prerequisites: MG 811 and CE 825.
Also listed under MG 826

CE 827 Specifications and Contracts* **2½:0:3**
Principles of contract law as applied to construction industry; legal problems in preparing and administering construction contracts. Prerequisite: CE 825.
Also listed under MG 827

GUIDED READINGS, SEMINARS, PROJECTS AND THESES

CE 901 Guided Readings in Civil Engineering **3 units**
Individual study of selected literature in civil engineering under guidance of 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 Master's Degree **each 3 units**
An analytical, design or experimental study in civil engineering under guidance of faculty adviser. Written report required. Project may be expanded into master's thesis with approval of thesis adviser. Registration for a minimum total of six (6) units required. A maximum of six project units counted toward degree. Prerequisites: degree status and project adviser's approval.

CE 997 Thesis for Degree of Master of Science **each 3 units**
An original investigation or design in student's principal field of study prepared under close supervision of faculty adviser. Candidate must successfully defend thesis orally. Registration for a minimum total of twelve (12) units required. Maximum of 12 units counted toward degree. Prerequisites: 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 faculty adviser. Emphasis on up-to-date techniques. Written report 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 of civil engineering problem. Must demonstrate creativity and include features of originality and utility worthy of publication in recognized engineering journal. Candidate must successfully defend thesis orally. Registration for minimum of 30 thesis units required prior to defense. Registration must be for minimum of six units per term. Prerequisites: degree status, passing the qualifying examination and thesis adviser's approval.

FACULTY

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

Paul R. DeCicco, Professor and Director of CUES
B.C.E., M.C.E., Polytechnic Institute of Brooklyn
Urban systems, fire safety

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

James Michalos, Professor of Civil Engineering
B.S., University of Wisconsin; M.Eng., Yale University; Ph.D., Northwestern University
Structures

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
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, sanitary engineering

Erick R. Gidlund, Associate Professor of Civil Engineering
B.C.E., Ph.D., University of Washington
Hydraulic engineering

Albert H. Griswold, Associate Professor of Civil Engineering
B.S.C.E., University of Connecticut; M.S.C.E., Columbia University
Fluid mechanics

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

Stephen T. Mikochik, Associate Professor of Civil Engineering
B.C.E., Manhattan College; M.S., Rutgers—The State University
Soil mechanics and foundations

Alan H. Molof, Associate Professor of Environmental Engineering
B.S., Bucknell University; M.S.E. (Ch.E.), M.S.E. (Sanitary Eng.), 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
Hydraulic engineering

George Fagan, Academic Associate
B.S., Polytechnic Institute of Brooklyn; M.S.C.E., Ph.D., Polytechnic Institute of New York
Water resources engineering

ADJUNCT FACULTY

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

Siddhartha Bagchi, Lecturer
B.S.C.E., M.S.C.E., Calcutta University; Ph.D., Polytechnic Institute of New York
Water resources and hydraulic engineering

Herman Bomze, Lecturer
B.C.E., CCNY; M.S.C.E., Columbia University
Water resources and hydraulic engineering

Joseph C. Cataldo, Lecturer
B.C.E., M.S.C.E., Ph.D., CCNY
Environmental engineering

Warren H. Chesner, Lecturer
B.C.E., CCNY; M.C.E., Ph.D., New York University
Environmental engineering

Clifford Gordon, Lecturer
B.S.C.E., Missouri School of Mines
Construction management

William F. Graner, Jr., Lecturer
B.S., Polytechnic Institute of Brooklyn; M.C.E., New York University
Environmental engineering

John K. Paik, Lecturer
B.S., Southern Methodist University; M.S., Ph.D., New York University
Structures

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

Ahmed H. Sayed, Lecturer
B.S., Cairo University; M.S., Ph.D., Polytechnic Institute of New York
Structures

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

Herbert F. Shatzman, Lecturer
B.C.E., CCNY
Construction management

M. Llewellyn Thatcher, Adjunct Associate Professor
B.S.E., Princeton University; B.S., Columbia University; S.M., Sc.D., Massachusetts Institute of Technology
Ocean and coastal engineering

Joseph W. Vellozzi, Lecturer
B.S., University of Miami; M.S., Ph.D., Rensselaer Polytechnic Institute
Structures

Constantine Yapijakis, Lecturer
M.C.E., National Technical University of Athens; M.S., New York University; Ph.D., Polytechnic Institute of New York
Environmental health engineering

EMERITUS FACULTY

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

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 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 degree programs in computer engineering.

UNDERGRADUATE PROGRAMS

The programs in computers are 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 in business and government 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 in computer science degree described in the present section of the catalog, or (b) the computer engineering option leading to the bachelor of science in electrical engineering degree described in the electrical engineering section of the catalog (pp. 92). 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, minicomputer laboratory, etc.) courses; both programs also require the same mathematics, physics and chemistry courses.

The computer science undergraduate program is designed for the student who wishes to major in computer science and pursue a minor in a second area, which may be chosen according to individual interest. The core sequence consists of 33 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. Although the minor can be chosen from any of the areas of science and engineering, the computer engineering option should be considered by those students interested in combining electrical engineering and computer science. A total of 128 credits is required for the B.S. (computer science) degree.

Combined Computer Science and Life Sciences Programs—Students interested in combining a career in the life sciences with computer science have a choice of two programs: (a) the bachelor's degree program in computer science with a minor in life sciences or bioengineering, with an optional fifth year leading to the master of science in bioengineering degree, and (b) the computer science option leading to the bachelor's degree in life sciences, with an optional fifth year leading to the master's degree in computer science. The computer science option for the bachelor of science in life sciences degree incorporates a strong minor in computer sciences courses, including the two computer laboratory courses taken by students in the computer science and computer engineering programs. Graduates of this option are well prepared for the graduate program in computer science. Consult the life sciences section of the catalog for details of the bachelor's curriculum.

Transfer Students—Transfer students are accepted into the computer science B.S. program on the same basis described earlier in the catalog under admissions.

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.

Curriculum for the B.S. Degree in Computer Science (for Freshmen Entering 1981)

Freshman Year

First Semester		Hours/Week			Second Semester		Hours/Week		
No.	Subject	Cl.	Lab.	Cr.	No.	Subject	Cl.	Lab.	Cr.
CS 111	Computer Progr. I	3	0	3	CS 203	Computer Progr. II	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	1½	4
CM 101	General Chemistry I	2½	0	2½	CM 102	General Chemistry II	2½	0	2½
CM 111	Gen. Chem. Lab I	0	1½	½	CM 112	Gen. Chem. Lab. II	0	1½	½
HU 101	College Composition[h]	3	0	3	HU 200	Intro. to Literature[h]	3	0	3
PE 101	Physical Education[r]	0	2	0	PE 102	Physical Education[r]	0	2	0
				16					17

Sophomore Year

CS 204	Data Structures	3	0	3	CS 236	Switching & Dig. Sys.	3	0	3
MA 104	Appl. Diff. Equations	3	0	3	MA 103	Calculus III	3	0	3
PH 103	Introductory Physics III	2½	1½	3	PH 230	Atom. & Nucl. Physics	2	0	2
HU 110	Report Writing I[h]	3	0	3	SS 104	Contemp. History[h]	3	0	3
	Hum./Soc. Sci. elective[h]	3	0	3		Hum./Soc. Sci. elective[h]	3	0	3
PE 103	Physical Education[r]	0	2	0		Elective			3
				15	PE 104	Physical Education[r]	0	2	0
									17

Junior Year

CS 205	Ass'y & Machine Lang.	3	0	3	CS 206	Compilers	3	0	3
CS 237	Computer Architecture	3	0	3	CS 297	Computer Lab. I[n]	1	3	2
MA 223	Probability	3	0	3	MA 358	Intro. Numerical Anal.	3	0	3
	Minor specialty[q]			3		Minor specialty[q]			3
	Hum./Soc. Sci. elective[h]	3	0	3		Elective[p]			3
				15		Hum./Soc. Sci. elective[h]	3	0	3
									17

Senior Year

CS 238	Computer Systems	3	0	3	CS 398	Sr. Project in CS	1	6	3
CS 299	Computer Lab II	1	3	2		MA or CS elective	3	0	3
CS 397	Sr. Seminar in CS	2	0	2		Minor specialty			3
	Minor specialty[q]			3		Elective[r,p]			3
	Elective[r,p]			3		Hum./Soc. Sci. elective[h]	3	0	3
	Hum./Soc. Sci. elective[h]	3	0	3					15
				16		Total credits required for graduation: 128			

[h]Students shall complete a minimum 30 credits in humanities and social sciences courses. Students must take HU 101 and HU 110, and either HU 200 and SS 104 or IS 140-141. Students who are placed in HU 103 on the basis of the English Composition Placement Test administered at the 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).

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

For the remaining credits in the humanities/social science requirement, the student should select courses in areas other than that of the concentration.

[n]CS 297 (1:3:2) may be replaced by EE 188 (2:3:3).

[p]The elective credits should be from engineering and/or science.

[q]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.

[r]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 131, 142, 143, 146, for six credits of technical electives.

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 the computer sciences 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 day student whose performance in the first three years is outstanding will be named as a senior honor student and, in consultation with the adviser, is permitted to replace some of the required senior technical courses by other courses, usually more advanced, which are directed to the student's professional goals.

DEPARTMENTAL STANDARDS AND PROBATION

To earn a degree in computer science, students must earn a minimum C average (2.0 grade point average) in all technical courses: mathematics, physics, computers and engineering.

Students are automatically placed on departmental probation if their semester or cumulative technical average is less than 2.0, if they receive C – or less in any sophomore year computer science course or if they fail to obey course prerequisites. Students on probation must consult with their advisers during registration week prior to the beginning of each term. They may be required to repeat courses in which they have earned a grade of C – or less or an Incomplete, to postpone an advanced course, to take a special program of courses to improve their understanding, or to withdraw from the department in cases of repeated departmental probation. Almost without exception, students earning a C – or less in CS 111 or CS 203 will be required to repeat the course. Likewise a student who earns a combined average C – or less in all technical courses during one semester, or in a closely related sequence of courses, will almost invariably be required to repeat some of these courses.

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 such basic areas as information structures, programming languages, computer design and organization, compilers and translators, operating systems, artificial intelligence, interactive computer graphics, information retrieval, data-base management, switching theory, theory of computation, numerical analysis, software reliability.

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 the 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 a research fellowship, teaching fellowship 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 desirable. 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 M.S. degree programs are as follows:

Computer Science:
1. At least one year of university-level science.
2. A working knowledge of a higher-level programming language (such as PL/I).
3. A basic understanding of computer fundamentals, such as: computer organization and operations, data structures, assembly language programming, elements of logic and automata.

Information Systems:
A working knowledge of PL/I and/or FORTRAN programming languages equivalent to CS 530 or CS 531.

It is anticipated that entering students with a B.S. degree in computer science as well as students with degrees in technical areas and strong minors in computer science from an accredited institution will unconditionally satisfy the entrance requirements for the M.S. degree programs.

Students having superior academic credentials but lacking sufficient background will be required by the divisional director to take additional preparatory courses, as specified from the available computer science undergraduate courses and/or from the series of four graduate orientation courses, CS 530, CS 540, CS 550, CS 560. The successful completion of the specified preparatory courses with a B average or better is a necessary condition for admission to degree status.

The demonstrated ability to communicate in written and spoken English is an essential ingredient for success in pursuing graduate studies in computer science and information systems and is required for degree status. Foreign students and others for whom English is a second language should plan to take HU 008 and HU 103 (as determined by the English Composition Placement Test administered by the Department of Humanities prior to the start of each semester). Alternatively, a student can demonstrate competence in English by adequate grades on the TOEFL (Test of English as a Foreign Language) through the services of TOEFL, Box 899, Princeton, N.J. 08541.

Admission with advanced standing is accepted in accord with Polytechnic regulations published elsewhere in this catalog. A maximum of 9 units may be applied to the M.S. degree for previous graduate work at an acceptable institution.

Degree Requirements: To satisfy the requirements for the master's degrees, the student must complete a total of 36 units as described below, with an overall average of B. In addition, a B average is required in specified groups of courses as indicated below.

Students with a strong undergraduate computer science background may be allowed to replace required courses with more advanced electives. Permission of the graduate adviser is required.

Master of Science (Computer Science major)

		Units
1. Core Requirement (B average required)		15
CS 603	Information Structures and Algorithms	
CS 613	Computer Architectura 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 and Approximate Analysis I	
	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 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 toward the degree may be earned. 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 major)

		Units
	Required Courses	27
CS 603	Information Structures and Algorithms	
CS 606	Software Engineering	
CS 608	Data-Base Management Systems	
CS 609	Information Analysis and System Design I	
CS 623	Operating Systems I	
IE 600	Engineering Economic Analysis	
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 course from each of the following groups:
Group A: CS 610, 616, 624, 633, 637, 653, 661.
Group B: IE 619; OR 614, 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 have given evidence of ability for independent scholarly work may consider extending their goals toward the degree of doctor of philosophy (computer science major). The requirements for admission to the program include the following:

1. A B.S. degree in science, engineering or management from an accredited school and a superior academic record.

2. An M.S. 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 B.S. degree, including 24 units of dissertation.

2. Qualitative rather than quantitative considerations will determine the final approval of the program of

graduate studies; however, the following should be included:

a. The basic M.S. requirements in computer science.

b. A major concentration in some computer science area.

c. Appropriate supporting courses in noncomputer areas, for breadth.

d. One meaningful 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. Reading knowledge of French, German or Russian.

4. Qualifying examinations consisting of 3 or 4 written examinations, generally covering topics corresponding to the M.S. requirements.

5. Presentation of an in-depth seminar talk on the subject of the dissertation, at such time as the thesis adviser deems appropriate.

6. Preparation and defense of a scholarly dissertation that embodies an original research contribution.

UNDERGRADUATE COURSES

Students are advised to consult the Departmental Student Manual and the Registration Bulletin for changes in courses, course content and prerequisites in effect subsequent to the publication of this catalog edition.

General Prerequisite: Students may not register for any junior- and senior-level courses until every freshman requirement is 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.

CS 101 Introduction to Digital Computing 3:0:3
A first course in computing. Analysis of problems for computer solution. Organization and characteristics of computers. Structure and properties of algorithms and programs, flow charting. Debugging and verification. Number systems, data representation, numerical error analysis. FORTAN IV language used.

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 are solved on the Polytechnic computer. Prerequisite: **MA 101.**

CS 203 Computer Programming II 3:0:3
Elements of FORTRAN, BASIC, ALGOL, SNOBOL and APL. Formulation of algorithms for numerical solution of problems: algebraic and transcendental equations in one unknown, integration, interpolation, simultaneous linear equations and least-square approximation. The PASCAL programming language: data types, assignments, loops and conditional statements, arrays and subprograms. Prerequisites: CS 111, **MA 102.**

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 203.

CS 205 Assembly and Machine Language Programming 3:0:3
Assembly and machine language instructions for the IBM System 370. Binary and hexadecimal arithmetic. Program and job structure, register-to-register and memory reference instruction. Branching and loop control character manipulation, the program status word. Program debugging and testing. Subroutines, bit manipulations, data forms and conversions, input/output programming. Prerequisite: CS 100 or CS 111.

CS 206 Compilers 3:0:3
Grammars, lexical analysis, parsing algorithms, intermediate languages and global optimization techniques, storage assignment, push-down stacks and run-time organization. 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, use 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. Prerequisite: CS 100 or CS 101 or CS 111.

CS 217 Information Organization and Retrieval* 3:0:3
Characteristics of information systems. Techniques of information retrieval. File organization and search strategies. Automatic text-processing methods, editing and output of textual information. Statistical and syntactic language analysis methods. Examples and evaluation of information retrieval and dissemination systems. Prerequisite: CS 204.

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 101 or CS 111.

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 Computer 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 Electronic Music Composition* 2:3:3
Analysis of representative works of electronic music from

musical and technical viewpoints. Notational systems. Physics of tone production. Techniques of sound recording, tape editing and electronic sound synthesis by analog and digital means. Creation of original composition. Enrollment limited. Prerequisite: interest in music.

CS 297 Computer Laboratory I 1:3:2
A series of required experiments provides an introduction to small computers: digital and analog circuit techniques, small computer assembly language programming, minicomputer and microcomputer organization and operations. Lab fee required. Prerequisite: **CS 237.**

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 297.

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 297.

CS 398 Senior Project in Computer Science 1:6:3
Term project. Several students work as group with staff member and graduate students on topic of interest. Written report and presentation required. Prerequisites: CS 397 and **CS 299** or **EE 189.**

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
Concentrated orientation course for students interested in pursuing graduate work in computer science. Types of languages, problem-solving, algorithms, flow charts. Basic PL/1 instructions, programs, programming style, structured programming. Character and bit strings, arrays, built-in functions, function and subroutine procedures. Assigned problems. 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
Machine and assembly language instructions. Arithmetic and logical operations. The condition code and branch instructions. Subroutines linkages and the passing of parameters. Relationships with higher level languages. Applications. Prerequisite: CS 530.

CS 560 Introduction to Logic and Automata 2½:0:3
Automata and switching theory. Boolean algebra, truth tables, predicate calculus. State and Venn diagrams. Deterministic and nondeterministic finite state automata. Regular sets. Introduction to Turing machines. Prerequisite: CS 530.

CS 570 Fundamentals of Computer Science 2½:0:3
Concentrated orientation course for students entering computer science from other fields. Machine and assembly language. Organization and representation of data. Stacks, queues, lists and trees. Applications. Prerequisite: CS 530. (Offered only in 1981.)

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 about 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. Prerequisite: Graduate status. No credit will be allowed for CS 531 toward graduate degree in computer science, information systems or other degree programs administered by the Department of Electrical Engineering and Computer Science.
Also listed under IE 601 and OR 601

CS 603 Information Structures and Algorithms 2½:0:3
Organization and processing of various types of information. Interative and recursive programming techniques. Information structures, linear lists, trees, multi-linked structures. Dynamic storage allocation, garbage collection, hashing, searching and sorting techniques. Prerequisite: CS 204 or CS 540.

CS 606 Software Engineering 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, reliability, availability. Testing: modular, integration, paths, exhaustive, regression. Management: costs, productivity, controls. Prerequisites: MA 223 and one of the following: CS 603, CS 623, CS 641.

CS 608 Data-Base Management Systems 2½:0:3
The effective management and utilization of data. Objectives of DBMS, data independence, integrity, security. Organization and access techniques, architecture, data definition and manipulation languages. Data models, hierarchical, network, relational. Practical applications of state-of-the-art techniques, foundations and underlying theories. Prerequisite: CS 603.

CS 609 Information and Analysis and System Design I 2½:0:3
Introduction to the system life cycle of a computer information system. System life cycle management. Basic analysis tools, determining system economics. Logical system design. Introduction to physical system design. Prerequisite: CS 530.

CS 610 Information Analysis and System Design II 2½:0:3
Basic design tools and objectives. Hardware/software selection and evaluation. Software design and software engineering. Data-base 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, minicomputer architecture; machine languages and systems principles (knowledge of a programming language required). Prerequisites: CS 550 and CS 560; CS 237 recommended.

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 networks. Prerequisite: CS 613.

CS 616 Microprocessors 2½:0:3
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 237 or CS 613, and CS 205 or CS 550.

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: CS 540 and CS 550; CS 237 or CS 613 are strongly recommended.

CS 624 Operating Systems II 2½:0:3
Continuation of CS 623. Overall organization of multiprogramming operating systems, processor and management (scheduling), deadlock detention end avoidance, file system management. Prerequisite: CS 623.

CS 633 Information Retrieval and Natural Language Processing* 2½:0:3
Characteristics of information retrieval systems. Search strategies, file organization, generalized data-base 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 Data 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 packet radio networks. Reliability. Regulatory traffic. Interconnection of networks. Course will provide a broad overview of current issues on networks. An assessment of state-of-the-art technique and a glimpse at emerging questions. Prerequisite: graduate status.
Also listed under EL 635

CS 637 Programming Languages 2½:0:3
Introduction to the structure of programming languages. Comparison of list processing, string manipulation and general purpose languages. Formal specification of syntax and semantics. Programming problems in different languages. Prerequisites: CS 540 and CS 550.

CS 641 Compiler Design and Construction I 2½:0:3
Organization of compiler, including lexical analysis, symbol table organization, linear and two-dimensional source text reconstruction, 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 simple statements. Prerequisites: CS 540, CS 550, CS 560.

CS 642 Compiler Design and Construction II 2½:0:3
Further consideration 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
Problems in computer graphics. Display components and algorithms, data structures, classical graphics, image detection, processing techniques. Prerequisite: CS 613.

CS 653 Interactive Computer Graphics* 2½:0:3
Analysis and synthesis of graphical information. Discussion of display devices, graphical data structures, graphic languages, transformations. Interactive techniques, characteristics of interactive input devices, light pen, tablets, scanners. Computer manipulation of two-dimensional forms. Three-dimensional graphics, hidden lines and surfaces, perspective, shading. 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. Description of cognitive processes. Heuristic vs. algorithmic methods of problem solution. Game-playing programs. Formula manipulation, symbolic integration, automation of programming. General problem-solvers. Introduction to pattern recognition and picture-processing. Prerequisites: CS 540 and CS 560.

CS 662 Artificial Intelligence II* 2½:0:3
Further study of automation of intellectual processes. Automatic theorem-proving. Semantic information processing and question-answering programs. Simulation of verbal learning behavior. Learning machines, adaptive systems, robots, decision-making problems. Practical techniques and adequacy of existing theoretical treatments. Prerequisite: CS 661.

CS 663 Artificial Intelligence and Pattern Recognition* 2½:0:3
Heuristic programming, problem-solving, representation, simulation of cognitive processes, self-organizing machines, neural nets, perceptions, learning devices, classification techniques. Prerequisite: graduate status.

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.

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 losslessness, diagnosing and homing experiments, machine identification end 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 question. Prerequisite: 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. Mathematical maturity but no special knowledge of set theory.

CS 907-912 Selected Topics in Computer Science each 2½:0:3
Topics of current interest in computer science. Recent offerings include software reliability, microprocessors, data-base management systems, computer architecture. 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 935 Computer Science 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.

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: degree status and permission of director of division.

CS 996 Advanced Projects 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: degree 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 6 units toward the degree may be earned. 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: degree 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 recognized journal. Candidate must successfully defend dissertation orally. Registration of 24 units required (continuous dissertation registration required). Prerequisite: degree candidacy, passing of qualifying examination and approval of the computer science graduate adviser.

FACULTY

Edward J. Smith, Professor of Electrical Engineering and Director of Division of Computer Science
B.E.E., Cooper Union; M.E.E., D.E.E., Polytechnic Institute of Brooklyn
Computer organization, switching and automata

Bruce L. Hicks, Visiting Professor of Computer Science
B.S., M.S., Ph.D. (Physics), California Institute of Technology
Educational applications of computers, computer graphics

Melvin Klerer, Professor of Computer Science
B.A., M.S., Ph.D., New York University
Programming systems, languages, artificial intelligence

Arthur E. Laemmel, Professor of Electrical Engineering
B.E.E., Polytechnic Institute of Brooklyn
Computer architecture, coding

Stanley Preiser, Professor of Mathematics and Dean of Westchester Center
B.S., CCNY; M.S., Ph.D., New York University
Numerical analysis, applied mathematics, algorithms, system performance evaluation

Martin L. Shooman, Professor of Electrical Engineering and Computer Science
S.B., S.M., Massachusetts Institute of Technology; D.E.E., Polytechnic Institute of Brooklyn
Software engineering, system reliability and safety

Ronald J. Juels, Visiting Associate Professor of Computer Science
B.E.E., M.E.E., Polytechnic Institute of Brooklyn; D.Sc., Stevens Institute
Computer architecture, microprocessor systems

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

Henry Ruston, Associate Professor of Electrical Engineering and Computer Science
B.S.E. (Math), B.S.E. (EE), Ph.D., University of Michigan; M.S., Columbia University
Software engineering, programming, circuit theory

A. David Klappholz, Assistant Professor of Computer Science
B.S., Massachusetts Institute of Technology; M.S.E., Ph.D., University of Pennsylvania
Parallel processing, computer architecture

Jamshed H. Mirza, Assistant Professor of Computer Science
B.Tech., Indian Institute of Technology, (Khoragpur, India); M.S., Ph.D., Polytechnic Institute of New York
Computer architecture, pipeline processing

Norman Rubin, Assistant Professor of Computer Science
B.S., CCNY; M.A., Ph.D., New York University
Artificial intelligence, programming languages, compilers

ADJUNCT FACULTY

Michael Adamowicz, Adjunct Professor
B.A., B.E., M.E., Ph.D., New York University

Barry V. Gordon, Adjunct Professor
B.E.E., M.E.E., New York University

Fred Grossman, Adjunct Professor
B.S., Polytechnic Institute of Brooklyn; M.S., Ph.D., New York University

Naresh N. Gupta, Adjunct Professor
B.S., Panjab University; B.S., Indian Institute of Science; M.S., University of Ottawa; Ph.D., Polytechnic Institute of Brooklyn

John P. O'Donohue, Adjunct Professor
B.E.E., Polytechnic Institute of Brooklyn; M.S., Union College

Thomas W. Parsons, Adjunct Professor
B.A., B.S., University of Wisconsin; M.S., Columbia University; Ph.D., Polytechnic Institute of New York

Robert L. Schoenfeld, Adjunct Professor
B.A., New York University; B.S., Columbia University; M.E.E., D.E.E., Polytechnic Institute of Brooklyn

Joel B. Snyder, Industry Professor
B.E.E., M.E.E., Polytechnic Institute of Brooklyn

M. Wayne Wilson, Industry Professor
B.A., M.A., University of Western Ontario; Ph.D., Brown University

John H. Chang, Adjunct Associate Professor
B.S., National Taiwan University; Ph.D., Yale University

David R. Doucette, Adjunct Associate Professor
B.S., M.S., Ph.D., Polytechnic Institute of Brooklyn

Robert Flynn, Adjunct Associate Professor
B.S., Manhattan College; M.S., Ph.D., Polytechnic Institute of Brooklyn

Edward J. Lancevich, Adjunct Associate Professor
B.S., CCNY; M.S., Columbia University; Ph.D., Polytechnic Institute of New York

Dimitri Protopapas, Adjunct Associate Professor
B.Sc., University of Athens; M.S.E.E., University of Toronto; Ph.D., Polytechnic Institute of New York

Arthur Appel, Lecturer
B.M.E., M.M.E., City College of New York

Shakuntala Atre, Lecturer
M.Sc., University of Poona (India); Dipl., University of Heidelberg (Germany)

Kenneth R. Aupperle, Lecturer
B.S., M.S., Polytechnic Institute of New York

Charles J. Bontempo, Lecturer
B.A., M.S., University of Maryland

Peter G. Capek, Lecturer

Roy S. Freedman, Lecturer
B.S., M.S. (Math), M.S. (E.E.), Ph.D., Polytechnic Institute of New York

Harry Goldberg, Lecturer
B.A., Queens College; M.S., Polytechnic Institute of New York

Daniel J. Gorman, Lecturer
B.S., University of Massachusetts (Amherst); M.S., Columbia University

Ronald B. Greenwald, Lecturer
B.E., Pratt Institute; M.S., Columbia University

Frank M. Gruppuso, Lecturer
B.S., M.S., Polytechnic Institute of Brooklyn

Carlton B. Hensley, Lecturer
B.A., Oberlin College; M.S., Carnegie-Mellon University

Robert Hong, Lecturer
B.S., (I.E.) Columbia University; B.S. (E.E.), Cooper Union

David Jacobson, Lecturer
B.A., Ph.D., Yeshiva University

Lawrence L. Leff, Lecturer
B.S., Polytechnic Institute of New York

Leonard Librizzi, Lecturer
B.E.E., CCNY; M.E.E., Polytechnic Institute of Brooklyn; M.S., Polytechnic Institute of New York

Howard W. Loewenstein, Lecturer
B.C.E., CCNY; M.S., Polytechnic Institute of Brooklyn

Marsha Moroh, Lecturer
B.S., Dickinson College; M.S., New York University; Ph.D., Polytechnic Institute of New York

Robert O'Hara, Lecturer
B.A., Pennsylvania State University; M.S., Union College

Richard M. Rosenberg, Lecturer
B.E., Cooper Union; M.S., Ph.D., New York University

Mark Seiden, Lecturer
A.B., Columbia University

Martin V. Sternberg, Lecturer
B.S., M.S., Polytechnic Institute of New York

Fred J. Strauss, Lecturer
A.A.S., Queensborough Community College; B.S.E., Arizona State University; M.S., Polytechnic Institute of New York

Mehmet Ulema, Lecturer
B.S., M.S. (M.E.), Technical University of Istanbul; M.S. (C.S.), Ph.D., Polytechnic Institute of New York

Walter Vasilaky, Lecturer
B.A., Rutgers University; M.A., University of Maryland; Ph.D., New York University

J. Douglas Wright, Lecturer
S.B., Massachusetts Institute of Technology

COOPERATIVE EDUCATION PROGRAM

The Cooperative Education 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 a student to combine the required number of classroom credits with approximately 20-24 months of work experience. The first and fifth years are spent on the campus in the conventional September to May study schedule, while the middle years, including summers, are devoted to alternating periods of training in industry, and study on the campus.

For graduate students and undergraduate transfer students, the length of the program and sequence of alternation will be determined through faculty recommendation.

Students who are accepted in the program will start interviewing with participating Co-op companies during the semester prior to their first scheduled work experience. The Cooperative Education Office will be responsible for setting up the interviews. In most cases, the company interview will determine whether the student is hired as a Co-op employee.

Once *on-the-job,* the Co-op student employee will be paid a salary and, in most cases, receive company benefits. The student will be given work that is directly related to the student's career goals and level of academic experience.

ELIGIBILITY

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 the Cooperative Education Seminars CP 101-102. Freshmen would be eligible for their first work experience during the summer following the completion of the first academic year. Second semester juniors and seniors are not eligible for the program. Graduate students and transfer students are eligible, usually after completion of one semester.

UNDERGRADUATE AND GRADUATE REGISTRATION

The Cooperative Education Program is designed to meet the professional training needs of students as they progress through their academic program. Within the Co-op Program there are two special programs: Women's Late Entry for those mature women who wish to pursue a career in engineering or science and the Cooperative Education Minority Scholars Program for black, Spanish-speaking and native Americans.

Regarded as a professional practice period, the Co-op courses are non-credit but will be recorded on the official transcript as either S or U on a non-credit basis. The grade of "satisfactory" or "unsatisfactory" will be based on the employer evaluation of the student and the cooperative education coordinator evaluation. The transcript notation will include the Co-op course number, the employer name and the functional department to which the student is assigned.

A $25.00 registration fee is charged for each work period.

The Cooperative Education courses are assigned to each student in sequence, starting with Co-op 10 to Co-op 14 by the Cooperative Education Office.

The level of the Co-op course number is used as an administrative device to keep track of the actual number of work assignments completed by each student. A student entering into an industrial assignment after the freshman year will normally complete five work periods—Co-op 10 through Co-op 14, while a student entering after the sophomore year might be eligible to complete only two work periods, Co-op 10 and Co-op 11. The Co-op course number does not indicate the type of work, level of difficulty or responsibility of the actual work assignment, which may vary, depending on the company's product or service, and the student's ability and interest. Some firms may assign a student according to current work-load and the student's level of experience and/or academic standing. Others have a formalized training program that all students are required to complete. A typical formalized training program might contain the following assignments:

Co-op 10—Shop on laboratory indoctrination. Rotating assignments to give the future engineer or scientist a working knowledge of production methods.

Co-op 11—Quality control or data acquisition. Working directly with a senior technician or engineer.

Co-op 12—Production engineering or testing. At this point the student is usually given a task for which he or she is totally responsible under the supervision of a senior engineer or scientist.

Co-op 13—Research or design. The student is exposed to engineering or scientific methods relating to the state of the art.

Co-op 14—Usually the student's choice.

UNDERGRADUATE COURSES

CP 101 Cooperative Education Seminar I[a, b] **1:0:N.C.**
The development and practice of pre-employment skills to specifically prepare students for their first and succeeding cooperative education work periods with industry and government. Methods of discovering fields in which individuals should find the greatest rewards in personal satisfaction and material gain, the techniques of resume writing and interviewing, adjusting of attitudes to adapt to varying conditions, making contacts with prospective employers, planning for advancement and other problems bridging the gap between education and work will be examined. Seminar will be conducted by the Coop staff, faculty and guest lecturers from industry.

CP 102 Cooperative Education Seminar II[a, b] **1:0:N.C.**
The development and practice of skills in oral and written presentation in order to help the prospective Coop students meet the demand of employers while on their work periods. The rudiments of technical report writing and public speaking will be explored.

COORDINATORS

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

Irene H. Dorzback, Assistant Director
B.A., University of Kentucky; M.A., University of Michigan

Russell P. Reeder, Coordinator, Farmingdale Campus
A.A., Orange County Community College; B.A., SUNY (Richmond College); M.A., Columbia University

Sandra P. Santana, Coordinator, Cooperative Education
B.A., Fordham University

---

[a]Completion of CP 101 and 102 required for all freshmen and sophomore applicants to the Cooperative Education Program prior to the first work assignment. Transfer or upper division students, who meet eligibility requirements, must complete CP 101 or 102 prior to the first work assignment.

[b]A grade of S (satisfactory) or U (unsatisfactory) will be recorded on the student record upon completion of each course, however the course will not be computed in the Grade Point Average (G.P.A.), and is not required for graduation.

ELECTRICAL ENGINEERING

The Department of Electrical Engineering and Computer Science administers a variety of degree programs, summarized in the table below. This section of the catalog specifically describes the programs and courses in electrical engineering. Programs and courses in computer science and the graduate program in information systems are described in the computer science section of the catalog, page 81. The graduate programs in electrophysics and in system engineering are described in the appropriate catalog sections, page 112 and 247 respectively; however, the courses for these two programs (except for thesis) are located in the electrical engineering section.

The Electrical Engineering Profession—Electrical engineering is a rapidly growing profession which has evolved from its early beginnings in electrical power generation and distribution through the development of radio to television and computers. More recently the profession 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 the undergraduate and graduate programs in electrical engineering are designed primarily to develop talents in the areas mentioned above, 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 of specialization. Principal areas of teaching and research are electronic devices and systems, quantum electronics and material science, electro-optics and electro-acoustics, microwave engineering, power systems and energy conversion, plasma science, information and communications science, system and control engineering, computer engineering and computer science.

UNDERGRADUATE PROGRAM

The program for the degree of bachelor of science in electrical engineering gives the student a broad-based preparation for a career in electrical engineering in any of its specializations, preparing him or her for immediate employment in industry or government, or for further graduate education. The department offers a standard program, as well as four specialized options: computer engineering, power engineering, electrophysics and bioengineering. The first two years of all programs are essentially the same. In the standard program, upperclassmen are able to sample several different areas through their choice of elective courses. The four options represent modified courses of study constructed for those juniors and seniors who desire to concentrate on some areas in greater detail.

All of Polytechnic's electrical engineering undergraduate programs, on both campuses, day and evening, standard program as well as options, are accredited by the Accreditation Board of Engineering and Technology (ABET) (formerly called Engineers' Council for Professional Development, ECPD), on which the Institute of Electrical and Electronics Engineers (IEEE) is a participant.

UNDERGRADUATE OPTIONS

Programs in Computers—The programs in computers are designed to provide the student with a broad, basic preparation in the theory, organization and application of computers and information processing systems. The student interested in computers may choose either one of the following programs: (a) the computer engineering option, leading to the bachelor of science in electrical engineering, or (b) the computer science program, leading to the bachelor of science in computer science (see page 82). Both programs draw from

Degree Programs Administered by the Department of Electrical Engineering

UNDERGRADUATE

Electrical Engineering
Bachelor of Science

Options: Standard Program
Bioengineering
Computer Engineering
Electrophysics
Power Engineering

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 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, minicomputer laboratory, etc.) courses; both programs also require the same mathematics, physics and chemistry courses. The computer engineering option offers the engineering-oriented student the opportunity of obtaining the bachelor of science in electrical engineering while simultaneously acquiring a thorough grounding in the basics of computers. Beginning in the fifth semester, the computer engineering option contains a required sequence of integrated course offerings, which covers such areas as switching circuits and digital computer organization, machine and assembly language programming, and two digital laboratory courses with hands-on minicomputer and microcomputer experience. The program is completed in the senior year by an appropriate selection of computer or computer-related elective courses, including programming language translators, computer systems and an optional senior project.

Power Engineering Option—The power option is intended to provide the student with workable knowledge of the field in line with the needs of today's electric power industry. The intention is not to provide strong specialization, but rather to give focus to the student's studies. The knowledge acquired will enable the graduate to understand the physical reasons of why an electrical machine functions, and to analyze its external characteristics as a system unit. Other topics covered are transmission and distribution of electric power, design and analysis of fault prevention, and safety measures. The background thus acquired will give the student a head start in all branches of the electric power industry.

Electrophysics Option—The electrophysics option is intended for the electrical engineering student whose interests lie in the broad areas of electromagnetic and solid-state devices, as opposed to circuits, systems, computers or power. A variety of senior elective courses cover the principles that underlie the hardware of electrical engineering and the influence of these principles on device design. This option prepares a student for work in such areas as antennas and microwave components, such as are found in radio and radar systems; lasers and optical components, such as are used in optical communications; and integrated circuits, parametric amplifiers, Gunn oscillators, etc., which are the elements used to generate and process electric signals.

Combined Electrical Engineering and Life Sciences Programs—Students interested in combining a career in the life sciences with electrical engineering have a choice of two programs: (a) the bioengineering option, leading to the bachelor of science in electrical engineering with an optional fifth year leading to the master of science in bioengineering and (b) the electrical engineering option leading to the bachelor of science in life science, with an optional fifth year leading to the master of science in electrical engineering. See page 153.

The bioengineering option includes all the requirements of the standard B.S. in electrical engineering program. The specialized coursea in the option, taken in lieu of electrical engineering electives, give the student a background in biology, chemiatry and physiology. The program enables the student to become an engineering member of medical and hospital teams, to work in areas such as prosthesis design, medical instrumentation, and medical data analysis, or to continue with graduate study in bioengineering.

The electrical engineering option for the life sciences degree incorporates a majority of the sophomore and junior-level electrical engineering courses. Completion of the courses in the electrical engineering minor with a minimum 2.7 grade-point average guarantees admission into the M.S. in electrical engineering program without undergraduate deficiencies. Consult the life sciences section of the catalog for details of the bachelor's curriculum and the graduate electrical engineering section for details on the master's program.

Evening Undergraduate Program—The bachelor of science in electrical engineering degree can alao be earned in an evening program. The Polytechnic Institute of New York is unique among engineering colleges in that it offers identical programs and diplomas to day and evening students. Classification as day or evening student is purely administrative, not curriculiar. Day and evening sections of a course have identical content. Full-time day students and part-time evening students are likely to attend the same evening classes, and they are subject to the same academic standards. Transfer between day and evening status is possible at any time.

Since the needs of evening students vary, a prescribed sequence of courses is not possible. Consequently each individual student should consult with the evening adviser in person or by telephone.

Transfer Students—Qualified graduates of two-year pre-engineering programs, such as those given at liberal arts colleges and community colleges, may fulfill the requirements for the B.S. in electrical engineering in two additional yaars. Since pre-engineering programs very, a prescribed program is not possible; consequently, the student should consult with an undergraduate adviser.

Graduates of technology programs may be able to fulfill the requirements for the B.S. in electrical engineering in two to three-and-one-half years, depending on the scope and level of their previous education. Consult with 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 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 for their first semester at Polytechnic.

Program Availability

Brooklyn: All of the above described programs are available to day students. Evening students should plan to follow the standard program, because not all courses required for the four specialized options are offered in the evening session.

Long Island: The standard program as well as the computer engineering and electrophysics options can be completed on the Long Island campus. The principal specialized courses for the power engineering and bioengineering options are not offered on Long Island in 1981-83. Evening course sections are offered occasionally, usually in the spring and summer semesters, as make-up or catch-up courses for transfer students and others with irregular programs.

Senior Honors Students—A full-time day student whose performance in the first three years is outstanding will be named as a senior honors student and is permitted to replace some of the required senior technical courses with other courses, usually more advanced, which are directed to the student's professional goals.

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

Departmental Standards and Probation—To earn a degree in the Department of Electrical Engineering, students must earn a minimum C average (2.0 grade-point average) in all *technical* courses: mathematics, physics, computers and engineering.

Students are automatically placed on departmental probation if their semester or cumulative technical average is less than 2.0, if they receive C- or less in any sophomore year electrical engineering course, or if they fail to adhere to course prerequisites. Students on probation must consult with their advisers during the registration week prior to the beginning of each term. They may be required to repeat courses in which they have earned grades of C- or less or an incomplete, to postpone an advanced course, to take a special program of courses to improve their understanding or to withdraw from the department in cases of repeated departmental probation. Almost without exception, students earning a D+ or less in EE 101 or EE 102 will be required to repeat the course. Likewise, a student who earns a combined average of C- or less in all technical courses during one semester, or in a closely related sequence of courses, will almost invariably be required to repeat some of these courses.

Information—The *Undergraduate Student Manual,* issued to every student, contains further details on courses approved as electives, new courses, special sections and other matters of interest. Last-minute announcements are posted on the bulletin boards outside of the undergraduate office in Brooklyn and the department office in Farmingdale. Each student is responsible for keeping informed.

GRADUATE STUDY

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 of the catalog. 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 that specializes 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, 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.

Curriculum of Study for the Bachelor of Science Degree in Electrical Engineering (for Freshmen Entering 1981)

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	Gen. Chem. Lab I	0	1½	½
HU 101	College Composition[h]	3	0	3
SS 104	Contemporary History[h]	3	0	3
PE 101	Physical Education[f, d]	0	2	0
				16

Second Semester		Hours/Week		
No.	Subject	Cl.	Lab.	Cr.
CS 111	Computer Progr I	3	0	3
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	Gen. Chem. Lab II	0	1½	½
HU 200	Intro. to Literature[h]	3	0	3
PE 102	Physical Education[f, d]	0	2	0
				17

Sophomore Year

EE 101	Elec. Systems I	3	0	3
EE 193	Soph. EE Lab I	0	3	1
CS 203	Computer Progr. II	3	0	3
MA 104	Appl. Diff. Equations	3	0	3
PH 103	Introductory Physics III	2½	1½	3
	Hum./Soc. Sci. elective[h]	3	0	3
PE 103	Physical Education[f, d]	0	2	0
				16

EE 102	Elec. Systems II	3	0	3
EE 194	Soph. EE Lab II	0	3	1
MA 103	Calculus III	3	0	3
PH 230	Atom. and Nucl. Physics	2	0	2
AM 115	Eng. Mechanics[e]	4	0	4
	Hum./Soc. Sci. elective[h]	3	0	3
PE 104	Physical Education[f, d]	0	2	0
				16

Junior Year

First Semester		Hours/Week		
No.	Subject	Cl.	Lab.	Cr.
EE 103	Elec. Systems III	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 and Dig. Sys.	3	0	3
	Hum./Soc. Sci. elective[h]	3	0	3
				19

Second Semester		Hours/Week		
No.	Subject	Cl.	Lab.	Cr.
EE 104	Feedback Systems	3	0	3
EE 112	Solid State Circ. II	3	0	3
EE 162	Electromag. Fields	4	0	4
EE 196	Jr. EE Lab II	1	3	2
MA 223	Probability	3	0	3
	Hum./Soc. Sci. elective[h]	3	0	3
				18

Senior Year

EE 113	Solid State Circ. III	3	0	3
EE 141	Signal Processing	3	0	3
EE 180	Elec. Machinery I			
EE 167	Quantum Electronics	6	0	6
	Technical elective[t]			
EE 197	Sr. EE Lab I	1	3	2
	Technical elective[f, t]	3	0	3
				17

EE 199	Sr. EE Lab II[z]	1	3	2
	Technical elective[t]	3	0	3
	Technical elective[t]	3	0	3
	Technical elective[t]	3	0	3
	Hum./Soc. Sci. elective[h]	3	0	3
	Free elective[f, t]	3	0	3
				17

Total credits required for graduation: 136

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 circuits.

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 structured media. Applications to technology include waveguide structures, antennas, parametric interactions, diffraction, scattering, surface and bulk acoustic wave propagation and transduction.

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 deals 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 materials.

BIOENGINEERING OPTION

Freshman and sophomore courses as in standard program.

Junior Year

EE 103	Elec. Systems III	4	0	4	LS 106	General Biology II	3	0	3
EE 111	Solid State Circ. I	3	0	3	LS 116	General Biology Lab II	1	3	2
EE 161	Lines and Waves	4	0	4	EE 112	Solid State Circ. II	3	0	3
EE 195	Jr. EE Lab. I	1	3	2	EE 162	Electromag. Fields	4	0	4
MA 223	Probability	3	0	3	EE 196	Jr. EE Lab II	1	3	2
	Hum./Soc. Sci. elective[h]	3	0	3		Hum./Soc. Sci. elective[h]	3	0	3
				19					17

Senior Year

EE 113	Solid State Circ. III	3	0	3	EE 104	Feedback Systems	3	0	3
EE 180	Elec. Machinery I				EE 199	Sr. EE Lab II[z]	1	3	2
EE 167	Quantum Electronics } x	6	0	6	EE 141	Signal Processing	3	0	3
	Concen. elective[t]				BE 611	Physiology for BE II	2½	0	3
EE 197	Sr. EE Lab I	1	3	2		Hum/Soc. Sci. elective[h]	3	0	3
CS 236	Switch. and Dig. Sys.	3	0	3	CM 164	Phys. Chem of L.S.	3	0	3
BE 610	Physiology for BE I	2½	0	3	LS 310	Biology Seminar	1	0	1
				17					18

Total credits required for graduation: 136

COMPUTER ENGINEERING OPTION

Freshman Year

CS 111	Computer Progr. I	3	0	3	CS 203	Computer Progr. II	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	1½	4
CM 101	General Chemistry I	2½	0	2½	CM 102	General Chemistry II	2½	0	2½
CM 111	Gen. Chem. Lab I	0	1½	½	CM 112	General Chemistry Lab. II	0	1½	½
HU 101	College Composition[h]	3	0	3	HU 200	Intro. to Literature[h]	3	0	3
PE 101	Physical Education[f, d]	0	2	0	PE 102	Physical Education[f, d]	0	2	0
				16					17

Sophomore Year

EE 101	Elec. Systems I	3	0	3	EE 102	Elec. Systems II	3	0	3
EE 193	Soph. EE Lab I	0	3	1	EE 194	Soph. EE Lab II	0	3	1
CS 204	Data Structures	3	0	3	MA 103	Calculus III	3	0	3
MA 104	Appl. Diff. Equations	3	0	3	PH 230	Atom. and Nucl. Physics	2	0	2
PH 103	Introductory Physics III	2½	1½	3	AM 115	Eng. Mechanics	4	0	4
SS 104	Contemporary History[h]	3	0	3		Hum./Soc. Sci. elective[h]	3	0	3
PE 103	Physical Education[f, d]	0	2	0	PE 104	Physical Education[f, d]	0	2	0
				16					16

Junior Year

First Semester			Hours/Week		Second Semester			Hours/Week	
No.	Subject	Cl.	Lab.	Cr.	No.	Subject	Cl.	Lab.	Cr.
EE 103	Elec. Systems III	4	0	4	EE 104	Feedback Systems	3	0	3
EE 111	Solid State Circ. I	3	0	3	EE 112	Solid State Circ. II	3	0	3
EE 195	Jr. EE Lab I	1	3	2	EE 188	Computer Lab I	2	3	3
CS 205	Ass'y and Machine Lang.	3	0	3	CS 237	Computer Architecture	3	0	3
CS 236	Switching and Dig. Sys.	3	0	3		Concen. elective[t]	3	0	3
	Hum./Soc. Sci. elective[h]	3	0	3		Hum./Soc. Sci. elective[h]	3	0	3
				18					18

Senior Year

EE 113	Solid State Circ. III	3	0	3	EE 141	Signal Processing	3	0	3
EE 161	Lines and Waves	4	0	4	EE 199	Sr. EE Lab II[z]	1	3	2
EE 189	Computer Lab II	1	3	2		Concen. elective[t]	3	0	3
MA 223	Probability	3	0	3		Concen. elective[t]	3	0	3
	Technical elective[f, t]	3	0	3		Hum./Soc. Sci. elective[h]	3	0	3
	Hum./Soc. Sci. elective[h]	3	0	3		Free elective[f, t]	3	0	3
				18					17

Total credits required for graduation: 136

See footnotes on page 97.

ELECTROPHYSICS OPTION

Freshman and sophomore courses as in standard program.

Junior Year

EE 103	Elec. Systems III	4	0	4	EE 104	Feedback Systems	3	0	3
EE 111	Solid State Circ. I	3	0	3	EE 112	Solid State Circ. II	3	0	3
EE 161	Lines and Waves	4	0	4	EE 162	Electromag. Fields	4	0	4
EE 167	Quantum Electronics	3	0	3	EE 196	Jr. EE Lab II	1	3	2
EE 195	Jr. EE Lab I	1	3	2	MA 223	Probability	3	0	3
	Hum./ Soc. Sci. elective[h]	3	0	3		Hum./Soc. Sci. elective[h]	3	0	3
				19					18

Senior Year

EE 113	Solid State Circ. III	3	0	3	EE 141	Signal Processing	3	0	3
EE 180	Elec. Machinery I }	3	0	3	EE 199	Sr. EE Lab. II[z]	1	3	2
	Technical Elective[t] }					Concen. elective[t]	3	0	3
EE 197	Sr. EE Lab I	1	3	2		Technical elective[t]	3	0	3
CS 236	Switching and Dig. Sys.	3	0	3		Hum./Soc. Sci. elective[h]	3	0	3
	Concen. elective[t]	3	0	3		Free elective[r, t]	3	0	3
	Technical elective[r, t]	3	0	3					17
				17					

Total credits required for graduation: 136

POWER ENGINEERING OPTION

Freshman and sophomore courses as in standard program.

Junior Year

CS 236	Switching and Dig. Sys.	3	0	3	EE 104	Feedback Systems	3	0	3
EE 103	Elec. Systems III	4	0	4	EE 112	Solid State Circ. II	3	0	3
EE 111	Solid State Circ. I	3	0	3	EE 162	Electromag. Fields	4	0	4
EE 161	Lines and Waves	4	0	4	EE 183	Power Systems	3	0	3
EE 195	Jr. EE Lab I	1	3	2	EE 196	Jr. EE Lab II	1	3	2
	Hum./Soc. Sci. electives[h]	3	0	3		Hum./Soc. Sci. elective[h]	3	0	3
				19					18

Senior Year

EE 113	Solid State Circ. III	3	0	3	EE 141	Signal Processing	3	0	3
EE 180	Elec. Machinery I	3	0	3	EE 181	Elec. Machinery II	3	0	3
EE 197	Sr. EE Lab I	1	3	2	EE 199	Elec. Mach Lab.[z]	1	3	2
MA 223	Probability	3	0	3		Technical elective[t]	3	0	3
	Technical elective[r, t]	3	0	3		Hum./Soc. Sci. elective[h]	3	0	3
	Concen. elective	3	0	3		Free elective[r, t]	3	0	3
				17					17

Total credits required for graduation: 136

---

[d]Day students only.

[e]Evening students may replace AM 115 by AM 116 plus AM 117.

[h]The student shall complete a minimum of 24 credits of humanities and social science courses. The student must take HU 101 and either HU 200 and SS 104 or IS 140-141. Students who are placed in HU 103 on the basis of the English Composition Placement Test administered at the 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).

In addition, the student is strongly urged to select an area of concentration (such as literature, communications, the arts, philosophy or 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 this concentration, in consultation with an adviser. A modern language may be chosen as a suitable concentration, but a student without prior knowledge of the language should plan to devote at least 12 credit hours to the subject. For the remaining credits in the humanities/social science requirement, the student should select courses in areas other than that of the concentration.

[r]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 131, 142, 143, 146, for three credits of free electives and three credits of technical electives.

[t]Technical electives are chosen from a list of approved courses, departmental and out-of-department, published and updated each year. Concentration electives are chosen from a restricted list published for each curriculum option. Any course can be chosen as a free elective as long as it does not duplicate material studied under another course number. See note z for restriction on project courses.

[x]Choose any two of the three courses or one of two, as listed.

[z]Students may replace EE 199 by Project Laboratory EE 198, or by B.S. Thesis EE 397. Not more than six credits of project courses (EE 198, EE 397, EE 398, CS 398) may be offered toward the B.S. in E.E. degree.

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 individual basis, and may be admitted subject to the completion of appropriate undergraduate courses to remove deficiencies in preparation. In the event that such a student also desires to obtain a Polytechnic B.S. in electrical engineering degree, he must do so first, *before* beginning to study 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 will count toward the master's degree. (This applies for example to graduates of the Polytechnic B.S. in life sciences with a concentration in electrical engineering.) Students without an electrical engineering B.S. may also want to consider the departmental master's degree programs in electrophysics, page 112, and in system engineering, page 247.

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

DEGREE REQUIREMENTS

To satisfy the requirements for the M.S. in electrical engineering degree, the student must complete a total of 36 units of courses as described below, with an overall grade average of B. 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 EL 641 Advanced Electronic Circuitry I EL 671 Fields and Waves CS 671 Switching and Automata I	9
2. Two one-year sequences which may include the courses in group (1)	6-12
3. Approved electives, which may include a thesis (9 units) and one reading course (3 units maximum)	21-15
	36

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 in the program 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 subsequent to 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 offered as electives.

Thesis: An exceptional student may elect to write a master's thesis for which 9 units toward the degree may be earned. Such a student should find an appropriate adviser who has agreed to monitor the thesis research. The research need not be original, but should adequately demonstrate the student's proficiency in the subject material. An 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 Institute regulations on page 21 of this catalog can be applied toward the one-year sequence requirements and toward the electives.

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 663, 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, page 114.

THE ENGINEER DEGREE

The engineer in electrical engineering degree is offered in recognition of the need of system 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 department 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 another department. The committee is appointed shortly 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 that 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 guidance committee and is officially approved on the student's submission of an acceptable written proposal that details the problem, background and approach, gives a budget for estimated project expenses and states the desired number of units (6, 9 or 12 units) to be earned. On 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 requirement 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.

DOCTORAL PROGRAM

General—Graduate students who have exhibited a high degree of scholastic proficiency and have given evidence of ability for conducting independent research may consider extending their goals toward the doctorate. The degree of Ph.D. is awarded after completing the program of study and research described below and on preparation and defense of a dissertation representing an original and significant contribution deemed worthy of publication in a recognized scientific or engineering journal.

Admission to Program—Entrance into a doctoral program of study and research is contingent on the candidate's passing the departmental qualifying examinations 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 examination within the calendar year.

Students entering the doctoral program at the baccalaureate level must meet the above-listed entrance requirements 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 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 a broad coverage of 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 and (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 from the latest *Graduate Student Manual.*

Guidance Committee—On passing the qualifying examinations, the graduate student suggests a guidance committee composed of three members of the faculty, one selected from the student's major area of interest and the other two from the two minor areas. The member representing the major area is named chairman of the committee and becomes the student's prospective thesis adviser. Information regarding selection of thesis topics and advisers is available in the electrical engineering graduate office. In the event a thesis adviser other than the chairman is agreed on, the adviser becomes a fourth member of the guidance committee. In consultation with the chairman and student, the committee members from the minor areas will approve the student's minor program. In addition, the guidance committee will approve the student's dissertation and conduct the thesis defense examination.

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 minimum of 12 units of courses in each of two minor areas. The minor must be 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 chairman of the guidance committee. The major program should constitute a coherent study in depth of the most advanced knowledge in the student's chosen 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 is an oral examination administered by the guidance committee and is normally taken at the midpoint of the student's dissertation research program. The function of the examination is primarily to assess the depth of knowledge and understanding possessed by the student and secondarily to monitor the student's progress in the initial phase of the doctoral research program. The area examination is attended by the members of the guidance committee together with other appropriate faculty members who, because of their knowledge in the student's area of concentration, will assist in meeting the objective of the examination. An outline of the area defined for examination is prepared by the student and approved by the chairman of the guidance committee. Postponement of the examination beyond the midpoint (12 units) of EL 999 registration will require the approval of the doctoral adviser.

Language Requirement—The Department of Electrical Engineering and Computer Science normally requires the student to demonstrate reading knowledge in either French, German or Russian. Substitution of another language requires demonstration of the existence of a body of relevant technical literature and approval by the Graduate Language Board.

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 Graduate Studies of the candidate's readiness to submit to examination so that the Office of Graduate Studies may schedule the examination date. The student is advised to consult the Office of Graduate Studies in order to meet the regulations regarding submission of the final manuscript, reproduction and binding.

UNDERGRADUATE COURSES

Students are advised to consult the departmental *Undergraduate* or *Graduate Student Manual* and the Registration Bulletin for changes in courses, course content and prerequisites in effect subsequent to the publication of this catalog.

General prerequisite: Students may not register for any junior- or senior-level courses until every freshman requirement is completed.

BASIC COURSES

EE 101 Electrical Systems 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 104** and **PH 103.**

EE 102 Electrical Systems II **3:0:3**
Continuation of EE 101. Coupled circuits and transformers, sinusoidal steady-state response, resonance, positive real functions, power calculations, three-phase systems, introduction to Fourier series. Prerequisites: EE 101 and MA 104.

EE 103 Electrical Systems III **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. Prerequisite: EE 102.

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**
Design of linear feedback control systems in the complex and real-frequency domains. Lag, lead, lag-lead compensators. Design of pole-placement controllers. Sampled-data systems. Integral and sum-squared error criteria. Parameter optimization. Prerequisite: EE 104.

EL 511† Computer-Aided Analysis and Design of Linear Networks*
See graduate course listings.

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.

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 114 Physical Electronics* **3:0:3**
Introduction to study of physical electronics including motion of charged particles in presence of electric and magnetic fields. Space-charge limited devices, elements of semiconductor physics as applied to P-N junction theory, photo-diodes and solar cells, breakdown effects and transistor devices. Prerequisite: EE 111.

EE 115 Advanced Electronics **3:0:3**
Special topics in electronic circuits and instrumentations, 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 ferromagnetic 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

COMMUNICATIONS AND INFORMATION TRANSMISSION

EE 141 Signal Processing **3:0:3**
Discrete Fourier transforms, sampling theorems, digital filtering. Random signals in noise, spectral density, autocorrelation, statistical measurement of signals, spectral estimation. Detection, estimation and linear recursive estimation. Prerequisites: EE 103, CS 111 and MA 223.

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 paremeter estimation. Simulation of dynamic systems and signals. Pattern processing and recognition. Projects with small and large computers. Prerequisite: EE 141.

EL 533† Introduction to Communication Systems
See graduate course listings.

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 freespace in integral form. Prerequisites: EE 102, 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 megnetic materials. Plane waves in dielectrics and conductors. Electrostatics, 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.

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: EE 162 and PH 230.

EL 551-552† Electro-Optics I, II
See graduate courses 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 are presented for the four types of electrical machine: transformer, induction motor, synchronous machine and DC machine. Equivalent circuits and vector diagrams are derived and used as the primary tools for analysis. Prerequisite: EE 162.

EE 181 Electrical Machinery II **3:0:3**
Two alternative unifying viewpoints of electrical machines are presented. One is based on physical considerations and leads to design guidelines. The second is based on Kron's theory and provides means for system analysis. Prerequisite: EE 180.

EE 183 Electric Power Systems **3:0:3**
Principles of operating electric power systems. Transmission lines: inductance and capacitance parameters and current-voltage relations. Power system representation. Introduction to network calculations, symmetrical phase components, dynamic stability and economic dispatch. Prerequisite: EE 102.

EE 199 Electrical Machinery Laboratory
See course listing under electrical engineering laboratory. Prerequisite: **EE 181.**

EL 564† Electromechanical Power Conversion*
See graduate course listings.

EL 581† Introduction to Plasma Engineering*
See graduate course listings.

ELECTRICAL ENGINEERING LABORATORY

Students enrolled in electrical engineering laboratory courses may be required to purchase a laboratory kit consisting of electronic parts and components. This is in addition to the indicated laboratory fees.

EE 188 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. Prerequisite: CS **237.**

EE 189 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. Prerequisite: EE 188 and CS 237.

EE 193 Sophomore Electrical Engineering Laboratory I **0:3:1**
Introduction to electrical measurements. Lab fee required. Prerequisite: **EE 101.**

EE 194 Sophomore Electrical Engineering Laboratory II **0:3:1**
Electric circuits laboratory. Lab fee required. Prerequisite: **EE 102.**

EE 195 Junior Electrical Engineering Laboratory I **1:3:2**
Circuits and electronics laboratory. Lab fee required. Prerequisites: EE 194, EE 102, **EE 111.**

EE 196 Junior Electrical Engineering Laboratory II **1:3:2**
Experiments selected from various areas of electrical engineering. Lab fee required. Prerequisites: **EE 195, 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 and **EE 113.**

EE 198 Project Laboratory **1:6:3**
Laboratory project under supervision of an adviser. Must be an experimental project with a final report: either designing, building and testing a piece of equipment or developing, debugging and documenting a software package. Lab fee required. Prerequisite: EE 197 or EE 189.

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. Prerequisites: EE 197 or EE 189. (Additional prerequisites may be 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. Electric power devices including transformers, DC motors and generators, and induction motors. Cannot be used to satisfy any electrical engineering degree requirements. Prerequisite: **MA 104,** PH 102.

EE 374 Instrumentation Laboratory **0:3:1**
Experiments designed to supplement EE 370. Cannot be used to satisfy any electrical engineering degree requirements. Prerequisite: **EE 370.**

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 397 Bachelor's Thesis in Electrical Engineering **3 credits**
Individual solution of electrical engineering problem, involving adequate statement of problem, choice of method 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 close supervision of adviser. Written report. 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 511† Computer-Aided Analysis and Design of Linear Networks* **2½:0:3**
Network functions. Circuit analysis by computer. Computer-aided design of LC and RC driving-point impedances, transfer functions and filters. Design of active circuits. Approximations for computer-aided implementation. Applications. Prerequisites: CS 530 and EE 103.

EL 610 Linear Systems **2½:0:3**
Basic systems 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, pulse and impulse response. Transform methods. Time-variable systems. Prerequisite: EE 103.

EL 611 Signals, Systems and Transforms **2½:0:3**
Continous 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: 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: MA 103 and 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: MA 223 or MA 561 or equivalent.
Also listed under IE 685 and OR 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 components reliability. Prerequisite: MA 223 or MA 561 or equivalent.
Also listed under IE 686 and OR 686

EL 711 Advanced Signals and Systems* 2½:0:3
Approximation methods in digital simulation of analog signals. Sampling theorems. Maximum system response under constraints. Analytic properties of Laplace transforms, complex inversion factorization, windows, extrapolation, maximum entropy. Two-dimensional and Hankel transforms. Diffraction. Fourier optics. Ambiguity functions and pulse compression. Spectral estimation. Prerequisite: EL 611.

EL 713 Digital Signal Processing* 2½:0:3
Time and transform domain description of discrete-time signals and filters. Z-transforms, difference equations, discrete Fourier analysis and the FFT. Properties and design of recursive and non-recursive filters. Effects of finite precision arithmetic and round-off errors. Hardware realizations of digital filters. Introduction to spectral analysis. Prerequisites: EL 610 and 611.

EL 714 Smoothing and Prediction of Discrete-Time Signals* 2½:0:3
Review of discrete-time random signals in time and frequency domains. Finite memory and expanding memory predictor-corrector estimators. Linear mean-square estimation, the discrete-time Wiener-Hopf equation, Wiener and Kalman-Bucy filters with nonlinear applications. Prerequisites: EL 713 and EL 631.

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. Prerequisite: 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 stabilizing controllers for the single-loop feedback system. Minimal controller realizations, observability and controllability. Prerequisites: EL 610 and EL 613.

EL 721 Nonlinear Control Systems* 2½:0:3
Analysis and design techniques for nonlinear control systems. Phase plane, piecewise linearization, Lyapunov's second method, describing function, Popov locus and circle criterion methods. Applications to relay and saturating systems and systems with other nonlinearities. Prerequisites: EL 610 and EL 621.

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. Prerequisites: 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 Lyapunov 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 maximum principle and dynamic programming. Hamilton-Jacobi theory as applied to synthesis problem. Optimization problems with state variable constraints. 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 systems 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 variable, distributions, moments, characteristic functions. Functions of random variables. Sequence of random variables. Limit theorems. Engineering applications of statistics. Prerequisite: MA 223.

EL 533† Introduction to Communication Systems 2½:0:3
Examples, 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.

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. Prerequisite: EL 631.

EL 635 Principles of Data 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 packet radio networks. Reliability. Regulatory traffic. Interconnection of networks. Course will provide a broad overview of current issues on networks. An assessment of state-of-the-art technique and a glimpse at emerging questions. Prerequisite: graduate status.
Also listed under CS 635

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. Prerequisite: EL 533.

EL 735-736 Computer-Communication Networks I, II each 2½:0:3
Analytical and design techniques for large centralized and distributed data networks. Examples of computer and terminal-oriented networks: modeling of sources, communications links, processors. Queuing analysis. Capacity assignment for distributed and centralized networks. Concentrators, multiplexers, polling, buffers, routing, network flow algorithms, topological design of networks, reliability, software considerations, design examples, societal questions. Emphasis on current literature. Students required to report on current literature in the field. EL 735 prerequisite: EL 531, EL 635. EL 736 prerequisite: EL 735.

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 theorem and source coding techniques. Extension to sources with memory, channel capacity and noisy channel coding theorem. Extensions to continuous waveforms. Prerequisite: EL 531.

EL 833 Advanced Signal Processing* 2½:0:3
Radon-Nikodym derivatives, Hajek-Feldman theorem for Gaussian stochastic processes. Detection and parameter estimation of stochastic and deterministic signals imbedded in colored and nonstationary Gaussian noise. Nonparametric methods in detection and estimation. Diversity reception systems. Prerequisite: EL 633.

EL 931-932 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 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 amplifier. 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 844 Semiconductor Technology 2½:0:3
Review of electrical transport properties of semiconductors. Preparation of semiconductor materials. Impurity diffusion, diffusion mechanisms, concentration profiles. Surface preparation and contacts. Integrated circuits, design of circuit components techniques used in fabrication, various limitations on performance. Prerequisite: graduate status.
Also listed under MT 705

EL 845 Principles of Semiconductor Devices I* 2½:0:3
Introduction and review of semiconductor physics. Non-equilibrium bulk and p-n junction properties discussed along with relevance to design and operation of photoconductive detectors, rectifiers, mixers, switches, varactors, snap diodes. Prerequisite: graduate status.

EL 846 Principles of Semiconductor Devices II* 2½:0:3
Development of phenomenological and engineering aspects of bipolar transistors, junction field-effect transistors, MOS capacitors, MOS field-effect transistors, charge-coupled devices. Prerequisite: EL 645.

EL 847 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: to be 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 structure and dynamics, lattice vibrations, the phonon, thermal conductivity of solids. Energy-band theory, 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 prerequisite: EE 167. EL 654 prerequisite: EL 653.

EL 655 Quantum Mechanics I **2½:0:3**
Quantum mechanics with applications to atomic systems. The use of Schroedinger's equations. Problems and approximation methods. Prerequisite: graduate status.
Also listed under PH 667

EL 656 Quantum Mechanics II* **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. Prerequisite: EL 655.
Also listed under PH 668

EL 657 Electric and Magnetic Properties of Solids* **2½:0:3**
Dielectric properties, anisotropy, ferroelectricity and piezoelectricity. Optical properties, optical activity and birefringence, electro-optic and magneto-optic effects and their applications. Magnetic properties, magnetization mechanisms, dia- and para-magnetism, ferro-, ferri, and antiferro-magnetism, nuclear magnetic, ferro-magnetic and electron paramagnetic resonance. Prerequisite: EL 557.

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 751-752 Quantum Optics I, II* **each 2½:0:3**
Temporal and spatial coherence, interference laws and experiments, interference spectroscopy, Lagrangian and Hamiltonian formulation of field equations. The Fock representation, field creation and annihilation operators, coherent states, spontaneous and stimulated emission of light. Quantum correlation functions, photon coincidences, the density operator, correlation functions and quasi-probability distributions. Light beam and laser field models. Photon counting, anti-correlation effects. EL 751 prerequisites: EL 671 and EL 655 or a course in modern physics. EL 752 prerequisite: EL 751.

EL 755 Parametric Electronics* **2½:0:3**
Review of passive systems. Discussion of lumped and distributed parametric circuits. Analysis by small signal theory, frequency-power relations, Floquet theory, coupled-mode principles, Brillouin diagrams. Semiclassical theory of parametric interactions. Applications to microwave, optical, ultrasonic and electron beam parametric systems and to laser-fusion research. Prerequisite: EL 673.

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 departmental 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. The equivalent circuit for an electromechanical power conversion system. Homopolar devices. The design of the magnetic circuit. 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 647 Power Electronics
See course listings under electronic devices, circuits and systems.

EL 661 Studies in Power System Engineering **2½:0:3**
Study of interconnected power utilities from system engineering point of view. Basic characteristics of power systems. Load

flow. Economic dispatch of power. Tie-line and frequency-control performance. Network decompositions. Prerequisite: graduate status.

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 665 Power System Stability I* **2½:0:3**
Introduction to the study of power systems dynamics: mathematical modeling of prime movers, power plants, synchronous machines, field exciters, transmission lines, relay loads and stabilizers. Prerequisite: graduate status.

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 961-962 Selected Topics in Power I, II **each 2½:0:3**
Topics of current interest in electric system engineering that are relevant to the electric power industry. (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 both 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, etc. EL 571 prerequisite: EE 162. EL 572 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 placed on understanding electromagnetic wave phenomena (interference, reflection, refraction, etc.) and their engineering applications over the entire electromagnetic spectrum. Prerequisite: graduate status.

EL 672 Electrodynamics: Wave Propagation and Guidance **2½:0:3**
Course for students requiring understanding of electromagnetic fields from 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, magnatic 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 674 Waves in the Atmosphere* **2½:0:3**
Static and dynamic conditions in the atmosphere. Wave types, theory of gravity waves and examples, effects of wind. Theory of tidal waves, dynamo effect, planetary and Rossby waves. Wave ducting, waves in the ionosphere. Turbulence in the atmosphere. Prerequisite: graduate status.

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 mathods. 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* **each 2½:0:3**
Engineering applications 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, 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**
Fundamental principles of linear and planar phased arrays, surface-wave and leaky-wave antennas, traveling-wave arrays. Concepts of gain, element pattern, element efficiency, active impedance, grating lobe series. Mutual coupling effects. Review of guided waves on open structures. 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 671 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 in inhomogeneous dispersive media, diffraction and transition phenomena for transients. Prerequisite: EL 772.

EL 673 Nonlinear Waves* **2½:0:3**
Generic nonlinear wave equations. Whitham's Lagrangian formulation and averaging method. Quasi-particle techniques in nonlinear problems. Inverse scattering method. Application of KdV, nonlinear parabolic, etc., equations in electrophysics. Prerequisite: EL 671.

EL 971-972 Selected Topics in Electromagnetic Theory I, II* **each 2½:0:3**
Aspects of electromagnetic and acoustic wave propagation, diffraction and radiation that are 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 681 Applied Plasma Physics* **2½:0:3**
Plasma diagnostic methods including electrostatic and magnetic probes, spectroscopic methods, microwaves, etc. Selected topics in applied plasmas, including controlled thermonuclear research, MHD generation, chemical processing, etc. Prerequisite: EL 581.

EL 683 Physics of the Atmosphere* **2½:0:3**
Origin of solar system, planets, atmosphere. Structures, composition of planetary atmospheres, minor constituents, natural and man made, gravitational effects and distribution, escape of gases. Sun and its relationship to earth and planets, atomic, molecular processes, stratosphere, ozone, winds and dynamics, mesosphere, thermosphere. Prerequisite: graduate status.
Also listed under AM 806

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 Processes 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.) Prerequisites: specified when offered.

DEPARTMENTAL PROJECTS, READINGS, THESIS AND SEMINARS

EL 891 Graduate Seminar* **2½:0:3**
Seminars in various areas of electrical engineering, 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 **each 2½:0:3**
Designed primarily for students who desire to push toward frontiers of their specializations in electrical engineering, electrophysics or system engineering and who have completed essentially all related course offerings. Readings conducted under guidance of 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 advanced graduate students. Projects assigned on basis of specialized interest and preparation of student. 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 candidacy.

EL 998 Project for Engineer Degree in Electrical Engineering **each 3 units**
Comprehensive planning and design of electrical engineering project under guidance of faculty adviser. Emphasis on up-to-date 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 candidacy.

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: degree candidacy and passing qualifying examination. Registration beyond twelfth unit requires passing of area examination.

FACULTY

Joel B. DuBow, Professor of Electrical Engineering and Head of Electrical Engineering and Computer Science
B.E.E., Polytechnic Institute of Brooklyn; M.S., Princeton University; Ph.D., Case Western Reserve University
Energy technology, electronic materials and devices

Leonard Bergstein, Professor of Electro-Optical Sciences
Ph.D., Polytechnic Institute of Brooklyn
Electro-optics

Henry L. Bertoni, Professor of Electrophysics
B.S., Northwestern University; M.S., Ph.D., Polytechnic Institute of Brooklyn
Electromagnetics, acoustics

Joseph J. Bongiorno, Jr., Professor of Electrical Engineering
B.E.E., M.E.E., D.E.E., Polytechnic Institute of Brooklyn
Control Systems

Robert R. Boorstyn, Professor of Electrical Engineering
B.E.E., CCNY; M.S., Ph.D., Polytechnic Institute of Brooklyn
Computer communication networks, telecommunications

Edward S. Cassedy, Professor of Electrical Engineering
B.S., Union College; S.M., Harvard University; Dr. Eng., The Johns Hopkins University
Plasmas, power, energy policies

Bernard R.-S. Cheo, Professor of Electrical Engineering
B.S., Taiwan College of Engineering (Taiwan); M.S., University of Notre Dame; Ph.D., University of California (Berkeley)
Electromagnetics, plasmas, power

Rudolf F. Drenick, Professor of System Engineering
Ph.D., University of Vienna (Austria)
System theory

Leopold B. Felsen, Institute Professor
B.E.E., M.E.E., D.E.E., Polytechnic Institute of Brooklyn
Propagation and diffraction, optics

Anthony B. Giordano, Professor of Electrical Engineering and Dean of Graduate Studies
B.E.E., M.E.E., D.E.E., Polytechnic Institute of Brooklyn
Electromagnetics, network theory, microwave networks

Stanley H. Gross, Professor of Electrophysics
B.S., CCNY; M.S., Ph.D., Polytechnic Institute of Brooklyn
Ionospheric plasmas and atmospheric physics

Alexander Hessel, Professor of Electrophysics
M.Sc., Hebrew University; D.E.E., Polytechnic Institute of Brooklyn
Antenna theory

Bruce L. Hicks, Visiting Professor of Computer Science
B.S., M.S., Ph.D. (Physics), California Institute of Technology
Educational applications of computers, computer graphics

Donald F. Hunt, Professor of Electrical Engineering
B.S., University of Pennsylvania
Networks, energy

Melvin Klerer, Professor of Computer Science
B.A., M.S., Ph.D., New York University
Programming languages

Frank Kozin, Professor of System Engineering
B.S., M.S., Ph.D., Illinois Institute of Technology
Stochastic systems

Ludwik Kurz, Professor of Electrical Engineering
B.E.E., CCNY; Eng. Sc.D., New York University
Communications, pattern recognition, and image processing

Arthur E. Laemmel, Professor of Electrical Engineering
B.E.E., Polytechnic Institute of Brooklyn
Coding and computer circuits

James T. LaTourrette, Professor of Electrophysics
B.S., California Institute of Technology; A.M., Ph.D., Harvard University
Quantum electronics, computer software

Enrico Levi, Professor of Electrophysics
B.S. (M.E.), B.S. (E.E.), Dipl. Ing., Technion (Israel); M.E.E., D.E.E., Polytechnic Institute of Brooklyn
Energy conversion

Frank J. Lupo, Professor of Electrical Engineering
B.E.E., M.E.E., New York University; Ph.D., Columbia University
Bioengineering, networks, and systems

Nathan Marcuvitz, Institute Professor
B.E.E., M.E.E., D.E.E., Polytechnic Institute of Brooklyn
Nonlinear and turbulent waves

Eli Absalom Mishkin, Professor of Applied Physics
Ingenieur, Sc.D., Technion (Israel)
Quantum and nonlinear optics, laser-induced fusion

Arthur A. Oliner, Professor of Electrophysics and Director of Microwave Research Institute
B.A., Brooklyn College; Ph.D., Cornell University
Electromagnetics, microwaves, integrated optics, acoustics

Istvan Palocz, Professor of Electrical Engineering and Electrophysics
Dip. E.E., Docent, University of Technical Sciences (Budapest, Hungary); Ph.D., Polytechnic Institute of Brooklyn
Wave propagation

Athanasios Papoulis, Professor of Electrical Engineering
M.E., E.E., Athens Polytechnic Institute (Greece); M.S., M.A., Ph.D., University of Pennsylvania
Signal theory

Philip E. Sarachik, Professor of Electrical Engineering
A.B., B.S., M.S., Ph.D., Columbia University
Optimal and adaptive systems

Harry Schachter, Professor of Electrical Engineering
B.E.E., CCNY; M.S., Columbia University; Ph.D., Polytechnic Institute of Brooklyn
Microwave acoustics and communications systems

Benjamin Senitzky, Professor of Electrophysics
B.E., Ph.D., Columbia University
Optical and semiconductor devices

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

Leonard G. Shaw, Professor of Electrical Engineering
B.S., University of Pennsylvania; M.S., Ph.D., Stanford University
Stochastic control, reliability

Jerry Shmoys, Professor of Electrical Engineering
B.E.E., Cooper Union; Ph.D., New York University
Antennas, propagation

Martin L. Shooman, Professor of Electrical Engineering and Computer Science
S.B., S.M., Massachusetts Institute of Technology; D.E.E., Polytechnic Institute of Brooklyn
Software engineering, system reliability and safety

Edward J. Smith, Professor of Electrical Engineering and Director of Division of Computer Science
B.E.E., Cooper Union; M.E.E., D.E.E., Polytechnic Institute of Brooklyn
Computer organization

Leonard Strauss, Professor of Electrical Engineering
B.E.E., CCNY; M.S., Columbia University
Integrated circuits

Theodor Tamir, Professor of Electrical Engineering and Electrophysics
B.S., Dipl. Ing., M.S., Technion (Israel); Ph.D., Polytechnic Institute of Brooklyn
Electromagnetics, electro-optics

Wen-Chung Wang, Professor of Electrical Engineering and Electrophysics
B.S., Taiwan Engineering College (Taiwan); M.S., Ph.D., Northwestern University
Microwave acoustics

Dante C. Youla, Professor of Electrical Engineering
B.E.E., CCNY; M.S., New York University
Networks, control systems

Frank A. Cassara, Associate Professor of Electrical Engineering
B.S., Rutgers—The State University; M.S., Ph.D., Polytechnic Institute of Brooklyn
Electronic circuits, communication systems

Douglas A. Davids, Associate Professor of Electrophysics
B.S., M.S., Newark College of Engineering; Ph.D., The Johns Hopkins University
Microwave acoustics, quantum electronics

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

Richard A. Haddad, Associate Professor of Electrical Engineering and Associate Dean of Westchester Center
B.E.E., M.E.E., Ph.D., Polytechnic Institute of Brooklyn
Digital filters, power systems

Ronald J. Juels, Visiting Associate Professor of Computer Science
B.E.E., M.S.E.E., Polytechnic Institute of Brooklyn; D.Sc.E.E., Stevens Institute of Technology
Computer architecture, microprocessor systems

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

Maurice C. Newstein, Associate Professor of Electrophysics
A.B., Temple University; Ph.D., Massachusetts Institute of Technology
Quantum electronics

Song-Tsuen Peng, Research Associate Professor of Electrophysics
B.S., Cheng-Kung University (Taiwan); M.S., Chiao-Tung University (Taiwan); Ph.D., Polytechnic Institute of Brooklyn
Electromagnetic theory

Saul W. Rosenthal, Associate Professor of Electrophysics
B.E.E., M.E.E., Polytechnic Institute of Brooklyn
Microwave techniques, bioengineering

Henry Ruston, Associate Professor of Electrical Engineering and Computer Science
B.S.E. (Math), B.S.E. (E.E.), Ph.D., University of Michigan; M.S., Columbia University
Software engineering, programming, circuit theory

Leo M. Silber, Associate Professor of Electrophysics
B.S., University of Massachusetts; M.S., Ph.D., Purdue University
Magnetic materials, plasmas

William T. Walter, Research Associate Professor of Electrophysics
A.B., Middlebury College; Ph.D., Massachusetts Institute of Technology
Quantum electronics, atomic physics, wave-matter interaction

Gerald Weiss, Associate Professor of Electrical Engineering
B.E.E., Cooper Union; S.M., Harvard University; D.E.E., Polytechnic Institute of Brooklyn
Feedback theory, control instrumentation

Zivan Zabar, Professor of Electrical Engineering
B.Sc., M.Sc., Sc.D., Technion (Israel)
Semiconductor applications, computer simulation of switching circuits, electrical drives

Leo Birenbaum, Research Assistant Professor of Electrical Engineering and Electrophysics
B.E.E., Cooper Union; M.E.E., M.S., Polytechnic Institute of Brooklyn
Bioeffects of microwaves, microwave measurements, electrical machinery

Christodoulos Chamzas, Assistant Professor of Electrical Engineering
Diploma in EE-ME, National Technical University of Athens; M.S., Ph.D., Polytechnic Institute of New York
Digital signal processing

A. David Klappholz, Assistant Professor of Computer Science
B.S. Massachusetts Institute of Technology; M.S.E., Ph.D., University of Pennsylvania
Parallel processing, computer architecture

Szu-Ping Kuo, Research Assistant Professor of Electrophysics
B.S., M.S., National Chiao-Tung University, (Taiwan); Ph.D., Polytechnic Institute of New York
Magnetohydrodynamics

Jamshed H. Mirza, Assistant Professor of Computer Science
B. Techn., Indian Institute of Technology (Kharagpur, India); M.S., Ph.D., Polytechnic Institute of New York
Computer architecture, pipeline processing

Norman Rubin, Assistant Professor of Computer Science
B.S., CCNY; M.A., Ph.D., New York University
Artificial intelligence, programming languages, compilers

ADJUNCT FACULTY

Hal Bloomberg, Adjunct Professor
B.S., Brooklyn College

Bernard Friedland, Adjunct Professor
A.B., B.S., M.S., Ph.D., Columbia University

Richard Gran, Adjunct Professor
B.E.E., M.E.E., Ph.D., Polytechnic Institute of Brooklyn

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

George Karady, Adjunct Professor
Dipl. Eng., Ph.D., Technical University of Budapest (Hungary)

Myron M. Rosenthal, Industry Professor
B.S., CCNY; M.S., Adelphi University

Joel B. Snyder, Industry Professor
B.E.E., M.E.E., Polytechnic Institute of Brooklyn

William D. Wade, Adjunct Professor
B.S., University of Missouri; M.S., Ph.D., Purdue University

Ralph Gittleman, Adjunct Associate Professor
B.S., Massachusetts Institute of Technology; M.E.E., Polytechnic Institute of Brooklyn

Kenneth S. Schneider, Adjunct Associate Professor
B.S., M.Eng., Ph.D., Cornell University

Frederick W. Scholl, Adjunct Associate Professor
B.E.E., Ph.D., Cornell University

Mustapha Acar, Lecturer
B.E.E., Middle East Technical University (Ankara, Turkey); M.S., Polytechnic Institute of Brooklyn; Ph.D., Polytechnic Institute of New York

Satish K. Gambhir, Lecturer
B.S.E.E., Birla Institute of Technology, India; M.S.E.E., Oklahoma State University; M.S.E.E., Stanford University; Ph.D., Polytechnic Institute of New York

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

Erh-Wen Hu, Lecturer
B.S., Cheng Kung University (Taiwan); M.S., University of Cincinnati; M.S., SUNY (Stony Brook); Ph.D., Polytechnic Institute of New York

Lee Jacknow, Lecturer
B.A., B.E., M.S., New York University

Alfred Jorysz, Lecturer
M.Sc., Institute of Technology (Vienna, Austria)

William W. Kestenbaum, Lecturer
B.M.E., CCNY; M.E.E., New York University

Daniel A. Mark, Lecturer
B.Eng., Bucharest Polytechnic Institute, Rumania; M.Eng., Power Institute, Ivanovo USSR; D.Eng., Bucharest Polytechnic Institute, Rumania

Bernard Masur, Lecturer
B.A., B.E.E., CCNY; M.S., Polytechnic Institute of Brooklyn; Engineer, Columbia University

Philip M. Paterno, Lecturer
B.E.E., M.E.E., Polytechnic Institute of Brooklyn

O. James Pfeifer, Lecturer
B.S., Polytechnic Institute of Brooklyn; M.S., SUNY (Stony Brook)

Sheldon J. Rosenberg, Lecturer
B.E.E., M.S., New York University

Sidney N. Smilowitz, Lecturer
B.E.E., M.E.E., CCNY

Rainer Weschke, Lecturer
B.S., M.S., Polytechnic Institute of Brooklyn

EMERITUS FACULTY

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

William A. Lynch, Professor Emeritus
M.E., M.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)

ELECTROPHYSICS

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 Farmingdale 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 in 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 Farmingdale and Brooklyn. At Farmingdale, experimental facilities include a 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 and 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.

Course Requirements

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		6-12 units
3. Approved electives		21-15 units
		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.

For graduation, a minimum average of B must be obtained in the required courses (the three selected from the above list, plus those in the two one-year sequences). In addition, an overall average of B or better is required for all 36 units offered toward the degree.

The *Electrical Engineering 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 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 electrophysics should provide adequate course preparation for the examinations.

Specific requirements for this degree parallel those for the Ph.D. in EE as described elsewhere in this catalog and in the *Electrical Engineering Graduate Student Manual*. These include course requirements, guidance committee formation, area examination, foreign language requirement, 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 doctoral adviser.

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 candidacy.

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 recognized journal. Candidate must successfully defend dissertation orally. Registration of 24 units required (continuous dissertation registration required). Prerequisite: degree candidacy and 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

KunMo Chung, Research Professor of Nuclear and Electrical Engineering

Leopold B. Felsen, Institute Professor

Stanley H. Gross, Professor of Electrophysics

Alexander Hessel, Professor of Electrophysics

James T. La Tourrette, Professor of Electrophysics

Enrico Levi, Professor of Electrophysics

Nathan Marcuvitz, Institute Professor

Eli Absalom Mishkin, Professor of Applied Physics

Arthur A. Oliner, Professor of Electrophysics

István Palócz, 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

Herman Farber, Associate Professor of Electrophysics

Maurice C. Newstein, Associate Professor of Electrophysics

Song-Tsuen Peng, Research Associate Professor of Electrophysics

Saul W. Rosenthal, Associate Professor of Electrophysics

Leo M. Silber, Associate Professor of Electrophysics

William T. Walter, Research Associate Professor of Electrophysics

Leo Birenbaum, Research Assistant Professor of Electrical Engineering and Electrophysics

Szu-Ping Kuo, Research Assistant Professor of Electrical Engineering and 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 human and physical resources at Polytechnic to provide cohesive curricular, research and service activities in technological, economic, managerial, social, political and humanistic areas. Thus Polytechnic resources are applied to the solution of global, regional and local energy problems through education, research and public service.

GRADUATE PROGRAMS IN ENERGY ENGINEERING AND POLICY

Interdisciplinary programs in energy policy and engineering lead to the master's degree in the 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 two courses are cross-listed in all participating departments and are accepted as departmental courses. Students may enter the energy program in one of 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 a participating department.

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. Student must satisfy minimum requirements of master of science program in the department.

b. Student 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. Student must complete an additional four courses from among 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 four different categories. The energy elective categories are the broad functional classifications listed under electives.

2. Certificate in Energy Policy and Engineering
On 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.

TYPICAL PROGRAMS

Chemical Engineering

No.	Required Subjects	Units
CH 631-632	Transport Phenomena I, II	6
CH 771-772	Chemical Engineering Thermodynamics I,* II	6
CH 781	Chemical Process Kinetics	3
CH 821	Process Dynamics & Control*	3
CH 902	Guided Studies	6
ES 927	Energy Policy Issues	3
ES 928	Energy Resources and Conversion Technology	3
Energy Electives		6
		36

Civil Engineering

12-18 units of 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 approved by departmental graduate adviser		6-0
		36

Economic Systems

OR 665	Microeconomic Models*	3
OR 666	Macroeconomic Models*	3
OR 674	Economic Models & Methods	3
ES 927	Energy Policy Issues	3
ES 928	Energy Resources and Conversion Technology	3
Major Electives		12
Electives		9
		36

Electrical Engineering

EL 531	Probability	3
EL 610	Linear Systems	3
	or	
EL 611	Signals, Systems and Transformers	

*Also energy elective

No.	Required Subjects	Units
EL 661	Studies in Power Systems*	3
EL 663	Electrical Transients in Power Systems*	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 Economic Analysis	9
EL 621	Feedback Control	
EL 647	Power Electronics	
EL 961-2	Selected Topics in Power I, II and/or electives approved by departmental graduate adviser	
		36

Energy Management

Required:		
ES 927	Energy Policy Issues	3
ES 928	Energy Resources and Conversion Technology	3
Electives: Select two		
MG 631	Theories of Complex Organizations*	6
MG 640	Resource Economics*	
MG 664	Legal Environment of Business*	
MG 865	Research, Development and Management of Innovation*	
MG 866	Technology Management and Policy*	
Additional electives approved by management division graduate adviser		24
		36

Industrial Engineering

IE 611	Statistical Quality Control*	3
IE 619	Production Planning and Control	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		9
		36

Management

MG 600	Management Process	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 Analysis	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 energy electives or electives approved by departmental graduate adviser		3
		42

Aerospace Engineering or Mechanical Engineering

Aeronautics and astronautics, and mechanical engineering (thermal/fluids/energy option)

AM 701	Thermodynamics I*	3
AM 710	Convection	3
AM 740	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		9
		36

Mechanical Engineering

(Mechanical analysis and design)		
AM 601-02	Stress Analysis I, II	6
AM 651	Advanced Dynamics I, II	6
	or	
AM 653-54	Dynamics of Machines; Mech. 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		12
		36

Metallurgy

MT 610	Metallurgical Thermodynamics	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		9
		36

Nuclear Engineering

NU 601	Intro. Nuclear Engineering I*	3
NU 602	Intro. Nuclear Engineering II*	3
NU 603	Nuclear Engineering Lab. I*	3

*Also energy elective.

NU 604	Nuclear Engineering Lab. II*	3
NU 606	Radiation Protection	3
NU 607	Reactor Licensing, Safety and Environment	3
ES 927	Energy Policy Issues	3
ES 928	Energy Resources and Conversion Technology	3
Energy electives and departmental electives		12
		36

Operations Research

IE 600	Engineering Economic Analysis*	3
OR 631	Linear Programming*	3
OR 650	Queuing Systems I	3
Major electives		12
ES 927	Energy Policy Issues	3
ES 928	Energy Resources and Conversion Technology	3
Electives		9
		36

Transportation Planning and Engineering

TR 600	Transportation Studies and Characteristics	3
TR 601	Travel Demand Forecasting*	3
TR 630	Urban and Regional Planning Principles	3
TR 629	Transportation Workshop	3
TR 701	Traffic Operations, Control and Management*	3
TR 750	Transportation Economics	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		9
		36

Transportation Management

MG 600	Management Process	3
MG 601	Organizational Behavior	3
MG 604	Managerial Accounting	3
TR 601	Travel Demand Forecasting*	3
TR 750	Transportation Economics	3
TR 751	Transportation Finance*	3
TR 660	Urban Public Transportation	3
TR 757	Transportation Management	3
TR 830	Energy in the Transportation Sector*	3
ES 927	Energy Policy Issues	3
ES 928	Energy Resources and Conversion Technology	3
TM 997	Thesis in Transportation Management	3
Transportation Management electives		9
		45

*Also energy elective.

Acceptable Energy Electives

Energy Conversion

AM 761	Energy Conversion	3
AM 769	Special Topics in Energy Conversion	3
AM 763	Solar Thermal Engineering I	3
AM 764	Solar Thermal Engineering II	3
CH 760	Energy Resources, Conversion Technology, Distribution and Utilization	3
CH 791	Electrochemical Engineering	3

Energy Transfer Processes

AM 711	Convective Heat Transfer	3
AM 712	Conduction Heat Transfer	3
AM 713	Radiative Heat Transfer	3
AM 715/NU 715	Heat Transfer	3
AM 716/NU 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 753/CH 753	Dispersion of Pollutants in the Atmosphere	3
CE 758/CE 752	Air Pollution Engineering Control	3
TR 630	Principles of Urban and Regional Planning	3
TR 631	Methods of Urban and Regional Analysis in Planning	3
TR 640	Environmental Aspects of Transportation Projects	3
CH 756/CE 756/ MO 608	Air Pollution Analysis	3
CE 757/MO 637	Air Pollution Effects	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 961	Electric Drives	3
AM 746	Fluid Dynamics of Rotating Machinery	3

Management and Economics of Energy Systems

NU 721	Economics of Nuclear Power and Radiation	3
MG 603	Economic Environment of Management	3
MG 631	Theories of Complex Organizations	3
MG 664	Legal Environment of Business	3
MG 800	Policy Planning and Analysis	3
MG 805	Research, Development and Management of Innovation	3
MG 866	Technology Management and Policy	3
IE 600	Engineering Economic Analysis	3
IE/OR 620/ MG 810	Project Planning and Control	3
IE/MG 757/ SS 675	Technology Transfer to Developing Countries	3
OR 665	Microeconomic Models	3
OR 666	Macroeconomic Models	3
MG 640	Resource Economics	3
MG/OR 671	Business and Economic Forecasting	3
MG 672/ SS 672	Technological Forecasting	3
CH 611	Unit Processes of Chemical Technology	3
CE 759	Engineering Aspects of Regional and Master Planning	3
AM 765	Energy Conversion and Environmental Control	3

Materials

NU 726/ MT 726	Metallurgy of Nuclear Reactor Materials	3
PH 651	Introduction to Solid-State Physics I	3
PH 652	Introduction to Solid-State Physics II	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

Nuclear Energy

NU 601	Intro. Nuclear Engineering I	3
NU 602	Intro. Nuclear Engineering II	3
NU 603	Nuclear Engineering Lab. I	3
NU 604	Nuclear Engineering Lab. II	3
NU 619/ EL 667	Introduction to Thermonuclear Power	3
NU 721	Economics of Nuclear Power	3

Plasma and Controlled Fusion

EL 581	Introduction to Plasma Physics	3
EL 681	Applied Plasma Physics	3
NU 619/ 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 724	Water Resource Planning	3
CE 890	Earthquake Engineering I	3
CE 891	Earthquake Engineering II	3
AM 605	Limit Analysis of Structures	3
AM 630	Design Methods for Power Plant Structures	3
AM 632/ CE 632	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/ OR 685	System Reliability	3
EL 618/IE/ OR 686	Component Reliability	3
EL 621	Feedback Control I	3
EL 622	Feedback Control II	3
EL 647	Power Electronics	3
EL 661	Studies in Power System	3
EL 663	Electrical Transients in Power Systems	3
EL 665	Power System Stability Analysis I	3
EL 666	Power System Stability Analysis II	3
EL 962	Relay Fault Protection	3
NU 607	Reactor Licensing, Safety and Environment	3
NU 712	Radiation Shielding	3
IE 611	Statistical Quality Control	3
IE 612	Advanced Quality Control	3
IE/OR 700	System Effectiveness	3
IE 765	Human Factors in Engineering Design	3
IE 775	Industrial Safety Engineering	3

System Optimization

IE/OR 614	Modeling of Social Systems I	3
IE/OR 615	Modeling of Social Systems II	3
IE/OR 621	Facility Layout and Locations	3
IE/OR 680	System Simulation I	3
IE/OR 681	System Simulation II	3
IE/OR 846	Urban Systems Analysis	3
OR 627	Operations Research Deterministic Models	3
OR 628	Operations Research Stochastic Models	3
OR 631	Linear Programming	3
OR 632	Nonlinear Programming	3
OR 634	Dynamic Programming	3

Thermodynamics, Combustion and Chemical Processes

AM 701	Thermodynamics I	3
AM 703	Combustion	3
AM 704	Aerothermochemistry	3

CH 742	Design of Solid Waste Processing Systems	3
CH 771	Chemical Engineering Thermodynamics I	3
CE 770	Solid Waste Management	3

Transportation

TR 660	Urban Public Transportation	3
TR 661	Intercity Passenger and Freight Transportation	3
TR 830	Energy in the Transportation Sector	3

REQUIRED COURSES

Registration for these courses 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 broad policy problems connected with energy shortages. Development of new energy sources, methods of energy conservation and long-term energy plans. Priorities for energy policy options and associated energy research and development projects. Aims: to review essence of issues in order to comprehend total energy policy framework and analytical tools to evaluate changing world, domestic conditions and impact of alternative policy actions.

ES 928 Energy Resources and Conversion Technology **2½:0:3**
Summary of present energy resources and global energy requirements. Twentieth-century advances in science and technology now being applied or soon to be applied to United States energy economy. 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 and Computer Science
Chairperson, Energy Program Steering Committee
Policy analysis, plasma research

Irving Cadoff, Professor of Physical and Engineering Metallurgy
Thin film epitaxy, photo voltaics

John R. Lamarsh, Professor and Head of Nuclear Engineering
Nuclear engineering

Joachim I. Weindling, Professor and Director of Operations Research Program
Management Division
Mathematical programming, optimum design, economic evaluation

Anthony J. Wiener, Professor and Director of Policy Studies
Management Division
Long-range planning, public policy studies, political, economic, and social environment of business, technology management and assessment

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

Leonard I. Stiel, Associate Professor of Chemical Engineering
Thermodynamics and energy conversion systems

Romualdas Sviedrys, Associate Professor of Social Sciences
Technology forecasting and technology assessment

Richard S. Thorsen, Associate Professor and Head of Mechanical and Aerospace Engineering
Solar energy, nuclear reactor safety

William H. Crowell, Assistant Professor of Transportation Planning and Engineering
Public finance, economic analysis, management

FACULTY PARTICIPANTS

Martin H. Bloom, Institute Professor Mechanical and Aerospace Engineering
Combustion and energy systems

Joel D. DuBow, Professor and Head of Electrical Engineering and Computer Science
Synthetic fuel, photovoltaics, hybrid energy systems

Alvin S. Goodman, Professor of Civil and Environmental Engineering
Hydroelectric power, water supply, and facilities for thermal plants, environmental effects of energy systems

Enrico Levi, Professor of Electrical Engineering and Computer Science
Electrical engineering, computer science, energy conversion

Wheeler K. Mueller, Jr., Professor of Mechanical & Aerospace Engineering
Heat transfer, thermodynamics, and energy conversion

Pasquale M. Sforza, Professor of Mechanical and Aerospace Engineering
Wind Power

Richard A. Haddad, Associate Professor of Electrical Engineering & Computer Science
Controls, power system stability

Alan H. Molof, Associate Professor of Civil and Environmental Engineering
Environmental engineering, water pollution, and water supply

Zivan Zabar, Associate Professor of Electrical Engineering & Computer Science
Power electronics, electric drives

Richard E. Wener, Research Assistant Professor of Social Sciences
Environmental psychology

HUMANITIES AND COMMUNICATIONS

The Department of Humanities and Communications offers an undergraduate degree program with a concentration in journalism and technical writing and another with a concentration in humanistic studies. The department also offers a unique program in specialized journalism leading to an M.S. degree.

In addition, the department plays an essential role in the education of students who are majors in other departments. Today's engineers and scientists must have a solid education in the humanities to prepare them for the complex tasks they face. These tasks call for the ability to make well-reasoned decisions involving human values implicit in technological options, an understanding of the many ways in which human beings have seen and understood both themselves and the natural and social world, and the ability to communicate effectively in a variety of formats.

Thus, no engineer or scientist is as well prepared as he or she needs to be without training in the art of argument through a study of logic and philosophy; exposure to great literature, art and music; and the development of communication skills both written and oral.

UNDERGRADUATE PROGRAM

The non-major—The department is responsible for the general humanistic education of all Polytechnic students. In the freshman year, all students admitted to the Polytechnic will be placed at the appropriate level in the introductory English sequence. On the basis of SAT verbal scores and an English Composition Placement Test administered by the Department of Humanities and Communications, most students will be placed in one of the standard freshman courses (HU 101 or HU 103); some may be exempted from either of these courses and be placed in HU 200, the second required course in the sequence; others may first be required to take a pre-college, 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 (the IS 140-141 sequence may be substituted for HU 200 and SS 104, the required social sciences course), the non-major is encouraged to complete a sequence of courses in one of the disciplines within the department—literature, art and music, philosophy, religion, modern languages or communications—or to put together a combination of courses that will provide a coherent introduction to the humanities or that will comprise a program in interdisciplinary studies crossing departmental lines. Courses in technical writing and public speaking are especially practical for students preparing for a professional career in engineering and science. Advisers in the Department of Humanities and Communications will be happy to help any student work out such a program. (See "Degree Requirements" for more details.)

The major—The Department of Humanities and Communications offers a bachelor of science degree in the humanities with two concentrations: one in journalism and technical writing and one in humanistic studies. Both are flexible programs with a core program of 73-78 hours, allowing considerable choice of courses in the humanities, modern languages (optional for the concentration in communications), social sciences, mathematics, science and technology; 33 hours of studies in the major concentration; and 15-19 hours of free electives in which majors can pursue an associated interest in scientific and technological subjects, in the social sciences or in a variety of humanities or interdisciplinary studies.

Concentration in Journalism and Technical Writing

Our graduates have gone into successful careers in journalism, science writing and technical writing. Science and technical writers in particular—writers with the skills of the journalist combined with a strong interest in science and technology—will continue to be in great demand throughout the 1980's. In these fields, professional status and salary are on a par with those of engineers and scientists.

In the concentration in journalism and technical writing, the major will work out a program of studies in consultation with a departmental adviser, using the "Typical Course of Study," below, as a guide. Note that the required courses are listed in sequential order in the "Typical Course of Study." The required distribution of courses is as follows:

Core Program	Credits
Humanities	24
Modern Languages (or HU electives)	12
Social Sciences	18
Mathematics, Science and Technology	19-24
	73-78
Concentrated studies in major	33
Free electives	15-19
Total credits required for graduation	126

Concentration in Humanistic Studies

In the humanistic studies concentration, the major will work out a program of studies in consultation with a departmental adviser. Here, depending on the student's vocational goals, the concentrated studies may be in such fields as English, American and comparative literatures, modern languages, philosophy and religion or general humanistic studies. 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 courses as free electives in meeting degree requirements. The humanities major will find the department most helpful in providing individualized study and academic and career guidance.

Each program of studies will be designed by the student in close consultation with the faculty adviser and with the approval of the head of the department. All majors must satisfy the following requirements, however:

Core Program		Credits
HU 101	College Composition	3
HU 200	Introduction to Literature	3
HU 348	Great Philosophers	3
HU 371 or HU 382	Understanding of Music or Fine Arts I	3
HU electives		12
Modern Languages		12
SS 101	Main Themes in Western Civilization	3
SS 104	Main Themes in Contemporary History	3
SS electives		12
MA 091-092	Principles of Math. I, II†	8
Science electives		11-16
		73-78
Concentrated studies in major		33
Free electives		15-19
Total credits required for graduation		126

Note: See appropriate footnotes on following page.

The dual major—A number of students elect to pursue a dual major leading to two undergraduate degrees—one in humanities with a concentration in journalism and technical writing and another in engineering or science. In addition to completing all requirements for the degree in engineering or science, the student must complete 33 credits of communications courses in the Department of Humanities and Communications. These courses must be approved by a departmental adviser.

Interdisciplinary Studies—The Department of Humanities and Communications has initiated a series of courses in interdisciplinary studies, taught jointly with the Department of Social Sciences. For details of this program, see interdisciplinary studies, page 147.

GRADUATE STUDY

Specialized Journalism

To be eligible for admission as a graduate student specializing in science, technical and financial writing and journalism, an applicant 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—so long as they meet all other requirements for admission—but will be required to take undergraduate courses to fulfill the basic requirements for admission. No graduate credit will be 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 a lower grade point average will be considered if they have demonstrated success in some area of professional writing. Others with a lower grade point average may be admitted as provisional candidates. Applicants are not required to take the Graduate Record Examination.

Typical Course of Study for the Bachelor of Science Degree in the Humanities with a Concentretion in Journalism and Technical Writing

Freshman Year

First Semester		Hours/Week		
No.	Subject	Cl.	Lab.	Cr.
HU 101	College Composition	3		3
	Communications elective	3		3
	ML (or HU) elective	3		3
SS 101*	Main Themes in Western Civilization	3		3
MA 091†	Principles of Math. I	4		4
PE 101	Physical Education I		2	0
				16

Second Semester		Hours/Week		
No.	Subject	Cl.	Lab.	Cr.
HU 200*	Introduction to Literature	3		3
	Communications elective	3		3
	ML (or HU) elective	3		3
SS 104*	Main Themes in Contemporary History	3		3
MA 092†	Principles of Math II	4		4
PE 102	Physical Education II		2	0
				16

Sophomore Year

	Communications elective	3		3
	HU elective	3		3
	ML (or HU) elective	3		3
	Soc. Sci. elective	3		3
	Science elective†			2-4
PE 103	Physical Education III		2	0
				14-16

	Communications elective	3		3
	ML (or HU) elective	3		3
	Soc. Sci. elective	3		3
	Science elective†			3-4
	Free elective			3
PE 104	Physical Education IV		2	0
				15-16

Junior Year

	Communications elective	6		6
	HU electives	6		6
	Science elective†			3-4
	Free elective			0-3
				15-19

	Communications elective	3		3
	HU elective	3		3
	Soc. Sci. elective	3		3
	Science elective†			3-4
	Free elective			3
				15-16

Senior Year

	Communications elective	6		6
	HU elective	3		3
	Soc. Sci. elective	3		3
	Free electives			3-6
				15-18

HU 150	Special Projects in Communications	3		3
	Communications elective	3		3
	HU elective	3		3
	Free electives			6
				15

Total credits required for graduation: 126

---

*IS 140-141 may be taken in place of HU 200 and SS 104. See the Humanities and Social Sciences Requirements page 23. Humanities majors may substitute IS 140 or IS 141 for SS 101.

†The sequence MA 101-102 (Calculus I, II) is an acceptable substitute for MA 091-092. For science electives, two of the following sequences are to be chosen, though others may be acceptable to the department:

		Credits
CM 091-092	Principles of Chemistry I, II	6
or		
CM 101/111-CM 102/112	General Chemistry I, II	6
LS 101-102	General Biology I, II	8
PH 091-092	Concepts of Contemporary Physics I, II	8
or		
PH 101-102	Introductory Physics I, II	7
CS 100	Intro. to Computer Programming	2
or		
CS 111	Intro. to Programming	3
and		
IE 200	Concepts of Mod. Technology	3
or		
IE 314	Mdlg. of Soc. Systs. I	3

FIELDS OF SPECIALIZATION

Financial Reporting

Financial and business reporting calls for the professional journalist to write business and financial news developments and trends for both the knowledgeable businessman and market analyst as well as for the general public. The writer 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 understandably. Clear, crisp, concise writing is a must.

Trade-Magazine Journalism

Trade-magazine journalism entails writing and editing news and feature articles for both technical and marketing-oriented publications serving a particular industry. Such publications may be owned by independent publishing companies, professional societies or large corporations.

Medical and Science Reporting

Medical and science reporting offers opportunities in several fields: on professional 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 major hospitals, medical schools and research centers; in the writing departments of major corporations; and in textbook editing. In addition to having the ability to write clearly and succinctly, the professional medical and science writer and editor should have a sound background in the sciences.

Industrial Advertising and Public Relations

Industrial advertising and public relations are concerned with the promotion of a corporation's products and capability to sell such products to industrial clients rather than to the general public. Industrial advertising involves copy-writing, choosing graphics, selecting media, organizing ad campaigns and performing market research. Those entering this profession work as copywriters, account executives, advertising managers and media directors.

Industrial public relations has the same overall goal 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 client's industry, hold press conferences to announce new products and/or technology developed by the client company, prepare feature articles on the company's products for publication in trade magazines and technical journals, write speeches for top engineering and management personnel and prepare corporate literature (product brochures, annual reports, house organs and other technical and semi-technical material) for dissemination to corporate customers.

Technical Writing

Technical writers—also referred to as publications engineers and engineering writers—gather, organize, write and edit material of a technical and scientific nature for management and technical personnel within their own company 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. In addition, the technical writer may be called upon to write speeches and trade-magazine articles for the company's scientists and engineers.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE

The M.S. degree requires 36 units of graduate work. Eighteen of these units are to be taken in required courses. 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 an adviser:

		Units
JW 600	Introduction to Specialized Journalism	3
JW 601	Style for the Professional Writer	3
JW 602	Proposal Writing	3
JW 603	Reporting on Science, Technology & Medicine	3
JW 604	Graphics and Production Techniques	3
JW 606	Oral Technical Presentations	3

The remaining 18 units are to be taken in elective courses. Normally, students select electives from among the remaining graduate courses offered in the department. But students who wish to enhance their scientific and technical knowledge may take a maximum of nine credits of graduate courses in other departments of the Institute. Approval for this option must be given by the head of the department.

Elective courses are usually conducted as workshops, providing students with the types of writing and editing assignments they would receive were they 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 listed below.

		Units
Financial Reporting		
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 701	Special Projects in Professional Writing	3
Trade-Magazine Journalism		
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 701	Special Project in Professional Writing	3
Medical and Science Reporting		
JW 603	Reporting on Science, Technology and Medicine	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 701	Special Project in Professional Writing	3
Industrial Advertising and Public Relations		
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 701	Special Project in Professional Writing	3
Technical Writing		
JW 603	Reporting on Science, Technology and Medicine	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 701	Special Project in Professional Writing	3

CERTIFICATE PROGRAM IN A FIELD OF SPECIALIZATION

A certificate in Specialized Journalism is available to students completing five courses with a grade of B or higher. The courses must be taken in a prescribed sequence worked out with an adviser. Students enrolled in the certificate program must meet the same rigorous standards of performance required of those working for an M.S. degree. At any time during enrollment, or following the awarding of the certificate, students in this program may transfer into the master's degree program providing that their performance has been satisfactory and that they meet the standards for admission set by the department. Transfer into the master's program, however, may not mean automatic acceptance of every course students have taken while working toward the certificate. Acceptance of credits will depend on the area of specialization in which students plan to work for the degree.

ENGLISH AND HUMANISTIC STUDIES AND MODERN LANGUAGES

Advanced courses and seminars in the humanities will 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 a minor in the humanities to fulfill part of their requirements for an advanced degree; advisers in the Department of Humanities will be happy to recommend appropriate courses for such a minor.

UNDERGRADUATE COURSES

INTRODUCTORY 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. Concentration on development of grammatical control in writing and on 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 College Composition 3:0:3
Techniques of effective communication in English. Essay writing, editing, proofreading. Emphasis on fluency, flexibility, precision and imagination in writing and thinking. Introduction to use of source material in writing. Admission by placement examination.

HU 103 College Composition in English as a Second Language 6:0:3
Advanced English as a second language. Freshman composition skills for non-native speakers of English. Techniques of effective communication in English. Essay writing, editing, proofreading. Emphasis on fluency, grammaticality and precision in writing. Introduction to use of source material in writing. Admission by placement examination.

HU 200 Introduction to Literature 3:0:3
Study of works of poetry, fiction and drama that illustrate prevailing themes and conflicts of Western literature. Course also provides advanced work in more structured forms of writing: critical analysis, formal report, research paper. Some sections may be devoted to special themes. Prerequisite: HU 101 or HU 103 or advanced placement.

Please Note: HU 200 or its equivalent is a prerequisite for all undergraduate HU courses listed below except for HU 105 (Prerequisite: HU 101 or HU 103), HU 107 and HU 121 (no prerequisite), and a few courses with more advanced prerequisites as listed.

COMMUNICATIONS

HU 105 Advanced Composition 3:0:3
Intensive training in lucid expository writing. Emphasis on gathering and organization of factual material into larger units of composition. Methods of research and use of library. Topics based on models of expository prose. Long paper.

HU 106 Writing for Publication: The Magazine Article 3:0:3
Emphasis on developing the student's interviewing and writing skills to produce a medium-to-long length magazine article. With instructor's help, students develop a story idea on a technical or non-technical subject, carry out the necessary library research and personal interviews and write the piece for a specific publication. 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 107 Workshop in Journalism 2:3:3
Intensive training in writing for and producing publications under pressure of deadlines. Researching, organizing, writing and laying out news and feature articles (technical as well as non-technical) for newspapers and magazines. Also work on graphics. Laboratory work in coping with everyday editorial problems involves helping to write, edit and produce student publications of the Institute.

HU 108 News Writing 3:0:3
Application of good writing to journalistic practice. Workshop to guide student in all basic news writing techniques. Writing of leads. Style and structure of body 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 article 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
Application of fundamentals of report writing 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. Emphasis on writing summaries, process ad technical descriptions, instructions, analyses. Attention is given to 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
Intensive practice in writing the longer technical forms commonly used in industry. Emphasis is given to writing 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
Course designed to improve the student's 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. Emphasis on writing leads and in reorganizing garbled copy. Newspaper and magazine page layout and makeup. Prerequisite: HU 105.

HU 113 Writing for Advertising and Public Relations 3:0:3
The principles of writing effective advertising copy and publicity releases with an 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. Course covers the preparation and implementation of a typical advertising campaign and the arrangement of a press conference. Attention is given to layout of ad copy and to accompanying color, design, typographic and illustrative features. Prerequisite: HU 105.

HU 114 Libel Law and Ethical Issues in Journalism 3:0:3
Introduction to what libel is and how the writer can avoid its many pitfalls. Course covers both the complete and partial defenses raised during libel suits and the possible damages awarded, the principle of "fair comment and criticism," criminal and civil libel, and one's right to privacy vs. the public's "need to know." The course also takes up many of the ethical issues facing journalists and other writers today, issues such as writing about new products and technology believed to be defective or hazardous, pornography and the courts, writing in good taste, shield laws, gag orders and copyright.

HU 115 Reporting and Writing about Science and Technology 3:0:3
Students will learn how to interview scientists and engineers and how to present the information obtained in a format understandable to the layman. They will write both news and feature stories, and will be encouraged to publish their better pieces.

HU 121 Public Speaking 3:0:3
Training and practice in speaking before a group, preparation of material for oral presentation, extemporaneous speaking, individual criticism by instructor and fellow students.

HU 130 Creative Writing I 3:0:3
An introduction to the art and craft of writing poetry, fiction and drama. Students encouraged to experiment with all genres and discover where their talents lie. Emphasis throughout on students' own work. Weekly written assignments discussed and criticized in class.

HU 131 Creative Writing II 3:0:3
An advanced course in the art and craft of writing poetry, fiction and drama. Application of individual writing 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 150-151 Special Projects in Communications each 3:0:3
Independent work in an area of interest in the field of communications selected by the student in consultation with instructor. For majors only.

HU 155 Special Topics in Journalism 3:0:3
Courses on special topics in journalism will be offered from time to time by the staff of the department or by visiting scholars. The specific titles and prerequisites will be announced prior to registration. May be repeated for credit.

HU 160 Writing the News for TV and Radio 3:0:3
Intensive practice in the special format required for writing news for TV and radio. Students will rewrite newspaper articles and wire copy in the style necessary for these formats. They will also practice broadcasting the news and writing newscasts under pressure. Prerequisites: HU 108 or permission of instructor.

LITERATURE

(See also Literature in Translation: ML 311-313, ML 318-319, and interdisciplinary studies program.)

HU 201 Literature of Western Civilization I 3:0:3
Sources of modern ideals and values in ancient world: Greek drama, Plato, Lucretius, Bible, etc.

HU 202 Literature of Western Civilization II* 3:0:3
Sources of modern ideals and values from Middle Ages to 18th century: miracle plays, Shakespeare, Milton, Voltaire, etc.

HU 203 Literature of Western Civilization III* 3:0:3
Intellectual and cultural, moral and spiritual values of modern and postmodern world, examined in novels, drama, philosophy, poetry. Readings in literature of Romantic revolt, Goethe, Dostoevski, Brecht, Sartre, Solzhenitsyn, American and European verse.

HU 211 English Literature from Beowulf to 1800* 3:0:3
Great tradition of English literature from Beowulf through Chaucer, Elizabethans and Jacobeans to 1800.

HU 212 English Literature from 1800 to Present 3:0:3
Great tradition of 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 literature 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, Isaac Asimov.

HU 222 Shakespeare 3:0:3
Representative tragedies, comedies, histories. Cultural, social and literary influences. Textural 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. Background and thought of Jonathan Edwards, Paine, Irving, Poe, Hawthorne, Emerson, Thoreau, Whitmen, Twain, James and other representative writers.

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 analysis of such writers as Golding, Salinger, Updike, Roth, Vonnegut, Clarke, Bellow and others.

HU 264 The Short Story 3:0:3
Theme, structure, technique 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 analysis of such poets as Rexroth, Roethke, Patchen, Stafford, Berryman, Lowell, Levertov, Bly, Creeley, Ginsberg, Kinnell, Merwin, Wright, Levin, Plath, Snyder.

HU 281 Comedy 3:0:3
Nature and uses of humor as viewed by playwright, psychologist, philosopher. 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
Modern American drama, with emphasis on affirmative or negative statements regarding man's fate in the universe. Technical and philosophical analysis of works by O'Neill, Miller, Anderson, Hellman, Williams, Inge, Albee, etc. Discussions of selected, contemporary American films.

HU 291 Short Fiction 3:0:3
A study of major writers of the *novella* (long short story) form. This course emphasizes the relationship between literature and ideas. Among the authors to be considered are Saul Bellow, Albert Camus, Joseph Conrad, Ernest Hemingway, Franz Kafka, Thomas Mann, Alexander Solzhenitsyn, Nathaniel West. Class discussions, cinematic presentations of some of the works and theatre visits are integral parts of the 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 classicism, romanticism, realism, existentialism. Aesthetic problems of literary genres. Explication and interpretation of texts.

HU 297 English Language* 3:0:3
History and development of English language. Readings in old, middle and early modern English. Emphasis on middle English, as exemplified by selections from Chaucer's *Canterbury Tales*.

PHILOSOPHY AND COMPARATIVE RELIGION

HU 341 Introduction to Philosophy 3:0:3
Critical inquiry into problems, methods and terminology of philosophy through comparative study and discussion of selected philosophical texts.

HU 344 Logic and Scientific Method 3:0:3
Basic principles and techniques of correct reasoning in sciences and daily life. Varieties of deductive and inductive inference, the use and misuse of language in reasoning. Emphasis on detection of common fallacies.

HU 348 Great Philosophers 3:0:3
Fundamental ideas of central figures in history and philosophy from Greece through 18th century. Particular emphasis on philosophies of Plato, Aristotle, Descartes, Hume, Kant.

HU 349 Recent Philosophy 3:0:3
Major philosophic ideas, thinkers, movements of 19th and 20th centuries. Emphasis on pragmatism, empiricism, existentialism, other currently influential schools of thought.

HU 352 Philosophy of Science 3:0:3
Examination of central problems in theory 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 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 freedom, power, equality, rights, etc., as they appear in thought of leading exponents of communism, capitalism, socialism, fascism, democracy.

HU 363 Comparative Religion I* 3:0:3
Religion of primitive peoples, Egyptians, Greeks, Romans, Germans. Four living religions: Judaism, Zoroastrianism, Christianity, Islam. Basic texts. Religious art and music.

HU 364 Comparative Religion II* 3:0:3
Religions of Far East: Hinduism, Jainism, Buddhism, Sikhism, Confucianism, Taoism, Shintoism. Basic texts including *Tao Te Ching, Analects, Bhagavad Gita.* Religious art and music. Contrasts between Western and Eastern modes of thought.

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. Parallel trends in other arts and thought. A look at the changes in the social role of music.

HU 375 Modern Music 3:0:3
Music from 1850 to present: Wagner, Strauss, Mahler, Debussy, Stravinsky, Ives, Schonberg, 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. A look at jazz, modern popular 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. Comparisons between Oriental and Occidental arts as modes of thinking and feeling.

SPECIAL TOPICS

The following special topics courses will be offered from time to time by the staff of the department or by visiting scholars. The specific titles and prerequisites will be announced prior to 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 who have had no previous training in German. Audiolingual emphasis on developing proficiency in reading, comprehension, speaking. Early practice in reading original German prose and representative poems.

ML 112 German II 3:0:3
Continuation of basic foundation provided by course ML 111. Reading of original German prose; selections from Hesse, Kastner, Zweig, others. Prerequisite: ML 111 or equivalent.

ML 113 German III: Readings in German Literature Since 1800 3:0:3
Selected reading and discussion of significant works in prose, lyric, poetry and drama to acquaint student 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 selected reading of significant German writing with critical and aesthetic evaluation. Also selected readings 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 devoted 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 designed for students who wish to acquire facility in translation of scientific material from German into English. Involves introduction to 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
Study of 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 field of science. Prerequisite: ML 215.

ML 217-218 German Thought from Kant to Present I, II* each 3:0:3
Traces course of significant intellectual currents in writings of

philosophers, scientists, poets, social critics. First semester discussion on period from Kant to Nietzsche, second semester on period 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, the social and economic structures. Prerequisite: ML 114 or equivalent.

FRENCH

ML 131 French I: Foundation Course 3:0:3
For students who have had no previous training in French. Audiolingual emphasis on developing proficiency in reading, comprehension, speaking. Early practice in reading original French prose and representative poems.

ML 132 French II 3:0:3
Continuation of basic foundation provided by ML 131. Reading of modern French prose and poetry of intrinsic literary value. Prerequisite: ML 131 or equivalent.

ML 133 French III: Readings in French Literature Since 1800 3:0:3
Selected reading and discussion of significant works in prose, lyric poetry, drama to acquaint student 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 mature prose in 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; composition 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 discussion 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
Examination of varied currents of 20th-century literature as exemplified in authors ranging 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 who have had no previous training in Russian. Audiolingual emphasis on developing proficiency in reading, comprehension, speaking. Early practice in reading original Russian prose and representative poems.

ML 152 Russian II* 3:0:3
Continuation of basic foundation provided by ML 151. Reading of Russian prose and poetry of intrinsic literary value. Prerequisite: ML 151 or equivalent.

ML 153 Russian III: Readings in 19th-Century Russian Literature* 3:0:3
Selected reading and discussion of significant works in prose, lyric poetry, drama to acquaint student 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 mature prose in 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
Readings in Soviet prose and poetry. Simultaneous study of USSR's geographic, political, cultural status, to serve as appropriate background material. All readings in Russian. Prerequisite: ML 154 or equivalent.

SPANISH

ML 161 Spanish I: Foundation Course 3:0:3
For students who have had no previous training in Spanish. Audiolingual emphasis on developing proficiency in reading, comprehension, speaking. Early practice in reading original Spanish prose and representative poems.

ML 162 Spanish II 3:0:3
Continuation of basic foundation provided by ML 161. Readings of modern Spanish prose and poetry of intrinsic literary value. Prerequisite: ML 161 or equivalent.

ML 163 Spanish III: Readings in Spanish Literature Since 1800 3:0:3
Selected reading and discussion of significant works in prose, lyric poetry, drama to acquaint student 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 mature prose in 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
Survey of intellectual and literary aspects of Hispano-American civilization touching on historical, sociological, political, economic background material. Readings in Spanish. Discussion of contemporary scene and practice in speaking Spanish. Prerequisite: ML 164 or equivalent.

LITERATURE IN TRANSLATION

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. Students read 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 work within their own varying social and cultural settings. Students 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 major French authors: Jean-Paul Sartre, Albert Camus, Samuel Beckett, Eugene Ionesco, Jean Genet. Course work includes one complete work of each writer. Students encouraged to pursue interests in individual authors.

ML 313 Currents of Unrest in 20th Century: Russian Literature (in English translation)* 3:0:3
Study of modern Russian literature in post-revolutionary political and social setting. Course work based on works by Sholokhov, Pasternak, Solzhenitsyn. Students 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

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 the 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
Study of 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.

GRADUATE COURSES

SCIENCE, TECHNICAL AND FINANCIAL WRITING AND JOURNALISM

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 reaearch 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, key personnel, etc. 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 require 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 writers' 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 preaentation). Students will participate in speechmaking situations and in panel discussions covering a wide variety of technical subjects.

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 that 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 text-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 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 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 conatruction and motivetion 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 by cultural output—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
Analysis of central concepts of social and political thought: freedom, law, justice, rights, democracy, property, etc., as illustrated 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 idiome characteristic of scientific German. Intended to prepare students for M.S. and Ph.D. language examinations. Prerequisite: one year of German or instructor'a permission.

ML 655† Russian for Research I* 2½:0:3
Introductory course designed for students who wish to acquire facility in translation of scientific material from Russian into English. Involves introduction to fundamentals of grammar, problems of syntax and idioms, with emphasis on scientific terminology. Does not aim at thorough formal knowledge of the language. May not be offered in fulfillment of language requirement.

ML 656† Russian for Research II* 2½:0:3
Continuation of ML 655. Reading material selected from periodical and technical journals covering the several fields of engineering and science. Prerequisite: ML 655 or equivalent.

FACULTY

Donald Hockney, Professor of Philosophy of Science and Head of Humanities
B.A., McMaster University; Ph.D., Cornell University
Philosophy of science, philosophy of language

Victor Bobetsky, Professor of Modern Languages
B.A., M.A., Columbia University
German language and literature

Bernard Rechtschaffen, Professor of Modern Languages
B.S., M.A., Ph.D., New York University
Comparative literature, science and literature

Duane DeVries, Associate Professor of English
B.A., Kalamazoo College; M.A., Ph.D., Michigan State University
Dickens, nineteenth-century English novel, expository writing

Harley S. Thompson, Associate Professor of English
B.A., College of Wooster; Ph.D., Yale University
English Renaissance, Milton, classical literature

Anne Eisenberg, Assistant Professor of Communications and Humanities
B.A., Barnard College; M.A., University of Iowa; Ph.D., New York University
Linguistics, technical writing, reading

Barbara Quint Gray, Assistant Professor of Communications and Humanities
B.A., The University of Michigan; A.M., Harvard University; Ph.D., New York University
Linguistics, expository writing

Peter Z. Grossman, Assistant Professor of Communications and Humanities
M.A., M.F.A., Columbia University
Business and financial journalism, creative writing, dramatic literature

Sylvia Kasey Marks, Assistant Professor of English
B.A., M.A., University of Michigan; Ph.D., Princeton University
Samuel Richardson, eighteenth-century English novel, public speaking

Lowell L. Scheiner, Assistant Professor of Communications and Humanities
B.A., CCNY; M.A., Columbia University; M.S., Columbia University (Graduate School of Journalism)
Technical writing, journalism

ADJUNCT FACULTY

Frank Allen, Adjunct Instructor of Communications
M.A., University of Oregon

Edward Bell, Adjunct Instructor of Communications
B.A., CCNY

Trudy Bell, Adjunct Instructor of Communications
B.A., University of California, Santa Cruz; M.A., New York University

Elisabeth B. Boise, Adjunct Instructor of Modern Languages
Staatsexamen, University of Frankfurt/Main; Ph.D., New York University

Rogers Brubaker, Adjunct Instructor of English
B.A., Harvard University; M.A., University of Sussex

Bradley W. Clompus, Adjunct Instructor of English
A.B., Grinnell College; M.F.A., University of Iowa

Frederick Courtney, Adjunct Instructor of Modern Languages
A.B., Columbia College; M.A., University of Michigan; Ph.D., Columbia University

Manning Dandridge, III, Adjunct Instructor of English
B.A., M.A., SUNY at Stony Brook

Edward Edelson, Adjunct Instructor of Communications
M.S., New York University

Annette Henderson, Adjunct Instructor of Communications
B.A., Brown University

William D. Horn, Adjunct Instructor of Communications
B.A., M.A., University of California, Santa Barbara; Ph.D., University of California, Los Angeles

Elly Jesser, Adjunct Instructor of English
B.A., Herbert H. Lehman College; M.A., New York University

Eric Katz, Adjunct Instructor of Philosophy
B.A., Yale University; M.A., Boston University

Jerome M. Leitner, Adjunct Professor of Communications
B.A., Brooklyn College; LL.B., New York University Law School

Linda Lerner, Adjunct Instructor of English
B.A., M.A., Brooklyn College

Suzanne Loebl, Adjunct Instructor of Communications
B.S., Institute Maurice Chimie, Brussels

Robert M. McEntire, Adjunct Instructor of English
B.A., Westminster College; M.A., University of Michigan; Ph.D., Tufts University

Thomas A. Murray, Adjunct Instructor of Communications
B.A., Fordham University; M.A., University of North Carolina

Jerome M. Paris, Adjunct Instructor of English
B.A., Reed College; M.A., Johns Hopkins University; M.A., Teachers College, Columbia University; Ph.D., Cornell University

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

James W. Scow, Adjunct Instructor of Philosophy
B.A., University of Pennsylvania; M.A., M.Phil., Columbia University

Alice Svendson, Adjunct Instructor of English
B.A., St. Mary's Dominican College; M.A., Colorado State University

Roberta Ventsias, Adjunct Instructor of English
B.A., M.F.A., Brooklyn College

Philip S. Vitale, Adjunct Instructor of English
B.A., M.A., Queens College

Robert L. Whitney, Adjunct Instructor of English
B.A., University of New Hampshire; M.Div., Chicago Theological Seminary

Roslyn Willett, Adjunct Instructor of Communications
B.A., Hunter College

Anne P. Wong, Adjunct Instructor of English
B.A., Williams College; M.A., New York University

EMERITUS FACULTY

John G. Cavanna, Professor Emeritus
Ph.D., University of Minnesota

Conrad Hornberger, Professor Emeritus
Ph.D., University of Munich (Germany)

Clifford Osborne, Professor Emeritus
M.A., University of Denver

Warrington Winters, Professor Emeritus
Ph.D., University of Minnesota

INDUSTRIAL ENGINEERING

The field of 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 most urgent problems of society.

The discipline 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
- 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. The industrial engineer's primary task is to solve specific problems and to design new man-mschine configurations. They make heavy use of the computer, frequently employing heuristic rather than analytic approaches.

Industrial engineers concern themselves with systems in which the mission is imprecisely specified, in which limited resources are available, or in which there is great variability in input and output demands. They are involved in decision-making in the face of incomplete information and conflicting objectives that frequently cannot be adequately defined, that are subjective, and that are difficult to quantify. They 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 the orientation of industrial engineering.

Many industrial engineers eventually move from the analysis and design of productive systems to their administration. While engineering and management are different fields of endeavor, both require the ability to make decisions based on valid information. The industrial engineer is especially trained in obtaining and evaluating such information.

UNDERGRADUATE PROGRAM

The undergraduate program leads to the degree of bachelor of science in industrial engineering, which is accredited by the Accreditation Board of Engineering and Technology. The program is built on the essential scientific and mathematical foundations underlying the field.

The undergraduate program 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 that build on the core requirements. Some possible elective sequences are listed in the Operations Research section of this catalog.

While other engineers work primarily toward the creation of better products, the industrial engineer is also concerned with the economic and human effects of changing technology. The undergraduate curriculum therefore provides a strong background not only in engineering, mathematics and physical sciences, but also in economics and psychology. In addition, the industrial engineering courses emphasize the application of these disciplines in industry, government and service institutions such as hospitals, banks and schools. The industrial engineer is thus in a strategic position to bring about the best integration of men, materials, machines, time and money in any endeavor.

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 131, 142, 143, 146, for six credits of technical electives.

Graduate courses may be taken as electives by qualified juniors and seniors with at least a B average, who 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 Polytechnic policy.

Four-Year Program. A typical program sequence is shown on the following page covering eight semesters. Students may rearrange courses and increase or decrease load per semester to suit their educational needs, provided prerequisites are not violated.

*Footnotes are shown after program listing.

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, 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, AM 121, EE 370, EE 374, MT 301	16
Major:	IE 252, IE 254, IE 300, IE 306, IE 311, IE 319, IE 321, IE 324, IE 327, IE 328, IE 380	32
Electives:[2]	Chosen by student in consultation with departmental adviser	24
	Total	128

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 the 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 electives, the student can complete the requirements as shown on page 135.

EVENING PROGRAM

The degree requirements for part-time evening students in the industrial engineering program are in all respects identical to those for full-time students. The evening program is structured so that a student may complete all requirements in eight years without summer work.

A suggested sequence is shown on page 135. Students may change this sequence and increase or reduce the number of credits per term to suit their needs or available time, provided they do not violate the prerequisites.

SUGGESTED ELECTIVE SEQUENCES

Students often seek guidance in using the permitted electives to develop a meaningful sequence for concentration. Some suggested groupings from which the student may select electives are shown in the Operations Research section of this catalog; these are merely suggestions, not required sequences of study.

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

Freshman Year

First Semester			Hours/Week		Second Semester			Hours/Week	
No.	Subject	Cl.	Lab.	Cr.	No.	Subject	Cl.	Lab.	Cr.
CS 100	Intro. to Computer Prog.	2	0	2	AM 101	Graphics	1	3	2
HU 101	College Composition	3	0	3	HU 200	Intro. to Literature[1]	3	0	3
MA 101	Calculus I[1]	4	0	4	MA 102	Calculus II[1]	4	0	4
PH 101	Introductory Physics I	3	0	3	PH 102	Introductory Physics II	3½	1½	4
SS 251	Economics I: Micro-Econ.	3	0	3	SS 252	Economics II: Macro-Econ.	3	0	3
PE 101	Physical Education I	0	2	0	PE 102	Physical Education II	0	3	0
				15					16

Sophomore Year

AM 115	Engineering Mechanics	4	0	4	AM 121	Mechanics of Materials	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
IE 254	Industrial Management	3	0	3	IE 252	Cost Fundamentals	3	0	3
MA 104	Appl. Differential Equ.[1]	3	0	3	MA 103	Calculus III[1]	3	0	3
PH 103	Introductory Physics III	2½	1½	3	SS 104	Contemp. World Hist.[1]	3	0	3
PE 103	Physical Education III	0	2	0	PE 104	Physical Education IV	0	2	0
				16					15

Junior Year

EE 370	Princ. of Electrical Eng.	3	0	3	IE 300	Eng. Economic Analysis	3	0	3
EE 374	Instrumentation Lab.	0	3	1	IE 328	Operations Research II	3	0	3
IE 306	Work Design & Measurement	2½	1½	3	IE 380	System Simulation	3	0	3
IE 327	Operations Research I	3	0	3	MA 224	Intro. to Math. Statistics	3	0	3
MA 223	Intro. to Probability	3	0	3	MT 301	Mech. Behav. of Materials	2	3	3
SS 189	Intro. to Psychology	3	0	3		Electives[2]			3
				16					18

Senior Year

IE 311	Statis. Quality Control	3	0	3	IE 321	Facility Layout & Location	3	0	3
IE 319	Prodctn. Planning & Control	3	0	3	IE 324	Computers in Oper. Analysis	1	3	2
	Electives[2]			9		Electives[2]			12
				15					17

Total credits required for graduation: 128

[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.

[2]The 24 credits of electives are to be distributed as follows:

6 credits of industrial engineering design selected from below with adviser's approval:

IE 314	Modeling of Social Systems
IE 320	Project Planning & Control
IE 346	Operational Design of Public Systems
IE 365	Human Factors in Engineering Design
IE 375	Industrial Safety Engineering
IE 376	Material Requirements Planning
IE 377	Manufacturing Improvement Curves

3 credits of engineering science selected from courses below with adviser's approval (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.
EE 378	Principles of Control Systems
NU 301	Intro. to Nuclear Engineering I

3 credits of technical electives: engineering or science
6 credits of humanities and social science
6 credits of free electives

Typical Course of Study for Transfer Students

Junior Year

First Semester			Hours/Week		Second Semester			Hours/Week	
No.	Subject	Cl.	Lab.	Cr.	No.	Subject	Cl.	Lab.	Cr.
AM 115	Engineering Mechanics	4	0	4	AM 121	Mechanics of Materials	4	0	4
IE 254	Industrial Management	3	0	3	IE 252	Cost Fundamentals	3	0	3
IE 306	Work Design & Measurement	2½	1½	3	IE 300	Eng. Economic Analysis	3	0	3
IE 327	Operations Research I	3	0	3	IE 328	Operations Research II	3	0	3
MA 223	Intro. to Probability	3	0	3	MA 224	Intro. to Math. Statistics	3	0	3
				16					16

Senior Year

EE 370	Princ. of Elec. Engineering	3	0	3	AM 101	Graphics	1	3	2
EE 374	Instrumentation Lab.	0	3	1	IE 321	Facility Layout & Location	3	0	3
IE 311	Statist. Quality Control	3	0	3	IE 324	Computers in Oper. Analysis	1	3	2
IE 319	Prodctn. Planning & Control	3	0	3	IE 380	System Simulation	3	0	3
	Electives[2]			6	MT 301	Mech. Behav. of Materials	2	3	3
				16		Electives[2]			3
									16

See text for explanation.

Total credits required for graduation: 128

Typical Course of Study for Evening Students

First Year

First Semester			Hours/Week		Second Semester			Hours/Week	
No.	Subject	Cl.	Lab.	Cr.	No.	Subject	Cl.	Lab.	Cr.
HU 101	College Composition	3	0	3	CS 100	Intro. to Computer Prog.	2	0	2
MA 101	Calculus[1]	4	0	4	MA 102	Calculus II[1]	4	0	4
					PH 101	Introductory Physics I	3	0	3

Second Year

MA 103	Calculus III[1]	3	0	3	MA 104	Appl. Diffl. Equations[1]	3	0	3
PH 102	Introductory Physics II	3½	1½	4	PH 103	Introductory Physics III	2½	1½	3
					SS 104	Contemp. World Hist.[1]	3	0	3

Third Year

CM 101	General Chemistry I	2½	0	2½	AM 101	Graphics	1	3	2
CM 111	General Chemistry Lab. I	0	1½	½	CM 102	General Chemistry II	2½	0	2½
HU 200	Intro. to Literature[1]	3	0	3	CM 112	General Chemistry Lab. II	0	1½	½
IE 254	Industrial Management	3	0	3	IE 252	Cost Fundamentals	3	0	3

Fourth Year

AM 116	Engineering Mechanics I	2	0	2	AM 117	Engineering Mechanics II	2	0	2
IE 306	Work Design & Measurement	2½	1½	3	IE 300	Engrg. Economic Analysis	3	0	3
SS 251	Economics I: Micro-Econ.	3	0	3	MA 223	Intro. to Probability	3	0	3

Fifth Year

IE 327	Operations Research I	3	0	3	IE 328	Operations Research II	3	0	3
MA 224	Intro. to Math. Statistics	3	0	3	MT 301	Mech. Behav. of Materials	2	3	3
SS 189	Intro. to Psychology	3	0	3	SS 252	Economics II: Macro-Econ.	3	0	3

Sixth Year

AM 121	Mechanics of Materials	3	0	3	IE 321	Facility Layout & Location	3	0	3
IE 311	Stat. Quality Control	3	0	3	IE 380	System Simulation	3	0	3
						Elective[2]			3

Seventh Year

EE 370	Princ. of Electrical Eng.	3	0	3	IE 324	Computers in Oper. Anal.	1	3	2
EE 374	Instrumentation Lab.	0	3	1		Electives[2]			6
IE 319	Production Planng. & Control	3	0	3					

Eighth Year

	Electives[2]			9		Electives[2]			6

See footnotes on previous page

GRADUATE STUDY

The graduate program in industrial engineering leads to the degrees of master of science in industrial engineering, engineer in industrial engineering and doctor of philosophy.

Within these degree programs, students may pursue graduate studies in such specialized areas as information science, system simulation, quality control, experimental design, man-machine systems, social systems dynamics, production engineering, production and inventory models, reliability and maintainability. Certificate programs are available for more limited graduate study in many 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. One ingredient common to our students is a desire to develop techniques for problem-solving and decision-making in a technological world.

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.

MASTER OF SCIENCE DEGREE

The Division of Management offers a program leading to the degree of master of science in industrial engineering. The general requirements for the master of science degree are stated in this catalog under "Degree Requirements." Detailed requirements for this degree are shown below.

A bachelor's degree with mathematics through calculus (equivalent to MA 103) is required for admission to the program. Applications should be made to the Division of Management with industrial engineering indicated as the area of specialization. Requirements for the master's program are on page 156.

Requirements for the Master of Science Degree in Industrial Engineering

A. Basic Required Courses[1]
IE 600 Engineering Economic Analysis
IE 601 Intro. to Digital Computing
IE 606 Work Design & Measurement
MA 561 Elements of Probability
OR 608 Statistics
OR 627 Op. Res.: Deterministic Models[4]

B. Required Courses . . . . . 9 units
IE 611 Statistical Quality Control
IE 619 Production Planning & Control
OR 628 Op. Res.: Stochastic Models[4]

C. Major Electives[2]: Select 4 . . . . . 12 units
{ IE 614 Modlg. of Social Systems
{ IE 846 Urban Systems Analysis

{ IE 621 Facility Layout & Location
{ IE 776 Material Requirements Planning
{ IE 778 Advanced Production Planning

{ IE 624 Computer-Augmented Case Studies in Management Science
{ IE 680 System Simulation I

{ IE 685 Reliability I
{ IE 852 Applied Regression & Analysis of Variance

{ IE 853 Design of Experiments
{ IE 765 Human Factors in Engineering Design
{ IE 777 Manufacturing Improvement Curves
{ IE 779 Advanced Work Systems Design

{ OR 665 Microeconomic Models
{ OR 671 Business & Economic Forecasting

D. Other Relevant Electives[3] . . . . . 15 units
Minimum Total 36 units

ENGINEER DEGREE

The Division of Management offers a program leading to the degree of engineer in industrial engineering. The general requirements for the engineer degree are stated in this catalog under "Degree Requirements." Detailed requirements for this degree are shown below.

This professional degree is intended for engineers who desire to advance their professional development and training beyond the master's level but without the original research that is required of doctoral students.

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 the bachelor's degree or 36 units beyond the master's degree, including at least 6 units of a design project. On completion of the design project, the candidate will be required to make a final oral presentation before a faculty committee. The project requirement may be waived by the guidance committee for professionally mature candidates who have previously completed work in their major area that is judged to be of exceptional caliber and for those students who have completed a suitable master's thesis or project.

---

[1] All group A courses are required unless they are specifically waived by the adviser because the student either (a) has taken on 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 will be increased accordingly.

[2] Only one of each bracketed set of courses will be 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.

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 630, MG 602, or MG 605.

[4] Certain introductory courses will be waived if the student takes specified advanced courses, for which full credit will be given.
For OR 627: OR 631 and either OR 632 or OR 665
For OR 628: OR 650

Requirements for the Degree of Engineer in Industrial Engineering

The student, with his or her adviser, will work out an approved program of study, having at least 36 units, including (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, will 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 615	Social & Industrial Dynamics
IE 618	Inventory Models
OR 631	Linear Programming
OR 650	Queuing Systems I
OR 666	Macroeconomic Decision Models
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 Division of Management offers a program leading to the degree of doctor of philosophy in industrial engineering.

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 division's doctoral brochure.

Entrance to a doctoral program is contingent upon passing the program's qualifying examination. This will consist 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 will select a thesis adviser and prepare a formal proposal for the dissertation research. A thesis committee will be appointed to judge the merit of the proposed research. After approval of this proposal, the doctoral candidate shall register for research. On completion of the dissertation, the candidate must pass an examination in its defense.

CERTIFICATE PROGRAMS

The division offers several certificate programs designed for the professional with work experience. A certificate program requires five courses, which are selected in line 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 individual is issued a certificate. Students who choose to work toward a master's degree are able to apply all courses taken toward a certificate on admission to the degree program. Additional information may be obtained from the division.

UNDERGRADUATE COURSES

Note: Junior or senior standing is required for all undergraduate IE courses except IE 200, IE 252 and IE 254.

IE 200 Concepts of Modern Technology 2:3:3
Definition, formulation and evaluation of complex problems involving impact of technology on society. Modeling techniques, analysis and simulation are introduced, emphasizing similarities of approach among different problems. Understanding of important basic concepts is stressed, but techniques are introduced as needed. Prerequisite: knowledge of computer programming.

IE 252 Cost Fundamentals* 3:0:3
Managerial approach to problem of cost determination and analysis. Job order, process and standard cost systems. Analysis of indirect manufacturing expense. Preparation and analysis of balance sheet, income and manufacturing statements. Relation between accounting and engineering functions.

IE 254 Industrial Management* 3:0:3
Survey course introducing scope of industrial management to engineers, presenting broad view of planning, organization, direction and control of industrial enterprises.

IE 300 Engineering Economic Analysis 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, minimum cost or maximum profit determination, replacement and economic life, breakeven analysis, effects of taxes, intangible factors.

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.

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 Modeling of Social Systems 3:0:3
Social systems viewed as interrelated positive and negative feedback loops whose behavior are governed by structure, amplification and delays. Using the DYNAMO language, students prepare, analyze and restructure several models in ecology, management, economics or related areas individually chosen. Prerequisites: knowledge of calculus and computer programming.

IE 316 Commercial Data-Processing System Design* 2:3:3
Applications of unit record equipment and computers in system design, including order writing, billing, sales analysis. Accounts receivable, inventory control, payroll and labor accounting, accounts payable, general ledger, case studies. Laboratory use of data-processing equipment, including the IBM 360. Prerequisite: knowledge of 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, LBO, CPM, and probabilistic generalized networks. Heuristic models for multiproject scheduling and resource leveling. Other topics include network development, computer adaptation, progress reports and project monitoring. Prerequisite: knowledge of computer programming.

IE 321 Facility Layout and Location 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, minimax location and discrete vs. continuous location planning. Prerequisite: IE 327.

IE 324 Computers in Operational Analysis 1:3:2
Problems in industrial engineering and operations research are assigned. Students use available computer programs to analyze and solve all or parts of the problems. Oral and written reports required. Topics covered include statistical forecasting, inventory, ordering, decision trees, project scheduling, line balancing, control charts, maintenance, queuing, production control. Prerequisites: IE 300 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, dynamic programming. Prerequisites: IE 327 and MA 223.

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 357 Technology Transfer to Developing Countries* 3:0:3
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, economic factors in technology selection and utilization. Technology and political influence. Case studies of recently industrializing nations.
Also listed under SS 357

IE 358 Human Resource Development in Developing Countries* 3:0:3
Spectrum of technology-related manpower needs in less-developed countries; education of engineers, technicians and skilled mechanics. Using foreign personnel, foreign schools, "brain-drain" problems. Economic consequences. Comparisons of education systems of Western, Eastern and developing countries. Design of curricula to suit national needs. Role of technical assistance programs. Forecasting of human resource needs.
Also listed under SS 358

IE 365 Human Factors in Engineering Design* 3:0:3
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.

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.

IE 376 Material Requirements 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. Prerequisite: 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. Prerequisites: knowledge of computer programming and MA 223, or instructor's permission.

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* **3 credits**
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.

IE 401-402 Project Laboratory I, II **IE 401—1:3:2 IE 402—credit arranged**
Independent project combining elements of theory, experimentation design and construction used to discuss 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 students' exchange of ideas and methods, and to enhance each student's abilities in oral and written communication in engineering endeavors. Prerequisite: senior standing.

GRADUATE COURSES

IE 600 Engineering Economic Analysis **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, minimum cost or maximum profit determination, replacement and economic life, breakeven analysis, effects of taxes, intangible factors. Criteria in developing countries. (Not open to students who have taken IE 300.)

IE 601 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 101 or equivalent.)
Also listed under CS 531 and OR 601

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 stopwatch time study. (Not open to students who have taken IE 306.)

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: OR 608.

IE 612 Advanced Quality Control* **2½:0:3**
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 Systems I **2½:0:3**
Social systems viewed as interrelated positive and negative feedback loops whose behavior are governed by structure, amplification and delays. Using the DYNAMO language, students prepare, analyze and restructure several models in ecology, management, economics or related areas individually chosen. Not open to students who have taken IE 314. Prerequisites: knowledge of calculus and computer programming.
Also listed under OR 614

IE 615 Modeling of Social Systems II* **2½:0:3**
Continuation of IE 614, with greater emphasis on underlying theory. More complex systems are analyzed, and control algorithms are designed and tested to improve performance. Prerequisite: IE 614.
Also listed under OR 615

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 OR 627 or OR 631.
Also listed under OR 618

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: OR 627 or OR 631.
Also listed under OR 619

IE 620 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. 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 610 and OR 620

IE 621 Facility Layout and Location* **2½:0:3**
Development of quantitative models for analysis of facility layout and location problems. Solutions by both mathematical and optimization and heuristic algorithms. Location of single and multiple facilities in existing and new layout design. Other topics include computerized layout planning, minimax location and discrete vs. continuous location planning. (Not open to students who have taken IE 321.) Prerequisite: OR 627 or OR 631.
Also listed under OR 621

IE 624 Computer-Augmented Case Studies in Management Science 2½:0:3
Cases involving problems in forecasting, inventory, scheduling, line balancing, maintenance, queuing, and similar industrial engineering and operations research disciplines assigned. Students may write their own computer programs or may use existing packages to analyze the cases and design improved alternatives. Written reports required. Prerequisites: IE 600, OR 627 and OR 628.
Also listed under OR 624

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 OR 627 or OR 631.
Also listed under OR 636

IE 680 System Simulation I 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 SIMSCRIPT, introduction to other languages. Students program, code and run several simulation models. Not open to students who have taken IE 380. Prerequisites: IE 601 and MA 561, or instructor's permission.
Also listed under OR 680

IE 681 System Simulation II* 2½:0:3
Advanced concepts of discrete simulation. Statistical aspects of simulation design, run length, efficiency. Methods for generation of nonuniform random variables, including probability integral transform, rejection, composition techniques. Monte Carlo variance reducing techniques, including importance sampling, control variates and antithetic variates. Application to physical problems. Prerequisites: OR 608 and IE 680.
Also listed under OR 681

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: MA 223 or MA 561 or equivalent.
Also listed under EL 617 or OR 685

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 components reliability. Prerequisite: MA 223 or MA 561 or equivalent.
Also listed under EL 616 and OR 686

IE 700 System Effectiveness* 2½:0:3
Evaluation methodology in system analysis for decision-making process in selection of preferred solutions from set of competing alternatives. Discussions centered on origin and need of performance effectiveness, requirements and criteria, basic concepts, models, applications to real-world problems, computer methods. Prerequisites: IE 601, OR 627 and OR 628, or instructor's permission.
Also listed under OR 700

IE 716 Commercial Data-Processing System Design 2½:0:3
Applications of unit record equipment and computers in system design, including order writing, billing, sales analysis, accounts receivable, inventory control, payroll and labor accounting, accounts payable, general ledger. Laboratory use of data processing equipment, including the IBM 360. Case studies. (Not open to students who have taken IE 316.) Prerequisite: knowledge of computer programming.
Also listed under MG 716

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 OR 627 or OR 631.
Also listed under OR 720

IE 727 Case Studies in Management Science* 2½:0:3
Application of scientific and analytical methods to solving management decision-making problems, drawn from current practice and literature. Prerequisites: OR 627 or OR 631, OR 628 or OR 650.
Also listed under MG 727 and OR 727

IE 757 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, economic factors in technology selection and utilization. Technology and political influence. Case studies of recently industrializing nations. (Not open to students who have taken IE 357.)
Also listed under MG 757 and SS 675

IE 758 Human Resource Development in Developing Countries* 2½:0:3
Spectrum of technology-related manpower needs in less-developed countries; education of engineers, technicians and skilled mechanics. Using foreign personnel, foreign schools, "brain-drain" problems. Economic consequences. Comparisons of educational systems of Western, Eastern and developing countries. Design of curricula to suit national needs. Role of technical assistance programs. Forecasting of human resource needs. (Not open to students who have taken IE 358.)
Also listed under MG 758 and SS 676

IE 765 Human Factors in Engineering Design* 2½:0:3
Study of research techniques that yield information important in men-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.

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 teken IE 375.)

IE 776 Material Requirements 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.) Prerequisite: 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 eggregate 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.
Also listed under OR 778

IE 779 Advanced Work Systems Design **2½:0:3**
Study of work design with emphasis on parameters effecting installation of overall system. Advanced work sampling, workforce balancing, ergonomic work loads, incentive for machine-controlled operations, computer-assisted planning of systems. Prerequisite: IE 606.

IE 846 Urban Systems Analysis* **2½:0:3**
The overall urban system. Modeling for prediction and management of major components: population, economy, lend use, transportation network, facility location, governmental service systems. Cost-benefit viewpoint in social welfare context. (Not open to students who have taken IE 346, except with instructor's permission.) Prerequisite: OR 627 or equivalent.
Also listed under OR 846

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. Systematic treatment of analysis of multiple classifications involving fixed and random effects and crossed and nested varisbles of classification. Regression analysis and its reletion to analysis of variance. Prerequisites: MA 153 and OR 608.
Also listed under OR 852

IE 853 Design of Experiments **2½:0:3**
Basic designs for scientific end industrial experiments: single-factor and multiple-factor completely randomized designs, randomized blocks, incomplete blocks, orthogonal contrasts, general regression approach, Latin and higher squares, quantitative factors—orthogonal polynomials, complete and fractional factorial experiments including confounding methods. Introduction to statistical packages: SPSS and BMDP. Prerequisite: OR 608.
Also listed under OR 853

IE 911-912 Selected Topics in 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.
Also listed under OR 920

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 investigation of significant problem, utilizing modern techniques of enalysis and design. Project to be selected and developed in consulation 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 industrial engineering, constituting original contribution. Candidate required to teke 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.

The following courses listed under Operations Research are also considered in-program courses for Industrial Engineering:

OR 608	Statistics
OR 627	Operations Research: Deterministic Models
OR 628	Operations Reseerch: Stochastic Models
OR 631	Linear Programming
OR 632	Nonlinear Programming
OR 633	Integer Programming
OR 634	Dynamic Programming
OR 635	Advanced Linear Programming
OR 650	Queuing Systems I
OR 651	Queuing Systems II
OR 665	Microeconomic Models
OR 666	Macroeconomic Models
OR 671	Business and Economic Forecasting
OR 673	Time Series: Forecasting and Control
OR 674	Econometric Models and Methods
OR 851	Stochastic Processes
OR 870	Games and Decisions

FACULTY

Norbert Hauser, Professor of Industrial Engineering and Management Science and Dean of Management
B.M.E., Cooper Union; M.I.E., Eng. Sc.D., New York University
Modeling of social systems, computer simulation, quality control

John T. Chu, Professor of Operations Research
B.S., University of Chekiang (China); M.S., Ph.D., Iowa State University
Managerial decisions, behavioral approaches, national and international problems

Walter Helly, Professor of Operations Research
B.A., Cornell University; M.S., University of Illinois; Ph.D., Massachusetts Institute of Technology
Urban systems, stochastic modeling, vehicular traffic

John H.K. Kao, Professor of Industrial Engineering
B.S., National Central University (China); M.S., D.Eng.Sc., Columbia University
Applied statistics, quality control and reliability, operations research in nuclear engineering

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 (N.Y., PA.)
Mathematical programming, optimum design, 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, industrial management, project management

Seymour Kaplan, Associate Professor of Operations Research, Director of Economic Systems Program
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 Director of Industrial Engineering Program
B.S., Banaras Hindu University (India); M.S., Ph.D., University of Illinois
Production planning, operational control systems, facility location and layout

A. George Schillinger, Associate Professor of Management and Operations Research
B.E.E., City College of New York; M.S., Eng.Sc.D., Columbia University
Technology, management, policy studies, stochastic systems

ADJUNCT FACULTY

Geoffrey Gordon, Adjunct Professor
B.Sc. (Physics), B.Sc. (Mathematics), M.Sc. (Mathematics), University of London (England)

Samuel Gorenstein, Adjunct Professor
B.B.A., City College of New York; Ph.D., New York University

Peter M. Meier, Adjunct Professor
B.S., Swiss Federal Institute of Technology; M.Sc., Ph.D., University of Massachusetts

Arnold Ockene, Adjunct Professor
B.E.E., City College of New York; M.S., Columbia University

Lawrence W. Parks, Adjunct Professor
B.S., M.S., Ph.D., Polytechnic Institute of Brooklyn

Robert Marose, Adjunct Assistant Professor
B.S., University of Notre Dame; M.S., Stevens Institute of Technology; Ph.D., Polytechnic Institute of New York

Andrew Sipos, Adjunct Assistant Professor
Engineering Diploma, Technical University, Budapest; M.S.C.E., University of Pennsylvania (P.E.)

Moira LeMay, Adjunct Associate Professor
B.S., Queens College of City University of New York; M.S., Ph.D., Pennsylvania State University

Young W. Yoon, Adjunct Associate Professor
B.A., Yonsei University; M.B.A., New York University; Ph.D., Polytechnic Institute of New York

Michael P. London, Lecturer
B.S., M.S., New York University

Martin Sternberg, Lecturer
B.S., Polytechnic Institute of New York

INFORMATION MANAGEMENT

Information management deals with information needed by management 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 management with timely information needed to make decisions.

Currently, there is 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 the past 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, in addition to other project team members.

Polytechnic trains information management professionals who, after graduation, are usually assigned individual or team tasks which they are expected 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 objective is to provide students with the educational background and skills to qualify for entry level positions as applications programmers or analysts in the business world. Unlike computer science, where mathematics, science and software development are emphasized, information management is business oriented. The student must be aware of the types 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 of entering industry without additional course work. Finally, the program will provide a solid foundation for the academically inclined student who wishes to pursue graduate study.

Requirements for the 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 111, CS 203, CS 204, CS 205, CS 211, CS 217, IE 316, MG 736	24
Management/System Analysis: IE 252, IE 254, IE 300, IE 314, IE 320, MG 300, MG 401, MG 630, MG 606	27
Arts and Sciences: HU 101, HU 110, HU 200, SS 104, SS 189, SS 199, SS 251, SS 252, MA 101-102, MA 231, PE 101-104	35
Electives:	
Computing	9
Two of the following: IE 376, IE 380, MG 664, MG 851	6
One of the following: CM 091-092, PH 091-092, LS 105-106, LS 115	6-8
Humanities/Social Science	6
Free	13-15
Total Electives	42
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: MS 131, 142, 143, 146, for six credits of technical electives.

Graduate courses may be taken as electives by qualified juniors and seniors with at least a B average, who 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 Polytechnic policy.

Four-Year Program. 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 & INTERNSHIP

A five-year cooperative education program is available that permits the student to integrate academic courses and career preparation in order to develop an understanding regarding their career choice and realistically evaluate their career decision. While earning the B.S. degree the student is also provided with a chance to earn up to 75 per cent of college expenses.

Students who wish a less intensive work experience as part of their education, may wish to enroll in a summer internship with their adviser's permission.

TRANSFER STUDENTS

Transfer students from other accredited institutions are accepted into the B.S. program after evaluation of their transcripts by a faculty adviser. Graduates of technology programs may be able to fulfill the bachelor's degree requirements in two to three and one-half years, depending upon the scope and level of their previous education.

Typical Course of Study for the Bachelor of Science Degree in Information Management

Freshman Year

First Semester		Hours/Week			Second Semester		Hours/Week		
No.	Subject	Cl.	Lab.	Cr.	No.	Subject	Cl.	Lab.	Cr.
CS 111	Comp. Progr. I	3	0	3	MA 102	Calculus II	4	0	4
HU 101	College Composition	3	0	3	SS 252	Macroecon.	3	0	3
MA 101	Calculus I	4	0	4	CS 211	COBOL Progr.	3	0	3
SS 251	Microecon.	3	0	3	HU 200	Introd. to Lit.	3	0	3
SS 104	Main Themes in Cont. World History	3	0	3	PE 102	Phys. Ed.	0	2	0
PE 101	Phys. Ed.	0	2	0		Elective			3
				16					16

Sophomore Year

IE 254	Indl. Mgt.	3	0	3	CS 204	Introd. Data Struc.	3	0	3
CS 203	Comp. Progr. II	3	0	3	IE 252	Cost Fund.	3	0	3
HU 110	Basic Rept. Writ.	3	0	3	MA 231	Stat. Methods	3	0	3
PH 091	Conc. of Cont. Physics I	3	3	4	PH 092	Conc. of Cont. Physics II	3	3	4
PE 103	Phys. Ed.			0	PE 104	Phys. Ed.			3
	Elective			3					16
				16					

Junior Year

IE 320	Proj. Pl. & Contr.	3	0	3	IE 300	Eng. Econ. Analysis	3	0	3
MG 300	Mgt. Process	3	0	3	IE 316	Com. Data. Proc. Sys.	3	0	3
SS 189	Introd. to Psych.	3	0	3	CS 217	Inf. Org. & Retr.	3	0	3
CS 205	Assmb. & Mch. Lang. Prog.	3	0	3		Electives			7
	Elective			4					16
				16					

Senior Year

IE 314	Mod. of Soc. Sys.	3	0	3	SS 199	Org. Behavior	3	0	3
MG 630	Operations Mgt.	3	0	3	MG 401	Senior Project	3	0	3
MG 606	Managerial Finance	3	0	3	MG 736	Anal. & Desg. Mgt.	3	0	3
	Electives			7		Electives			7
				16					16

FACULTY

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

Norbert Hauser, Professor of Industrial Engineering and Management Science
Dean of Management
B.M.E., Cooper Union; M.I.E., Eng.Sc.D., New York University
Modeling of social systems, computer simulation, quality control

John T. Chu, Professor of Operations Research
B.S., University of Chekiang (China); M.S., Ph.D., Iowa State University
Managerial decisions, behavioral approaches, national and international problems

Walter Helly, Professor of Operations Research
B.A., Cornell University; M.S., University of Illinois; Ph.D., Massachusetts Institute of Technology
Urban systems, stochastic modeling, vehicular traffic

Bruce L. Hicks, Visiting Professor of Computer Science
B.S., M.S., Ph.D. (Physics), California Institute of Technology
Educational applications of computers, computer graphics

John H.K. Kao, Professor of Industrial Engineering
B.S., National Central University (China); M.S., D.Eng.Sc., Columbia University
Applied statistics, quality control and reliability, operations research in nuclear engineering

Melvin Klerer, Professor of Electrical Engineering and Computer Science
B.A., M.S., Ph.D., New York University
Programming systems, languages, artificial intelligence

Arthur E. Laemmel, Professor of Electrical Engineering
B.E.E., Polytechnic Institute of Brooklyn
Computer architecture, coding

Willard A. Lewis, Visiting Professor of Management
Professor Emeritus, New York University
B.A., New York University; A.M. in Public Law, Columbia University; LL.B., Ph.D., New York University
Industrial relations, legal environment of business, management and organizational behavior

Stanley Preiser, Professor and Dean of the Westchester Center
B.S., CCNY; M.S., Ph.D., New York University
Numerical analysis, applied mathematics, algorithms, system performance evaluation

Edward J. Smith, Professor of Electrical Engineering and Director of Division of Computer Science
B.E.E., Cooper Union; M.E.E., D.E.E., Polytechnic Institute of Brooklyn
Computer organization, switching and automata

Martin L. Shooman, Professor of Electrical Engineering and Computer Science
S.B., S.M., Massachusetts Institute of Technology; D.E.E., Polytechnic Institute of Brooklyn
Software engineering, system reliability and safety

Joachim I. Weindling, Professor of Operations Research and Director of Operations Research Program
B.M.E., CCNY; M.S., Ph.D., Columbia University; Professional Engineer (N.Y., PA.)
Mathematical programming, optimum design, economic evaluation

Anthony J. Wiener, Professor of Management and Director of Policy Studies
A.B., J.D., Harvard University
Long-range planning, public policy studies, political, economic and social environment of business, technology management and assessment

Herman Grau, Associate Professor of Industrial Engineering
B.M.E., Polytechnic Institute of Brooklyn; M.I.E., New York University
Methods, work measurement, industrial management, project management

Ronald J. Juels, Visiting Associate Professor of Computer Science
B.E.E., M.E.E., Polytechnic Institute of Brooklyn; D.Sc., Stevens Institute
Computer architecture, microprocessor systems

Seymour Kaplan, Associate Professor of Operations Research and Director of Economic Systems Program
B.S., Newark College of Engineering; M.S., Ph.D., New York University
Economic modeling, linear programming

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

Harold G. Kaufman, Associate Professor of Management
B.M.E., Cooper Union; M.I.E., Ph.D., New York University
Career management, science and engineering manpower, obsolescence and continuing education

Ravinder Nanda, Associate Professor of Industrial Engineering and Director of Industrial Engineering Program
B.S., Banaras Hindu University (India); M.S., Ph.D., University of Illinois
Production planning, operational control systems, facility location and layout

Henry Ruston, Associate Professor of Electrical Engineering and Computer Science
B.S.E. (Math), B.S.E. (EE), Ph.D., University of Michigan; M.S., Columbia University
Software engineering, programming, circuit theory

A. George Schillinger, Associate Professor of Management and Operations Research
B.E.E., CCNY; M.S., Eng.Sc.D., Columbia University
Technology management, policy studies, stochastic systems

A. David Klappholz, Assistant Professor of Computer Science
B.S., Massachusetts Institute of Technology; M.S.E., Ph.D., University of Pennsylvania
Parallel processing, computer architecture

Jamshed H. Mirza, Assistant Professor of Computer Science
B. Tech., Indian Institute of Technology, (Khoragpur, India); M.S., Ph.D., Polytechnic Institute of New York
Computer architecture, pipeline processing

Norman Rubin, Assistant Professor of Computer Science
B.S., CCNY; M.A., Ph.D., New York University
Artificial intelligence, programming languages, compilers

David A. Schrier, Assistant Professor of Management and Director of Organizational Behavior Program
B.S., Florida State University; M.B.A., D.B.A., George Washington University
Organization development and training

Dipayan Bhattacharya, Academic Associate
B.A., M.A., Jadavpur University (India); M.S. (Transportation), M.S. (Management), M.S. (Organizational Behavior), Polytechnic Institute of New York
Statistics, economics, financial institutions

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 side of the student's education by promoting 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.

COURSES

IS 140 Language and Communication **3:0:3**
A study of 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**
An examination of the changing pattern of nationalism in the United States and the changing self-definition of the American in response to forces from within the country 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.

PARTICIPATING FACULTY

Donald Hockney, Professor and Head of Humanities
Director of Interdisciplinary Studies Program

Marvin E. Gettleman, Professor of Social Sciences

Frederick C. Kreiling, Professor of Social Sciences

Duane DeVries, Associate Professor of Humanities

Pamela Kramer, Associate Professor of Social Sciences

I. Leonard Leeb, Associate Professor of Social Sciences

Thomas B. Settle, Associate Professor of Social Sciences

Harley S. Thompson, Associate Professor of Humanities

LIFE SCIENCES

In recent years, Polytechnic has developed strengths in the life sciences that complement those in its long-established teaching and research programs in engineering and the physical sciences. Specific curricula and areas of concentration, including premedicine, biology, biochemistry, environmental sciences, bioengineering and laboratory techniques are designed to offer exceptional preparation for medical, dental and other professional careers, as well as for graduate study in the life sciences and a wide variety of interdisciplinary programs. Qualified students have extensive opportunities to participate in faculty research programs, special projects and independent study.

Students have the flexibility of selecting a program of study best suited to their individual needs:

1. A biology curriculum, essential for graduate studies and a career in biology.

2. An interdisciplinary, premedicine curriculum, preparing for a professional career in the health-related sciences.

3. A career-oriented curriculum to provide skills required for laboratory work in a research, hospital or industrial setting.

4. A life sciences-computer curriculum, in which computer technology may be applied to a career in health-related fields. This course of study results in the student achieving a bachelor of science in life sciences, with a strong concentration in computers, at the end of four years. With an additional year, the student can fulfill the requirements for a master's degree in computers.

5. A life sciences-electrical engineering curriculum, to prepare for careers in which engineering technology may be applied to studies of living systems. This curriculum in life science gives the student in-depth exposure to electrical engineering, equivalent to that of a double major, and leads to a bachelor of science in life sciences. The student can fulfill the requirements for a master's degree in electrical engineering with only one additional year of study.

GENERAL REQUIREMENTS FOR ALL CURRICULA

Part of the biology requirement may be fulfilled by biochemistry courses, CM 201, 202, 204. Technical electives must include one from a group including electronics, living system analysis or research instrumentation; e.g. BE 201-202, CH 841, EE 370 or IE 314. A second course must be in the area of computers. Other technical electives should be chosen in consultation with the life sciences advisers. A total of 36 credits in humanities, social sciences and modern language are required in all curricula except the life sciences-electrical engineering program. Of these, a minimum of 15 credits are required in humanities, including HU 101, HU 200 and a course in technical writing. A minimum of 15 credits are also required in social sciences, including SS 104 and a nine-credit concentration in a specific area of study. Six credits of language are required in continuation of three years of a high school language. Four years of a language in high school eliminates this requirement. Students with fewer than three years of a modern language are required to take two years of language. Advanced language courses in literature may be used to fulfill a literature concentration. IS 140-141 can be substituted for HU 200 and SS 104.

BIOLOGY

Biology is concerned with the study of life in all of its manifestations—from the simple to the complex, from the invisible to the macroscopic and from the virus to the human. To move beyond the definitions of life to the understanding of life's fundamental nature, one must examine the characteristics of living systems, including growth, heredity and reproduction, metabolism, energy production and utilization, responsiveness, and locomotion. Further, one must probe both the structure and function of living matter at the molecular, cellular and organismal levels. An understanding of structure and function leads to a generalization of the principles involved and an understanding of how living systems operate. Indeed, viewpoints and techniques of biology, chemistry and physics all contribute to our study and understanding of living systems at all levels.

A core curriculum provides basic concepts and principles in modern biology and offers studies on a molecular, subcellular, cellular, organismal and population level. This training develops biological knowledge and skill with special competence in molecular biology and genetics, as well as in cellular, microbial, developmental and physiological studies. Despite the cellular emphasis of the curriculum, the organism is kept clearly in focus. Laboratory experiments utilize modern techniques and sophisticated instrumentation. Students are encouraged to design and carry out individual projects.

Students majoring in the life sciences are required to complete courses in biology, chemistry, physics and mathematics.

Biology Curriculum for Bachelor of Science Degree in Life Sciences

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	Chemistry Lab. II	0	1½	½
LS 105	General Biology I	3	0	3	LS 106	General Biology II	3	0	3
LS 115	General Biology Lab I	1	3	2	LS 116	General Biology Lab II	1	3	2
MA 101	Calculus I	4	0	4	MA 102	Calculus II	4	0	4
HU 101	College Composition	3	0	3	SS 104	Contemporary World History	3	0	3
				15					15

Sophomore Year

LS 103	Developmental Biology I	3	3	4	LS 104	Developmental Biology II	3	3	4
PH 101	Physics I	3	0	3	PH 102	Physics II	3½	1½	4
MA 231	Statistical Methods	2	3	3		Technical elective	3	0	3
HU 200	Introduction to Literature	3	0	3		Hum./Soc. Sci./Mod. Lang.	6	0	6
	Elective	3	0	3					17
				16					

Junior Year

LS 132	Cell Physiology	3	3	4	LS 112	Fundamentals of Genetics	3	3	4
PH 103	Physics III	2½	1½	3	CM 164	Phys. Chem. of Living Systems	3	0	3
CM 122	Organic Chemistry	3	0	3	CM 123	Organic Chemistry II	3	0	3
CM 124	Organic Chemistry Lab. I	⅓	5	2	CM 125	Organic Chemistry Lab. II	⅓	5	2
	Hum./Soc. Sci./Mod. Lang.	3	0	3		Hum./Soc. Sci./Mod. Lang.	6	0	6
				15					18

Senior Year

CM 118	Chemical Equilibria	⅓	5	4	LS 140	Environmental Biology	2½	1⅓	3
LS 130	Organismal Physiology	3	3	4		Biology elective	3	3	4
	Hum./Soc. Sci./Mod. Lang.	6	0	6		Technical elective	3	0	3
LS 310	Seminar in Biology	1	0	1		Elective	1	0	1
				15		Hum./Soc. Sci./Mod. Lang.	6	0	6
									17

Total credits required for graduation: 128

PREMEDICINE

The curriculum in premedicine is designed to prepare the student to meet the challenges in the life sciences, medicine and the medically oriented sciences. It provides a well-rounded program in the humanities and social sciences as well as a substantial preparation in the basic sciences. The individual student may shape a course of study so as to build a firm foundation for professional study in medicine, dentistry, osteopathy, veterinary medicine, optometry, podiatry and pharmacy.

Students in the ROTC program may substitute MS 131, 142, 143, 146 for six credits of electives during the junior or senior year.

Premedicine Curriculum for Bachelor of Science Degree in Life Sciences

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 Chem. Lab. I	0	1½	½	CM 112	General Chemistry Lab. II	0	1½	½
LS 105	General Biology I	3	0	3	LS 106	General Biology II	3	0	3
LS 115	General Biology Lab. I	1	3	2	LS 116	General Biology Lab II	1	3	2
HU 101	College Composition	3	0	3	HU 200	Intro. to Literature	3	0	3
SS 104	Contemp. Modern History	3	0	3		Soc. Sci./Mod. Lang.	6	0	6
	Modern Language	3	0	3					17
				17					

Sophomore Year

MA 101	Calculus I	4	0	4	MA 102	Calculus II	4	0	4
PH 101	Physics I	3	0	3	PH 102	Physics II	3½	1½	4
	Biology elective	3	3	4		Elective	3	0	3
	Hum./Soc. Sci./Mod. Lang.	3	0	3		Hum./Soc. Sci./Mod. Lang.	3	0	3
	Elective	3	0	3		Technical elective	3	0	3
				17					17

Junior Year

CM 122	Organic Chemistry	3	0	3	CM 123	Organic Chemistry II	3	0	3
CM 124	Organic Chemistry Lab. I	⅞	5	2	CM 125	Organic Chemistry Lab. II	⅞	5	2
PH 103	Physics	2½	1½	3	CM 164	Phys. Chem. of Living Systems	3	0	3
MA 231	Statistical Methods I	2	3	3		Hum./Soc. Sci./Mod. Lang.	3	0	3
	Hum./Soc. Sci./Mod. Lang.	3	0	3		Technical elective	2	0	2
	Elective	3	0	3		Elective	3	0	3
				17					16

Senior Year

CM 118	Prin. & Applic. of Chem. Equil.	2⅓	5	4		Hum./Soc. Sci./Mod. Lang.	3	0	3
	Technical elective	2	0	2		Technical elective	2	0	2
	Hum./Soc. Sci./Mod. Lang.	3	0	3		Elective	8	0	8
	Elective	4	0	4					13
LS 310	Seminar in Biology	1	0	1					
				14					

Total credits required for graduation: 128

CAREER-ORIENTED CURRICULUM

The career-oriented curriculum permits the student to develop expertise in a variety of laboratory skills such as: microscopy, chromatography, electrophoresis, centrifugation and radioisotopic methods, etc., which are required in research, hospitals and the industrial sectors. Within the curriculum, students select a subspecialty area such as management, technical writing, environmental biology or bioengineering, which further enhances the opportunity to achieve meaningful employment on graduation or to complete successfully an M.S. in one additional year, as well as to continue with graduate or professional school should they so desire.

Career-Oriented Curriculum for Bachelor of Science Degree in Life Sciences

Freshman Year

First Semester		Hours/Week		
No.	Subject	Cl.	Lab.	Cr.
CM 101	General Chemistry I	2½	0	2½
CM 111	General Chemistry Lab I	0	1½	½
MA 101	Calculus I	4	0	4
LS 105	General Biology I	3	0	3
HU 101	College Composition	3	0	3
SS 104	Contemp. World History	3	0	3
				16

Second Semester		Hours/Week		
No.	Subject	Cl.	Lab.	Cr.
CM 102	General Chemistry II	2½	0	2½
CM 112	General Chemistry Lab. II	0	1½	½
MA 102	Calculus II	4	0	4
LS 106	General Biology II	3	0	3
HU 200	Intro. to Literature	3	0	3
	Hum./Soc. Sci./Mod. Lang.	3	0	3
				16

Sophomore Year

LS 155	Lab. Techniques & Instrumentation in Biology I	1	9	4
CM 122	Organic Chemistry I	3	0	3
CM 124	Organic Chemistry Lab. I	3/10	5	2
PH 101	Physics I	3	0	3
	Hum./Soc. Sci./Mod. Lang.	3	0	3
				15

LS 156	Lab. Techniques & Instrumentation in Biology II	1	9	4
CM 123	Organic Chemistry II	3	0	3
CM 125	Organic Chemistry Lab. II	3/10	5	2
PH 102	Physics II	3½	1½	4
	Hum./Soc. Sci./Mod. Lang.	3	0	3
				16

Junior Year

LS 130	Organismal Physiology	3	3	4
CS 111	Computer Programming I	3	0	3
MA 231	Statistical Methods I	2	3	3
	Hum./Soc. Sci./Mod. Lang.	3	0	3
	Professional subfield	3	0	3
				16

LS 121	Clinical Microbiology	3	3	4
	Biology elective	3	3	4
PH 103	Physics	2½	1½	3
	Hum./Soc. Sci./Mod. Lang.	3	0	3
	Professional subfield	3	0	3
				17

Senior Year

LS 160	Histological Techniques	3	3	4
LS 310	Seminar in Biology	1	0	1
	Professional subfield	3	0	3
	Hum./Soc. Sci./Mod. Lang.	6	0	6
	Elective	2	0	2
				16

	Biology elective	3	3	4
	Professional subfield	3	0	3
	Hum./Soc. Sci./Mod. Lang.	3	0	6
	Elective	6	0	3
				16

Total credits required for graduation: 128

LIFE SCIENCES—COMPUTER SCIENCE

Life sciences-computer science is a five-year interdisciplinary program designed for students interested in the utilization of computer sciences in a career in the life sciences. Participants achieve a bachelor's degree in life sciences after four years and a master's degree in computer science with but one additional year. The four-year undergraduate curriculum in life sciences includes in-depth studies in biology, a strong concentration in computer science and demonstrates how computers can be utilized in the analysis and understanding of phenomena in living systems. Consult the computer science section of the catalog for details of the master's program in computer science. A 2.7 grade point average in technical subjects will automatically admit the student into the M.S. in computer science program without deficiencies.

See available M.S. curricula under course requirements for M.S. in electrical engineering or computer science.

Five-Year B.S.-M.S. Program in Life Sciences-Computer Science

Freshman Year

First Semester		Hours/Week			Second Semester		Hours/Week		
No.	Subject	Cl.	Lab.	Cr.	No.	Subject	Cl.	Lab.	Cr.
LS 105	General Biology I	3	0	3	LS 106	General Biology II	3	0	3
LS 115	General Biology Lab. I	1	3	2	LS 116	General Biology Lab. II	1	3	2
CM 101	General Chemistry I	2½	0	2½	CM 102	General Chemistry II	2½	0	2½
CM 111	General Chemistry Lab. I	0	1½	½	CM 112	General Chemistry Lab II	0	1½	½
MA 101	Calculus I	4	0	4	MA 102	Calculus II	4	0	4
HU 101	College Composition	3	0	3	SS 104	Contemporary World History	3	0	3
				15					15

Sophomore Year

PH 101	Physics I	3	0	3	PH 102	Physics II	3½	1½	4
CS 111	Computer Programming I	3	0	3	CS 203	Computer Programming II	3	0	3
	Biology elective	3	3	4	CS 236	Switching Circuits & Digital Systems	3	0	3
HU 200	Introduction to Literature	3	0	3		Hum./Soc. Sci./Mod. Lang.	6	0	6
	Soc. Sci.	3	0	3					
				16					16

Junior Year

PH 103	Physics III	2½	1½	3	CM 123	Organic Chemistry II	3	0	3
CM 122	Organic Chemistry I	3	0	3	CM 125	Organic Chemistry Lab II	⅗	5	2
CM 124	Organic Chemistry Lab I	⅗	5	2	CS 237	Intro. to Computer Architect.	3	0	3
CS 204	Data Structures	3	0	3	CS 297	Computer Laboratory I	1	3	2
CS 205	Assembly & Machine Language Programming	3	0	3		Biology elective	3	3	4
	Hum./Soc. Sci./Mod. Lang.	3	0	3		Hum./Soc. Sci./Mod. Lang.	3	0	3
				17					17

Senior Year

CS 299	Computer Laboratory II	1	3	2		Biology elective	3	3	4
MA 231	Statistical Methods I	2	3	3		Biology elective	3	3	4
IE 314	Modeling of Social System I	3	0	3	LS 310	Seminar in Biology	1	0	1
	Biology elective	3	0	3		Hum./Soc. Sci./Mod. Lang.	6	0	6
	Hum./Soc. Sci./Mod. Lang.	6	0	6					15
				17					

Total credits required for graduation: 128

See the graduate computer program section of the catalog for details of the fifth year.

LIFE SCIENCES–ELECTRICAL ENGINEERING

A five-year interdisciplinary program is offered that leads to the degrees of bachelor of science in life sciences, with a concentration in electrical engineering after four years and a master of science in electrical engineering with one additional year. This life sciences program includes a strong orientation in electronic instrumentation, computer programming, control systems, electromagnetics and systems analysis, which permits the student to complete a master's degree in electrical engineering within one additional year beyond the B.S. in life sciences. In addition to providing the necessary prerequisites for entry into advanced study in life sciences, it offers in-depth study of electrical systems. This course of study involves 136 credits. It is thus a synthesis of two degree programs and provides health-related scientists and practitioners with a new dimension and outlook in the definition of the function of living systems. A 2.7 grade-point average in technical subjects will guarantee admission into the M.S. in electrical engineering program without undergraduate deficiencies. Consult the graduate electrical engineering section of the catalog for details of the master's curriculum.

Five-Year B.S.-M.S. Program in Life Sciences–Electrical Engineering

Freshman Year

First Semester		Hours/Week			Second Semester		Hours/Week		
No.	Subject	Cl.	Lab.	Cr.	No.	Subject	Cl.	Lab.	Cr.
LS 105	General Biology I	3	0	3	LS 106	General Biology II	3	0	3
LS 115	General Biology Lab. I	1	3	2	LS 116	General Biology Lab II	1	3	2
CM 101	General Chemistry I	2½	0	2½	CM 102	General Chemistry II	2½	0	2½
CM 111	General Chemistry Lab. I	0	1½	½	CM 112	General Chemistry Lab. II	0	1½	½
MA 101	Calculus I	4	0	4	MA 102	Calculus II	4	0	4
HU 101	College Composition	3	0	3	HU 200	Introduction to Literature	3	0	3
SS 104	Contemporary World History	3	0	3		Social Science	3	0	3
				18					18

Sophomore Year

MA 231	Statistical Methods	2	3	3	MA 104	Appl. Diff. Equations	3	0	3
PH 101	Introductory Physics I	3	0	3	PH 102	General Physics II	3½	1½	4
CM 122	Organic Chemistry	3	0	3	CM 123	Organic Chemistry II	3	0	3
CM 124	Organic Chemistry Lab. I	⅗	5	2	CM 125	Organic Chemistry Lab. II	⅗	5	2
	Humanities	3	0	3	CS 111	Intro. to Programming	3	0	3
	Biology elective	3	3	4		Hum./Soc. Sci./Mod. Lang.	3	0	3
				18					18

Junior Year

	Biology Elective	3	3	4		Biology elective	3	3	4
MA 103	Calculus III	3	0	3		Biology elective	3	3	4
EE 101	Electrical System I	3	0	3	EE 102	Electrical System II	3	0	3
EE 193	Soph. Elec. Engineering Lab I	0	3	1	EE 194	Soph. Elec. Engineering Lab II	0	3	1
PH 103	General Physics III	2½	1½	3		Hum./Soc. Sci./Mod. Lang.	6	0	6
	Hum./Soc. Sci./Mod. Lang.	3	0	3					18
				17					

Senior Year

EE 103	Electrical System III	4	0	4	EE 112	Solid State Devices & Circuits II	3	0	3
EE 111	Solid State Devices & Circuits I	3	0	3	EE 161	Transmission Lines & Waves	4	0	4
EE 195	Jr. Elec. Engineering Lab I	1	3	2	LS 306	Sr. Project in Life Sciences	0	6	2
LS 305	Sr. Project in Life Sciences II	0	6	2		Hum./Soc. Sci./Mod. Lang.	3	0	3
LS 310	Seminar in Biology	1	0	1					12
BE 201	System Approach to Biomedicine I	2	0	2					
	Hum./Soc. Sci./Mod. Lang.	3	0	3					
				17					

Total credits required for graduation: 136

See the graduate electrical engineering section of the catalog for details of the fifth year.

UNDERGRADUATE COURSES

LS 103-104 Developmental Biology I, II **each 3:3:4**
Analysis of progressive, orderly changes which occur in development. Nature and mechanisms of differentiation, particularly in relation to cellular and embryonic transformations. Biochemistry and relation of inductors to metabolism. Role of cellular environment in differentiation. Relationship of development to genetic factors, immunity, evolution. Prerequisites: LS 106, 116. Lab charge: $40 each.

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 permission of the instructor.

LS 112 Fundamentals of Genetics **3:3:4**
Fundamental aspects of the genetics of bacteria, viruses and higher organisms. Emphasis is placed on both the genetic and biochemical analyses of gene replication, heredity, mutation, recombinetion and gene expression. Comparisons of prokaryotic and eukaryotic genetics and regulation as well as topics in human genetics are included. Laboratory techniques used in the biological and biochemical study of genetic phenomena in prokeryotes, eukaryotes and their viruses. Emphasis placed on modern approaches to genetic research. Lab fee required. Prerequisites: LS 106, 116 and **CM 122.**

LS 115-116 General Biology Laboratory I, II **each 1:3:2**
Recitations in relationship to laboratory experiments will 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 basis of behavior. Lab fee required. LS 115 prerequisite: **LS 105.** LS 116 prerequisite: **LS 106.**

LS 120 Microbiology **3:3:4**
Study of microbial organisms, especially bacteria and viruses. Microbial relationship to disease, infectious and immunologic processes. Mutation, transformation, transduction, induction and bioenergetic processes. Laboratory work: experimental analysis of microbial structure and physiology by biochemical and cytochemical means. Influence of environment on nutrition, enzymes and metabolism of representative microbial species. Lab fee required. Prerequisites: LS 106, 116 and CM 102, or instructor's permission.

LS 121 Clinical Microbiology **3:3:4**
Lectures and laboratory exercises in microbial structure, culturing, growth, metabolism and control. Special emphasis on bacteria that cause infectious diseases, medical virology, and mycology, and serological testing procedures. Lab fee required. Prerequisites: LS 106, 116 or permission of the instructor.

LS 130 Physiology* **3:3:4**
Mechanisms involved in functional processes of cells and multicellular organisms including integration and control aspects. Membrane function, transport, excitation, conduction, contraction, luminescence. Lab fee required. Prerequisites: LS 106, LS 116, CM 102, CM 112 and PH 103.

LS 132 Cell Physiology **3:3:3**
Analyses of chemical and physical mechanisms of cellular function. Molecular constituents of biological systems, enzymes and reaction rates, energetics and regulation of metabolic processes, membrane transport, contractility and irritability. Laboratory studies: examination of cellular components in terms of their functional activities (enzymes, oxidative-phosphorylation, photosynthesis), kinetics of soluble and membrane-bound enzymes, membrane transport. Lab fee required. Prerequisites: LS 106, LS 116, **CM 123** and **CM 164.**

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

LS 151 Cell Biology **3:0:3**
Analyses of the cell at all levels of organization to reveal its subcellular, macromolecular and molecular architecture. Topics include: microscopy, cell ultrastructure and function, mitosis, meiosis, the cell cycle, models of membrane structure, chromosomes and chromatin, microtubule and microfilaments structure and function, cell-cell interactions and cell differentiation. Lab fee required. Prerequisites: LS 106 and LS 116 or permission of the instructor.

LS 155-156 Laboratory Techniques and Instrumentation in Biology **each 1:9:4**
Theory and practical applications of basic analytical laboratory procedures. The course will progress from basic skills such as solution preparation, pH measurements and volume and mass determinations to more sophisticated procedures such as compositional analyses (protein, DNA, RNA, lipid and carbohydrate determinations), microscopy (light, phase contrast and fluorescence), electrophoresis (polyacrylamide gel and cellulose acetate), ultracentrifugation, chromatography (affinity, ion-exchange and permeation), radioisotopic methods (labeling procedures, radioimmune assays, autoradiography and liquid scintillation counting), tissue culture techniques, spectroscopy (UV-visible, infra-red and fluorescence). Lab fee required. Prerequisite: LS 106.

LS 160 Histological Techniques **3:3:4**
The microscopic study of tissues and organs is presented as background for their visual recognition as well as that of specific cell types. The functional significance of variations and alterations of cell types is stressed. Laboratories are designed to familiarize the student with basic techniques including: fixation, dehydration, embedding, microtomy, slide preparation, staining and histochemistry. Lab fee required. Prerequisite: LS 106.

LS 200 Close Encounters of a Biological Kind* **2½:1½:3**
Selected relevant topics may include chronic and acute health effects of physical and chemical environmental agents on biological systems (lead, asbestos, food additives, contaminants), organ transplantation, nutrition, drug addiction, genetic engineering, euthanasia, human experimentation, abortion, human sexuality, battered persons. Laboratory: field trips and experiential learning in project form.

LS 300-304 Thesis in Biology **each 2 credits**
Independent work undertaken by students in biology under guidance of faculty members. Original investigation involves careful search of literature, with active participation in conferences and seminars as work progresses. Oral presentation of work before departmental staff and written thesis required. Lab fee required. Prerequisite: departmental adviser's approval.

LS 305-307 Senior Project in Life Sciences **each 2 credits**
Investigation of problem in biology under supervision of faculty member. Library research, experimental studies, written reports required. Lab fee required. Prerequisite: senior status or adviser's approval.

LS 308 Life Sciences Internship **2 credits**
Supervised projects carried out in a hospital, community or industrial setting. 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 experience provides student with significant exposure to relationship between theoretical information and practical applications. Prerequisite: senior status or adviser's approval.

LS 310 Seminar in Biology* **1 credit**
Selected topics of current interest to be presented by participating students, staff and outside lecturers. Prerequisites: LS 105 and LS 106.

GRADUATE COURSES

LS 561 Electron Microscopy† **1:9:4**
Course oriented toward development of proficiency in electron microscopic techniques. Discussions and exercises in preparation of glass knives. Fixation, dehydration and embedment of biological specimens. Ultra thin sectioning, staining, use of the transmission electron microscope, and introduction to photographic techniques. Lab fee required. Prerequisites: LS 106 and LS 116 or permission of the instructor.

LS 600 Neurophysiology* **2½:0:3**
An in-depth discussion of basic nerve cell physiology covering such topics as the resting potential, sodium pump, action potential, synaptic mechanisms and local neuronal circuits. Prerequisite: LS 106 or BE 611.
Also listed under BE 692

LS 601 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 control nervous system disorders, etc. Topics will vary from semester to semester and course may be taken for repeated credit. Prerequisites: LS 106, BE 611 or permission of instructor.
Also listed under BE 693

LS 700-701 Cytology I, II* **each 2½:0:3**
Introduction to cellular biology emphasizing relationship of cellular structure to physiology and genetics using modern research methods. Analyses of cytoplasmic and nuclear structures with relationship to cell function. Structure and function of chromosomes. Regulation of chromosome activity and problems of differentiation. Specialized cells discussed. LS 700 prerequisites: LS 103 and CM 122. LS 701 prerequisite: LS 700.

LS 702 Cytology Laboratory* **0:4:2**
Experimental analysis of cellular structure and functions. Preparation of cells for microscopic examination supplemented by demonstrations of special methods and of representative preparations. Light field, dark field, fluorescence, interference, polarizing and electronc microscopy of cytoplasmic and nuclear components and of specialized cells. Lab fee required. Prerequisites: LS 700 and **LS 701.**

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

Shirley M. Motzkin, Professor of Biology and Director of Life Sciences Program
B.S. Brooklyn College; A.M., Columbia University; Ph.D., New York University
Developmental mechanisms, teratology and skeletal development, ionizing and nonionizing radiation

Tobianne Simmons, Assistant Professor of Biology
B.A., Barnard College; M.S., University of Denver; Ph.D., University of Pennsylvania
Molecular cell biology, biochemistry and genetics, mammalian cell cycle

MANAGEMENT

Among the programs offered by the Division of Management are an undergraduate bachelor of science degree in information management* and two graduate degrees: master of science in management** and master of science in organizational behavior. The graduate degrees are primarily evening programs offered to both full-time and part-time students.

Both graduate programs are open to any student who has earned a bachelor's degree from an accredited school. Students who show potential for advanced study but have undergraduate averages below B may be admitted to nondegree status; satisfactory performance at Polytechnic will permit later application for degree status.

MASTER OF SCIENCE PROGRAM IN MANAGEMENT

The Program—This program is aimed at developing a competence in planning and decision-making and in the selection, allocation and direction of human, financial, physical, technological and organizational resources.

These management skills can be applied in a broad range of professional settings: in the private as well as in the public sector, 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 a pragmatic approach to management and is intended to train professional managers who can function effectively in complex managerial systems.

Admission—In addition to holding an accredited bachelor's degree, each student must take the Graduate Management Admission Test (GMAT) or an acceptable equivalent test. Students who have not taken the test may be admitted to a nondegree status and will be required to take it at its next sitting, preferably during the current semester.

Degree Requirements—The maximum of 45 units at an overall B average performance may be reduced by waivers of not more than 3 core courses, and further reduced by not more than 9 evaluated transfer graduate course credits.

The Curriculum

1. Core Courses. A business administration base, designated as the management core, consists of eight core courses upon which a heterogeneous student body can build a variety of specializations within the degree programs. Core courses provide intensive introductions to the several disciplines that are basic to professional management. Students who have taken courses in any of these areas elsewhere or who have had substantial equivalent experience, may be excused from taking them; on proof of competence, the adviser may waive the corresponding core courses.

The core courses are:

MG 600 Management Process
MG 601 Organizational Behavior
MG 602 Computers in Management
MG 603 Economic Environment of Management
MG 604 Managerial Accounting
MG 605 Statistical Analysis
MG 606 Managerial Finance
MG 607 Marketing Management

2. Areas of Concentration. The student must choose an area of concentration. This may be one of those listed below or, with the adviser's approval, may consist of a set of courses designed to meet the student's special needs. A minimum of four courses must be selected in the student's area of concentration.

Courses in each of the following available options are shown below:

- Computer Applications
- Construction Management
- Economics and Finance
- Energy Management
- Human Resources Management
- Management and Business Administration
- Management Science
- Public Policy
- Technology Management
- Transportation Management

3. Free Electives. Two graduate courses may be chosen from those offered by any program of Polytechnic. They may include additional courses from the student's or other concentrations but may not include core courses.

4. Business Policy and Strategy with Project (MG 970). This required integrating course is recommended to be taken during the student's final semester. It includes a project, normally in the area of the student's specialization.

---

*See page 143.

**Master of science in management (MSM) is recognized, along with the master of business administration (MBA), by the Graduate Management Admission Council as a graduate professional management degree.

Concentration Course Requirements

Each concentration sequence consists of four courses. If students wish to take more than the minimum number of required courses, they may count the additional courses as electives. Substitution may be made with the adviser's approval in any concentration area.

Computer Applications
Select four:

CS 603	Information Structures and Algorithms
MG 716	Commercial Data-Processing System and Design
MG 736	Analysis and Design of Management Information Systems
OR 614	Modeling of Social Systems I
OR 680	System Simulation I
IE 776	Materials Requirement Planning

Construction Management
Select four:

MG 631	Theories of Complex Organizations
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 762	Managerial Economics
MG 766	Financial Institutions

Electives: Select two:

MG 640	Resource Economics
MG 671	Business and Economic Forecasting
MG 672	Technological Forecasting
MG 912	Seminar in Investment Analysis
MG 963	Seminar in Financial Planning and Control

Energy Management
(Refer to Energy Program, page 114.)
Required:

ES 927	Energy Policy Issues
ES 928	Energy Resources, Distribution and Conversion Technology

Electives: Select two:

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

Human Resources
Required:

MG 612	Human Resources Management
MG 624	Organization Development
MG 633	Research Methods

Elective: Select one:

MG 611	Career Management
MG 613	Industrial Relations
MG 622	Personnel Psychology
MG 623	Training in Organizations
MG 631	Theories of Complex Organizations

Management and Business Administration
Select four:

MG 612	Human Resources Management
MG 624	Organization Development
MG 630	Operations Management
MG 633	Research Methods
MG 664	Legal Environment of Business
MG 705	Managerial Planning Process
MG 762	Managerial Economics

Management Science
Students electing this option should substitute OR 601 for MG 636 and MA 551 for MG 702 in the required core courses.

Note that OR 624 has several prerequisites.

Select four:

MG 810	Project Planning and Control
OR 614	Modeling of Social Systems I
OR 624	Computer-Augmented Case Studies in Management Science
OR 627	Operations Research: Deterministic Models
OR 628	Operations Research: Stochastic Models
OR 680	System Simulation I

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
ES 927	Energy Policy Issues
OR 614	Modeling of Social Systems I

Technology Management
Select four:

MG 624	Organization Development
MG 630	Operations Management
MG 672	Technological Forecasting
MG 758	Technology Transfer for Developing Countries
MG 820	Project Management
MG 865	Research Development and Management of Innovation
MG 866	Technology Management and Policy
OR 614	Modeling of Social Systems I

Transportation Management
Select four:

MG 852	Legal and Regulatory Aspects of Transportation

MG 853	Public Finance and Economics in Transportation
MG 855	Analysis of Transportation Markets
MG 857	Transportation Management
MG 858	Transportation Policy and Decision-Making
TR 750	Transportation Economics

MASTER OF SCIENCE PROGRAM IN ORGANIZATIONAL BEHAVIOR

Program—A graduate evening program is offered to students who desire to specialize in the area of 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 the latest 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 should submit Graduate Record Examination aptitude scores directly to Polytechnic in advance of the application.

The Curriculum

Required Courses

MG 600	Management Process	3
MG 601	Organizational Behavior	3
MG 605	Statistical Analysis	3
MG 622	Personnel Psychology	3
MG 623	Training in Organizations	3
MG 624	Organization Development	3
MG 631	Theories of Complex Organization	3
MG 633	Research Methods	3
MG 634	Applied Research Methods	3
	Total units required	27

Research Project—All students are required to complete a research project, submitted as part of the requirements for MG 634.

Elective Courses—Nine units of approved electives may be taken in management or in other relevant disciplines. Courses in the Division of Management include such areas as psychology, human factors in design, computer techniques, statistical analysis, social systems analysis and technological forecasting.

Of special interest to students in organizational behavior are:

MG 611	Career Management
MG 612	Human Resource Management
MG 613	Industrial Relations
MG 614	Collective Bargaining
MG 800	Policy Planning and Analysis
MG 863	Market Research
MG 865	Research, Development and Management of Innovation
MG 985	Selected Topics in Organizational Behavior
MG 986	Readings in Organizational Behavior I
MG 987	Readings in Organizational Behavior II

CERTIFICATE PROGRAMS

The Division of Management offers several certificate programs designed for the professional with work experience. A certificate program requires five courses, which are selected in line with the needs of the individual. Applicants for a certificate program must hold a bachelor's degree. On completion of a sequence with a B average or better, the individual is issued a certificate. Students who choose to work toward a master's degree are able to apply all courses taken toward a certificate on admission to the degree program. Additional information may be obtained from the division.

Management Certificate—This program is designed to foster professional and personal growth through an intensive examination and study of the latest advances in management process and the newest quantitive techniques, ranging from management information systems to decision models.

Organizational Behavior Certificate—This program involves an intensive examination and study of the latest knowledge and techniques for dealing with human problems in the organization. The individualized program makes it highly appropriate for specialists as well as generalists who desire to improve and update their knowledge and skills in areas ranging from individual motivation to organizational development.

UNDERGRADUATE COURSES

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 the various disciplines within management as well as to the traditional business functions of marketing, accounting, finance, production, engineering, and research and development. In-class management simulation game.

MG 401 Senior Project **3 credits**
Independent work integrating the student's knowledge under faculty guidance. Student will design a system required to manage information regarding a specific management function. Prerequisite: senior standing in information management.

GRADUATE COURSES

MG 600 Management Process **2½:0:3**
Establishment of a conceptual perspective 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 theory, concepts, research and techniques for understanding of human behavior in organizations. Motivation and job satisfaction, personality and conflict, group dynamics, interpersonal relationships, supervision and leadership, communications, organization structure and process, the impact of technology, career development.

MG 602† Computers in Management 2½:0:3
Computers from management viewpoint. Introduction to Management Information Systems. Organization and characteristics of computers. Construction, updating and other manipulations of mass data files-sequential, indexed and indirect files on magnetic tapes and disks. Case studies of actual report writing from information systems. Laboratory use of IBM 360. ANSI-COBOL language used. (Formerly MG 636)

MG 603† Economic Environment of Management 2½:0:3
Central problems of economic society, supply and demand analysis, structure 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. (Formerly MG 650)

MG 604† 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 order, process and standard costing; relation between accounting, economic and financial perspectives.
(Formerly MG 700)

MG 605 Statistical Analysis 2½:0:3
Fundamental statistical models and their use in decision-making. Emphasis on alternative techniques, their assumptions and limitations. Normal and binomial distributions, sampling techniques, hypothesis testing, correlation and regression analysis and techniques, analysis of variance and chi-square testing. (Formerly MG 702)

MG 606 Managerial Finance 2½:0:3
Analysis of principles and practices of the finance function and its application in organizations. Survey of use 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 604** or equivalent.
(Formerly MG 751)

MG 607 Marketing Management 2½:0:3
Foundation course in marketing. The 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, managerial aspects stressed. Prerequisite: **MG 603.** (Formerly MG 851)

MG 611 Career Management 2½:0:3
An examination of careers from the perspectives of both management and the individual. Specific issues addressed include career stage models, entry "shock," 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 critically evaluated. Personal career planning exercises will be utilized.

MG 612 Human Resources Management 2½:0:3
The personnel function is investigated from the perspective of both the individual manager and the total organization. Topics include: manpower characteristics, recruitment and development, motivation, performance evaluation and rewards; effects of government policy on legislation; the changing labor force.

MG 613 Industrial Relations 2½:0:3
Policies and philosophies of management, organized labor and government with regard to solution of labor problems. Evaluation of industrial relations problems, particularly those of collective bargaining, emphasizing interrelationships with social, economic and legal trends. Prerequisite: **MG 600** or approval of instructor.

MG 614 Collective Bargaining* 2½:0:3
Analysis of nature of the collective bargaining process, its major issues and points of contention. Major trends examined with consideration given to broad economic and social implications. Prerequisite: MG 613.

MG 615 Labor Economics 2½:0:3
Analysis of the character and operation of labor markets through economic theory and empirical studies. Supply and demand, wages and employment, "scientific management," job opportunities, governmental micropolicy, collective bargaining and internal markets. Discrimination, unemployment and inflation, poverty and income distribution. Prerequisite: MG 650 or equivalent.

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 and measurement of predictors and criteria for validation and decision-making strategies. Prerequisites: MG 601 and MG 605.

MG 623 Training in Organizations 2½:0:3
The role of training in organizations focusing on department and line managers. Subjects addressed: need analysis, preparation of the employee for the job, management development, training program design, evaluation and employee obsolescence.

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 change. Planned structural revisions in formal organization. Dynamics of organizational change process. Experiential techniques and seminar approach emphasized. Prerequisite: MG 601.

MG 630 Operations Management 2½:0:3
Analytical techniques for designing and operating production and service systems. Facility layout and location, assembly line balancing, job sequencing, inventory control, project planning and introductory linear programming.

MG 631 Theories of Complex Organizations 2½:0:3
Analysis 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 informal organizations through wide variety of research studies. Prerequisite: MG 601.

MG 632 Business and Its Environment 2½:0:3
Discussion of various environments of business (economic, political, legal, social), together with conflicting values in these environments. Prerequisite: MG 600.

MG 633 Research Methods 2½:0:3
An introduction to theory and techniques of research methods. Primary objective: to provide an understanding and appreciation of why and how organizational research is carried out. Survey of research methods. Research projects designed and implemented. Prerequisite: MG 605.

MG 634 Applied Research Methods in Organizational Behavior 2½:0:3
Integration and application of advanced research techniques utilized in study of organizational behavior and human resource management. Students develop and carry out individual applied research projects. Prerequisites: MG 633 and advanced standing.

MG 640† Resource Economics* 2½:0:3
Theories of exhaustible natural resources with special emphasis on fossil fuels. Theories of extraction logistics and resource exhaustion. Theories of pricing and allocation of exhaustible resources under economic conditions of competition, monopoly and oligopoly. Present day behavior of the world oil market and the domestic markets for natural gas and coal will be discussed, as well as policy problems. Prerequisites: SS 251 and MA 103, or OR 665, or permission of the instructor.

MG 664 Legal Environment of Business 2½:0:3
Legal forces and regulatory patterns affecting business operations. Introduction to the American legal structure and judicial and legislative processes; reconciliation of societal needs and free enterprise. Impact of law on the firm in such areas as environmental protection, energy conservation, fair trade, deceptive advertising, product liability, occupational health and safety, inflation control, antitrust, patents and trademarks.

MG 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: OR 608 or equivalent.
Also listed under OR 671

MG 672 Technological Forecasting 2½:0:3
Introduction to problems of technological forecasting. Morphological analysis, extrapolation of trends, heuristic and intuitive forecasts. Consideration of rational directing of technological change. Students prepare forecast on topic of own choice.
Also listed under SS 672

MG 705 Managerial Planning Processes 2½:0:3
An introduction to strategic management and to formal planning as a method for translating the firm's goals into procedures or actions. Tactical planning at the operating level is stressed. One purpose of the course is to develop an appreciation of foresight and the classical methods for gathering information essential to decision-making in large-scale organizations. Prerequisites: MG 600 and MG 601.

MG 716 Commercial Data-Processing System Design 2½:0:3
Applications of unit record equipment and computers in system design, including order writing, billing, sales analysis, accounts receivable, inventory control, payroll and labor accounting, accounts payable, general ledger. Laboratory use of data-processing equipment including the IBM 360. Case studies. Prerequisite: MG 636.
Also listed under IE 716

MG 727 Case Studies in Management Science* 2½:0:3
Application of scientific and analytic methods to solving management decision-making problems, drawn from current practice and literature. Prerequisites: OR 627 or OR 631 and OR 628 or OR 650.
Also listed under IE 727 and OR 727

MG 736 Analysis and Design of Management-Information Systems 2½:0:3
The role of the information system in the management decision-making process. 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 602.

MG 740 Process of Policy Formation 2½:0:3
Situations faced by practitioners and alternative techniques employed to define issues, formulate policy goals and objectives, bargain over priorities, define implementation procedures and garner support.

MG 744 Social Forecasting 2½:0:3
How institutional, economic, social and cultural changes affect both private and public sector organizations in divergent—and sometimes dramatic—ways. Evaluation of methods employed to formulate forecasts and of how implicit beliefs and values of forecasters can subtly bias forecasts. Assessment of alternative forecasts. Prerequisite: MG 600.

MG 746 Public Sector Management 2½:0:3
Management in the public sector is distinguished by the political setting in which it occurs. It goes beyond technical canons of economy and efficiency to involve issues of social equity and political viability. This course is designed to show how these considerations alter the management decision-making process.

MG 757 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. (Not open to students who have taken IE 357.)
Also listed under IE 757 and SS 675

MG 758 Human Resource Development in Developing Countries* 2½:0:3
Spectrum of technology-related manpower needs in less developed countries. Education of engineers, technicians and skilled mechanics. Using foreign personnel, foreign schools, "brain-drain" problems. Economic consequences. Comparisons of educational systems of Western, Eastern and developing countries. Design of curricula to suit national needs. Role of technical assistance programs. Forecasting of human resource needs. (Not open to students who have taken IE 358.)
Also listed under IE 758 and SS 676

MG 760 International Development: Management and Technology 2½:0:3
The course provides a framework for development issues of particular significance to students in engineering and management. Economics of science and technology, appraisal and management of development projects and programs, appropriate technology and mechanisms of technology transfer. Political criteria and the impact of technological decisions on social and economic change in developing countries.

MG 762 Managerial Economics 2½:0:3
Application of economic analysis to practical business problems of the firm. Quantitative techniques for decision-making. Profit measurement, competition, oligopoly and monopoly, multiple product analysis, demand analysis and demand forecasting, cost analysis, pricing analysis, capital budgeting. Prerequisite: MG 603.

MG 766 Financial Institutions 2½:0:3
Financial institutions and their relative importance in the economy. Capital and money markets, commercial banking system, federal banking system, investment banks, insurance companies, savings and loan associations, mutual funds, brokerage companies, international banking.

MG 800 Policy Analysis and Planning 2½:0:3
Systems analysis of policy choices in areas facing federal and regional governments. Cost-benefit methods and related analytical techniques. Analysis and planning in an urban context. 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 multiproject scheduling and resource leveling. Other topics include network development, computer adaptation, progress reports and project monitoring. Prerequisite: knowledge of computer programming.
Also listed under IE 620 and OR 620

MG 820 Project Management* 2½:0:3
Specific managerial concepts and techniques related to management of projects in research and development, construction and engineering. Functional and administrative structures, coordination of activities, manpower planning, feasibility analysis, negotiations and contracts.

MG 825 Construction Administration 2½:0:3
Management problems unique to construction business including licensing, bonding, insurance, short-term financing, employee relations. Prerequisite: MG 600.
Also listed under CE 825

MG 826 Construction Estimates and Costs 2½:0:3
Estimates, costs from viewpoint of contractor or construction engineer, details of estimating, emphasis on labor, material equipment, overhead costs. Prerequisite: MG 825.
Also listed under CE 826

MG 827 Specifications and Contracts 2½:0:3
Principles of contract law as applied to construction industry; legal problems in preparing and administering construction contracts. Prerequisite: MG 825.
Also listed under CE 827

MG 840 Financial Aspects of Public Policy 2½:0:3
Politics of fiscal policy and the social welfare principles. Optimality of public policy with regard to social goods, supported research and development, and different taxation methods. Effect of external economies and diseconomies on the Pareto Optimum conditions; public regulation of social resources allocation. Prerequisite: approval of instructor.

MG 850 Cost Systems 2½:0:3
Methods used in industry for predicting and recording costs. Design and operation of standard and direct cost-accounting systems. Prerequisite: MG 604.

MG 852 Legal and Regulatory Aspects of Transportation 2½:0:3
An in-depth treatment of the origins, causes and effects of regulation on transportation and society in the U.S. Economic and conditional bases for transportation regulation. The legal basis, structure and function of federal, state and local regulating bodies and their interaction with transportation industries. Current controversies concerning the deregulation of sectors of the transportation industry.
Also listed under TR 755

MG 853 Transportation Finance 2½:0:3
Material is approached from a public finance perspective, including a review of those economic theories and analytical techniques that are of particular relevance to transportation. Special attention is given to such areas as (a) the equity vs. efficiency question in transport finance; (b) general vs. earmarked revenue methods; (c) the valid (and invalid) usee of cost-benefit and cost-effectiveness studies and (d) peak load (marginal cost) pricing.
Also listed under TR 751

MG 855 Analysis of Transportation Markets 2½:0:3
Application of the precepts of marketing to public and private transportation operations. Basic market structure of major modes is reviewed to demonstrate how gaining and using market data can increase efficiency and profitability of operations. Attention is given to (a) how factors that affect modal choice are determined and (b) how this information can be integrated into a "marketing plan" that includes service, pricing and promotional aspects.
Also listed under TR 752

MG 858 Behavioral and Sociological Aspects of Transportation 2½:0:3
Behavioral analysis of transportation decision-making and travel characteristics. Sociological factors involved in travel decisions—crime, social isolation, comfort and convenience.
Also listed under SS 195 and TR 756

MG 857 Transportation Management 2½:0:3
Management problems in the private and public transportation sectors, discussion of various types and forms of transportation organizations—planning organizations, modal operators, consulting firms, etc.—and treatment of organizational problems and issues from the managerial perspective. Private vs. public transportation operators and agencies. Public and semi-public operating authorities: legal basis, fiscal structure, purpose, interaction with private operators. Prerequisites: MG 601 and TR 660, or equivalent, or adviser's approval.
Also listed under TR 757

MG 858 Transportation Policy and Decision-Making 2½:0:3
A high-level treatment of policy formulation and decision-making in the transportation industry on several levels: federal policy, state and local policy, individual operating policies. Course uses an intensive case-study approach in a seminar or discussion format. Emphasis is on mass transit operations. Prerequisite: adviser's approval.
Also listed under TR 758

MG 860 Financial Planning, Internal Reporting and Operational Control 2½:0:3
The techniques of planning and control at various levels within the enterprise with emphasis on system analysis and quantifiable aspects of individual or corporate productivity. Applications in the public and private sectors. Budgeting, monitoring and evaluation of performance, "expense and investment centers," transfer pricing, relationship between control systems and organizational goals. Prerequisites: MG 604 and MG 606.

MG 862 Industrial Marketing 2½:0:3
Problems concerning the marketing of industrial products, particularly those of high technological content. Projecting consumer demand, establishing channels of distribution, sales and customer training, advertising and promotion, technical support of the marketing program and budgeting for these activities of the firm. Prerequisites: MG 600 and MG 607.

MG 863 Market Research 2½:0:3
An overview of the accepted methodology for identifying and sizing an existing or emerging market for a specific product so as to guide management action in research and development, manufacturing or marketing. Techniques appropriate to collecting, analyzing and reporting marketplace information to management are explored. Prerequisites: MG 605 and MG 607.

MG 884 Product Planning 2½:0:3
A systematic study of the process followed by successful companies in creating a commercially viable product from technology developed by or available to the firm. The steps involved up to market entry are reviewed sequentially: the 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 885 Research, Development and Management of Innovation 2½:0:3
Introduction to the environment of technological growth in this country with reference to the economy and the firm. Examination of policies and factors that 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 an era of rapid technological change. Prerequisite: MG 600.

MG 886 Technology Management and Policy 2½:0:3
Topics and issues in private and public management to which considerations of technology are central: strategic planning in high-technology corporations, the government's role in directing technology, defense, space, the SST and energy. Managing the large-scale technological enterprise. Science and technology in international relations. Prerequisite: MG 600.

MG 912 Seminar in Investment Analysis* 2½:0:3
Advanced techniques of capital budgeting and investment valuation under certainty and uncertainty; applications of portfolio theory and mathematical programming to corporate investment decision. Prerequisites: MG 605 and MG 606.

MG 940 Joint Project or Internship in Transportation Management each 3 units
An independent project or internship in transportation management for students enrolled in the joint M.S. program in Transportation Management.
Also listed under TR 940

MG 963 Seminar in Financial Planning and Control 2½:0:3
Study of theories of financial management. Application of concepts and procedures to short- and long-term financial planning and control. Risk analysis, portfolio theory, financial markets, national economy and its impact on financial planning and international finance. Prerequisites: MG 605 and MG 606.

MG 970 Business Policy and Strategy 2½:0:3
Integration of functional disciplines studied in the master's program to understand how organizations are managed strategically. The "top management" perspective is the focus. Setting organizational goals, establishing policies that assure realization of objectives, devising and implementing strategies to gain competitive advantage or capitalize on a corporate opportunity. Cases, research paper. Prerequisite: advanced standing.

MG 975 Selected Topics in Management 2½:0:3
Current topics in various fields analyzed and discussed. Prerequisites: advanced standing and permission of instructor.

MG 976-977 Readings in Management each 3 units
Directed individual study or supervised readings in advanced areas of management. Prerequisite: permission of dean.

MG 985 Selected Topics in Organizational Behavior 2½:0:3
Discussion and analysis of current topics in organizational behavior. Prerequisites: advanced standing and permission of instructor.

MG 986-987 Readings in Organizational Behavior each 3 units
Directed individual study or supervised readings in advanced areas of organizational behavior. Prerequisite: permission of dean.

MG 997 Thesis for Degree of Master of Science each 3 units
Original investigation in topic chosen by student. Conferences and progress reports required during work, and final written report required at completion; oral examination may be requested by department. Registration and degree credit beyond first six units require separate approval. Prerequisites: degree status and approval of supervising professor, adviser and department dean.

FACULTY

Norbert Hauser, Professor of Industrial Engineering & Management Science and Dean of Management
B.M.E., Cooper Union; M.I.E., Eng.Sc.D., New York University
Modeling of social systems, computer simulation, quality control

Anthony J. Wiener, Professor of Management and Director of Policy Studies
A.B., J.D., Harvard University
Long-range planning, public policy studies, political, economic and social environment of business, technology management and assessment

Seymour Kaplan, Associate Professor of Operations Research and Director of Economic Systems Program
B.S., Newark College of Engineering; M.S., Ph.D., New York University
Economic modeling, linear programming

Harold G. Kaufman, Associate Professor of Management
B.M.E., Cooper Union; M.I.E., Ph.D., New York University
Career management, science and engineering manpower, obsolescence and continuing education

A. George Schillinger, Associate Professor of Management and Operations Research
B.E.E., CCNY; M.S., Eng.Sc.D., Columbia University
Technology management, policy studies, stochastic systems

David A. Schrier, Assistant Professor of Management and Director of Organizational Behavior Program
B.S., Florida State University; M.B.A., D.B.A., George Washington University
Organization development and training

Willard A. Lewis, Visiting Professor of Management, Professor Emeritus, New York University
B.A., New York University; A.M. in Public Law, Columbia University; LL.B., Ph.D., New York University
Industrial relations, legal environment of business, management and organizational behavior

Dipayan Bhattacharya, Academic Associate
B.A., M.A., Jadavpur University (India); M.S. (Transportation), M.S. (Management), M.S. (Organizational Behavior), Polytechnic Institute of New York
Statistics, economics, financial institutions

ADJUNCT FACULTY

Patrick Mulvihill, Adjunct Professor
B.S., University of Notre Dame; M.S., University of Nebraska at Omaha; M.S., Long Island University

Alex Bernstein, Adjunct Associate Professor
B.S., CCNY

Stanley J. Jacoby, Adjunct Associate Professor
B.S., Polytechnic Institute of New York; M.S., Columbia University (P.E.)

Steven Kolman, Adjunct Associate Professor
B.S., M.B.A., New York University

David Brawerman, Adjunct Assistant Professor
B.B.A., Bernard M. Baruch College

Byron L. David, Adjunct Assistant Professor
B.A., Queens College of City University of New York; M.S., Polytechnic Institute of New York

Harry Frumerman, Adjunct Assistant Professor
B.S., College of the City of New York; M.A., Columbia University

Gerard P. Gorman, Adjunct Assistant Professor
B.S., Pratt Institute; M.S., New York University

Andrew Sipos, Adjunct Assistant Professor
Engineering Diploma, Technical University, Budapest; M.S.C.E, University of Pennsylvania (P.E.)

Clyde Stutts, Adjunct Assistant Professor
B.S. Carroi College; M.A., Ph.D., Bowling Green State University

Amadee Bender, Lecturer
B.A., C.W. Post College; M.B.A., New York University

Mauritz F. Blonder, Lecturer
B.B.A., CCNY; M.B.A., Baruch Graduate School of City University of New York; Ph.D., City University of New York

Robert E. Briefel, Lecturer
B.S., Wharton School, University of Pennsylvania; M.B.A., Harvard University

Eugene Brody, Lecturer
B.B.A., M.B.A., Baruch School of The City University of New York

Thomas Conoscenti, Lecturer
B.S., M.A., New York University

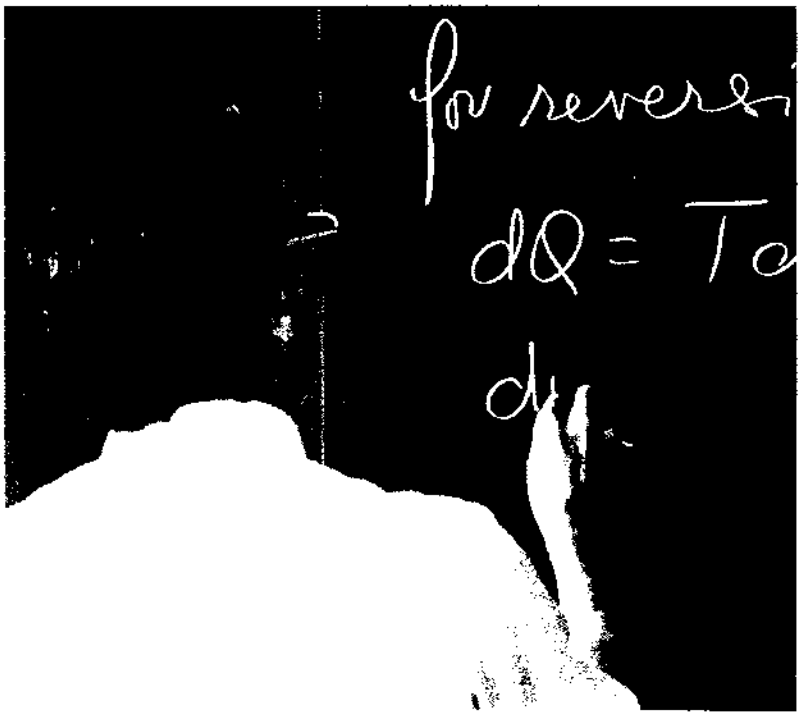
Harry Goldfarb, Lecturer
B.S., New York University

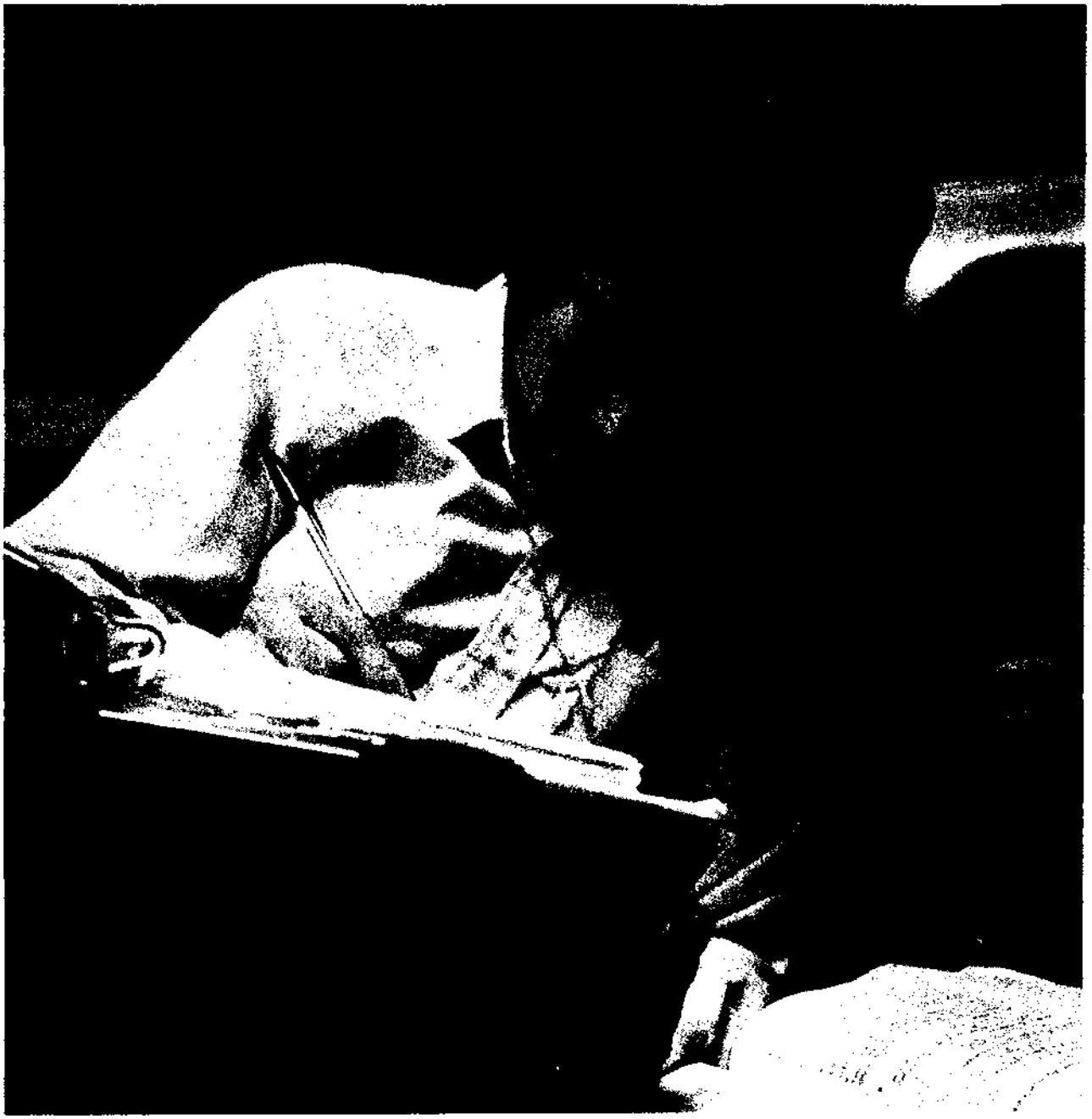
Joel H. Joseph, Lecturer
B.A., Yale University; J.D., Hofstra University

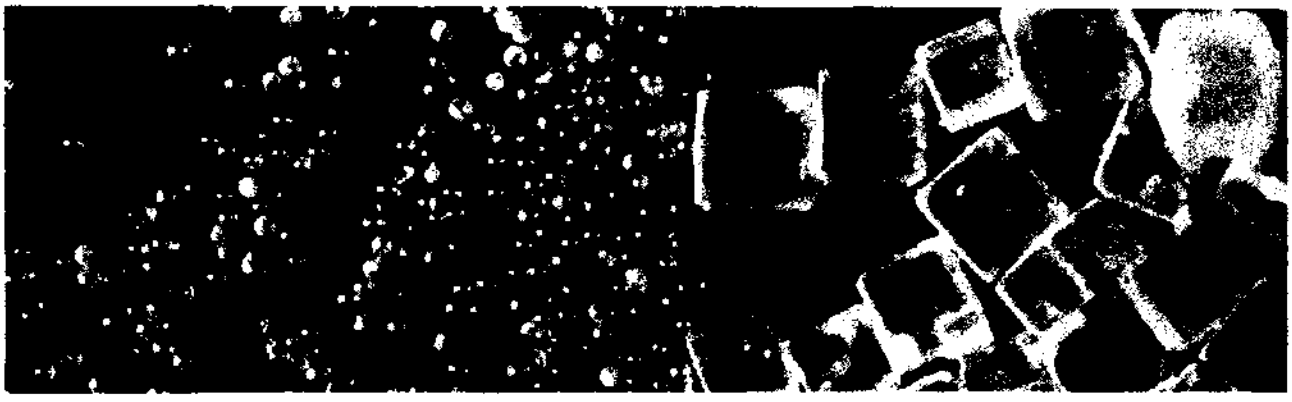
Kirtikumar K. Katkar, Lecturer
B.E., University of Bombay; M.S., Polytechnic Institute of New York

Richard Kurtz, Lecturer
B.S., M.S., City University of New York

Vincent Maieli, Lecturer
B.E.E., M.E.E., Polytechnic Institute of New York; M.S., C.W. Post College


for reversi
dQ = To
dq






FLUID AND THERMAL
ENGINEERING STUDIES
AT THE AERODYNAMICS
LABORATORIES

MATHEMATICS

Mathematics is a branch of learning 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 as well.

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 that enables students to prepare themselves for a career in statistics or in a field utilizing statistical theory and techniques. The graduate curriculum is more specialized. Course work, thesis work and informal departmental activities are all designed to familiarize students with the field of mathematics in general, while they become specialists in the particular area of their 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 the bachelor's degree. In addition, a sequence of elective courses in theoretical and applied statistics enables a student to prepare for a career in statistics or in a field utilizing statistical theory and techniques.

For the science and engineering major, mathematics courses provide the theory and methods essential for the comprehension of the mathematical aspects of their respective fields.

In accordance with these objectives, the Department of Mathematics offers a variety of 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 either of the two courses of study. Students wishing to focus their studies within mathematics itself may elect course of study I, emphasizing abstract mathematics (see page 168). Students particularly interested in applying mathematical knowledge and techniques to other fields may elect course of study II, emphasizing applicable mathematics (see page 169). Both programs provide basic grounding in mathematical knowledge. Details of each program follow.

REQUIREMENTS FOR THE BACHELOR OF SCIENCE DEGREE

MA 111-114 or MA 101-104, 153, 154, 217, 223, 333	26
CS 111, PH 101-103, CM 101, 102, 111, 112	18
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†	21
Minor specialty‡	12
Humanities/Social Sciences electives	9
Free electives§	21
	128

Options—In order to qualify for a New York State Teacher's Certificate in Mathematics, a student may have a maximum of 18 credits in courses in education accepted for transfer credits in place of the corresponding number of free elective credits. 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 131, 142, 143, 146, for six credits of technical electives.

*If less than 12 credits are needed, the remaining credits should be taken in the humanities/social science areas.

†Major specialty. Students must elect a coherent course of study in their major field; two typical selections follow:

Course of Study I	Course of Study II
MA 154, 570	MA 223, 224
MA 211, 212	MA 201, 202
Math electives— nine credits	MA 358
	IE 327, 328

‡Minor specialty: twelve credits beyond the required course 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 some knowledge in an area outside the Department of Mathematics. The faculty adviser of the department of interest should be consulted.

§Students may choose the pass/fail grade option only for free elective courses.

The Minor Specialty—In order to achieve some depth of understanding in a field other than mathematics, the student is asked to choose a 12-credit sequence from another discipline. This work must be in addition to courses taken under other categories of the program; e.g., required courses in physics do not count toward a minor in physics nor do French courses offered to fulfill the language requirement count toward a minor in French. With the exception of applied statistics and computing courses, all minor course work must be completed outside the department. Education courses will not be accepted toward a minor specialty nor will the first two years of a second foreign language.

The courses of the minor specialty will be chosen in consultation with an adviser. In appropriate cases, the adviser for the minor sequence may be from a department other than mathematics. The following are examples of possible minor concentrations:

Aerospace	AM 111, 112, 311, 312
Applied Statistics	MA 224, 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 377, 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

Advanced Placement—Advanced placement credit may be given for the first year of calculus. A student receiving a grade of 4 or 5 on the advanced placement examination in calculus, conducted by the College Entrance Examination Board, will be granted eight credits that may be applied toward the 128-credit requirement for the bachelor's degree in mathematics.

Typical Course of Study I for the Bachelor of Science Degree in Mathematics (Abstract)

Freshman Year

First Semester			Hours/Week			Second Semester			Hours/Week		
No.	Subject		Cl.	Lab.	Cr.	No.	Subject		Cl.	Lab.	Cr.
MA 111	Calculus Ia		4	0	4	MA 112	Calculus IIa		4	0	4
PH 101	General Physics I		3	0	3	PH 102	General Physics II		3½	1½	4
CS 111	Intro. to Computing		3	0	3	HU 200	Intro. Western Lit.		3	0	3
HU 101	College Composition		3	0	3	MA 153	Elem. Linear Algebra		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 113	Calculus IIIa	3	0	3	MA 114	Differential Equations	3	0	3
MA 154	Elem. Abstract Algebra	3	0	3	MA 570	Intro. Geometry	3	0	3
PH 103	General Physics III	2½	1½	3	CM 102	General Chemistry II	2½	0	2½
	Language course	3	0	3	CM 112	General Chemistry Lab. II	0	1½	½
CM 101	General Chemistry I	2½	0	2½		Language course	3	0	3
CM 111	General Chemistry Lab. I	0	1½	½		Electives*			3
PE 103	Physical Education	0	2	0	PE 104	Physical Education	0	2	0
				15					15

Junior Year

MA 211	Analysis I	3	0	3	MA 212	Analysis II	3	0	3
MA 217	Complex Variables	3	0	3		Minor specialty†			3
SS 104	Contemp. World History	3	0	3		Electives*			10
	Minor specialty†			3					16
	Electives*			5					
				17					

Senior Year

	Minor specialty†			3		Minor specialty†			3
	Electives			13		Electives*			13
				16					16

Total credits required for graduation: 128

*Electives total 45 credits, of which at least nine must be in the courses with MA labels and at least nine in courses with HU, SS or ML labels. Remaining elective may be freely chosen from the catalog.

†See minor specialty.

GRADUATE PROGRAMS

The Department of Mathematics offers graduate-level courses in the fields of 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 the master's degree in the fields of abstract mathematics, industrial and applied mathematics, applied statistics and mathematics teaching at the high school level. The doctor's degree is offered in the fields of 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 financial aid in the form of research fellowships, teaching fellowships or partial tuition remission.

REQUIREMENTS FOR THE MASTER'S DEGREE IN MATHEMATICS (ABSTRACT)

A bachelor's degree in mathematics is required for admission to this program. Students with degrees in other fields may be admitted, possibly with undergraduate deficiencies at the discretion of the departmental adviser.

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 111	Intro. to Computing	3	0	3	HU 200	Intro. Western Lit.	3	0	3
HU 101	College Composition	3	0	3	SS 104	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	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	Physical Education	0	2	0
				15					15

Junior Year

MA 201	Applied Analysis	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	Operations Res. Models I	3	0	3	IE 328	Operations Res. Models II	3	0	3
	Minor specialty*			3		Minor specialty			3
	Electives			5		Electives			4
				17					16

Senior Year

	Minor specialty*			3		Minor specialty			3
	Electives			13		Electives			13
				16					16

Total credits required for graduation: 128

*See minor specialty.

Before beginning graduate study, the student is expected to have completed a year's course in advanced calculus. In case of acceptance without these credits, the student will be asked to take the sequence MA 619-620 at Polytechnic in addition to the other requirements listed below for a master's degree.

Thirty-six units are required, 21 units by required courses. If the student elects, 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 the student's faculty adviser and certification that the work is satisfactory. A student offering only course work must pass a comprehensive oral examination before the degree is awarded. This examination covers the student's program of study and is scheduled toward the end of the semester in which the work will be completed.

REQUIREMENTS FOR THE MASTER'S DEGREE IN INDUSTRIAL AND APPLIED MATHEMATICS

The industrial and applied mathematics option is offered to students who are interested in certain areas of applied mathematics rather than in pure mathematics. By selecting appropriate sequences of courses, a student may major in mathematical statistics or in mathematical operations research. Department advisers will aid the student in the selection of a program of study. A student who elects this option may continue toward a Ph.D. in mathematics.

A bachelor's degree in some quantitative field, with at least a minor in mathematics, is required for admission to this program. A student who enters without a year's course in advanced calculus will be asked to take the sequence MA 619-620 at Polytechnic for which no graduate credit will be given. A student who enters without an undergraduate course in linear algebra or complex variables will be asked to take comparable courses (MA 703, 630, respectively) as part of the graduate program; for each such course successfully completed three units may be allowed toward the degree.

No.	Required Subjects	Units
MA 813	Linear Programming	3
MA 821	Numerical and Approximate Analysis	3
MA 851	Probability Theory	4½
	or	
MA 853	Probability I	3
MA 861	Principles of Statistical Inference	3
Applied electives—chosen from MA 812, 814, 815, 817, 822, 823, 852, 855, 862		9
Other electives		7½
	or	9
Additional electives or thesis		6
		36

Regulations governing the thesis option or final examination for this degree are the same as for the master's degree in mathematics.

REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN THE FIELD OF APPLIED STATISTICS

A bachelor's degree is 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 223-224 or MA 561-562. The student is also expected to have a working knowledge of FORTRAN and/or PL 1 programming languages. A student may be admitted with undergraduate deficiencies after consulting with the departmental adviser. Such a student will be required to take the courses necessary to remove the deficiencies.

Required Courses		Units
1. MA 619-620	Advanced Calculus	6
2. At least 2 of		6-12
MA 554	Applied Decision Theory	
MA 555	Design of Experiments	
MA 556	Correlation and Multivariate Models	
MA 557	Sampling	
3. MA 551	Data Analysis	3
4. MA 853	Probability	3
MA 855	Stochastic Processes	3
MA 861-862	Principles of Stat. Inference	6
		27-33
Electives, Project ST 995 (3 units), Thesis ST 997 (6 units)		3-9
		36

Regulations governing the thesis option or final examination for this degree are the same as for the master's degree in mathematics.

The thesis or project option includes an examination of the material by the student's faculty adviser and certification that the work is satisfactory. A student offering only course work must pass a comprehensive oral examination before the degree is awarded. This examination covers the student's program of study and is scheduled toward the end of the semester in which the work is completed.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE IN THE FIELD OF MATHEMATICS EDUCATION

A bachelor's degree in mathematics is required for admission to this program intended for teachers of mathematics in grades 7-12. Students with degrees in other fields may be admitted, possibly with undergraduate deficiencies, at the discretion of the department adviser. Acceptable mathematics courses are numbered 500 and above; the program should be approved by the departmental adviser.

MA 931-932	Selected Topics in the Teaching of Mathematics	6
Elective courses in mathematics		18
Electives (additional mathematics, history of science, psychology, etc.)		6
MA 996	Project	6
		36

REQUIREMENTS FOR THE DOCTOR'S DEGREE IN MATHEMATICS

With the requirements for the doctor's degree primarily qualitative rather than quantitative, each student's program must have the approval of the guidance committee.

The number of graduate units of course work usually associated with the doctoral program 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 student's career, covers real and complex variables, and algebraic structures. Part 2, covering three advanced elective topics, may be taken only after part 1 has been passed. The final examination, which follows the submission of an acceptable dissertation is also oral.

In addition to 72 units of course material, students must devote at least 24 units to dissertation reporting original research under the direction of a faculty adviser.

The student must satisfy the doctoral language requirements in one language selected from French, German or Russian.

Additional details are contained in a brochure, which may be obtained from the departmental office.

REQUIREMENTS FOR THE DOCTOR'S DEGREE IN APPLIED STATISTICS

Within the Department of Mathematics, Polytechnic offers graduate study in the field of applied statistics leading to the Ph.D. degree. 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 their graduate adviser.

A bachelor's degree with at least a minor in mathematics, which should include a one-year course in probability and statistics and a one-year course in advanced calculus is required. A working knowledge in FORTRAN and/or PL 1 programming languages is also desirable.

No.	Required Subjects	Units
MA 630	Elements of Complex Variables	3
MA 703	Linear Algebra	3
MA 621	Real Analysis	3
MA 853, 855	Probability, Stochastic Processes	6
MA 861-862	Principles of Statistical Inference	6
MA 863-864	Multivariate Analysis	6
MA 865-866	Regression and Analysis of Variance	6
	Subtotal	33
At least 3 of		
MA 551	Data Analysis	9-15
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		24-30
	Subtotal	72
Dissertation ST 999 (3 units each)		24
	Total	96

The student must satisfy the doctoral language requirements in one language selected from French, German or Russian.

REQUIREMENTS FOR CERTIFICATE PROGRAMS

The department offers certificate programs in the areas of applied statistics, mathematical statistics, computer mathematics and mathematical programming. Requirements for the certificate program is 15 units.

Applied Statistics
MA 223 Introduction to Probability
MA 224 Introduction to Mathematical Statistics

choice of three
MA 554 Applied Decision Theory
MA 555 Design of Experiments
MA 556 Correlation and Multivariate Models
MA 557 Sampling

Mathematical Statistics
MA 861 Statistical Inference I
MA 862 Statistical Inference II

choice of three
MA 863 Multivariate Analysis I
MA 864 Multivariate Analysis II
MA 865 Regression and Analysis of Variance I
MA 866 Regression and Analysis of Variance II
MA 881 Statistical Analysis of Time Series I
MA 882 Statistical Analysis of Time Series II
MA 867 Nonparametric Methods in Statistics

Computer Mathematics
MA 821 Numerical and Approximate Analysis I
MA 822 Numerical and Approximate Analysis II

choice of three
MA 823 Special Topics in Numerical Analysis
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 student who has not taken in preparatory school or who needs 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 student who has not taken subject in preparatory school or who needs 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 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 requires recommendation of departmental adviser.

UNDERGRADUATE COURSES

MA 091-092 Principles of Mathematics I, II **each 4:0:4**
Logic, sets, mathematical induction, geometry, trigonometry, 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 concept, trigonometric functions, limits of algebraic and trigonometric functions, differentiation, maximization, applications to geometry and physics. The integral, elementary techniques of integration of algebraic and trigonometric functions.

MA 102 Calculus II **4:0:4**
Application 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 111.

MA 103 Calculus III **3:0:3**
Solid geometry and fectors. 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. Use of Laplace transforms. 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 transcendental functions. Prerequisite: department's permission.

MA 112 Calculus IIa **4:0:4**
Sets and sequences of real numbers, properties of real number system. Theory of limits and continuity. Definition of Riemann integral and Riemann-Stieltjes integral. Vectors in 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. Introduction to partial differential equations. Prerequisite: MA 113.

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. MA 154 prerequisite: MA 153.

MA 161 Introduction to Point Set Topology **3:0:3**
Definition of topology and topological space, mappings, compact sets, separation axioms, metric space and completion of a metric space. Prerequisite: MA 211 or MA 202.

MA 177† Transformation Geometry **3:0:3**
Reflections, congruence, groups, homogeneous spaces. Isometrics, group of similarities, circular transformations. Hyperbolic and elliptic geometry. Prerequisite: MA 211 or MA 202.

MA 178† Projective Spaces **3:0:3**
Incidence structure, configuration theorems, partial projective

planes, finite projective planes, conics. 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 significance of mathematics in civilization. Prerequisite: MA 102.

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, Riemann integrals, line integrals, improper integrals, integrals with parameters, transformations, Riemann-Stieltjes integral, uniform, and absolute convergence of integrals. Beta, Gamma functions. Prerequisites: MA 103 and MA 104.

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-Riemann equations, integrals, Cauchy integral theory, power series, residue theory, conformal mapping, Schwarz-Christoffel transformation. Prerequisites: MA 103 and MA 104.

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 2:3:3
Descriptive statistics computed from data; means, variances, histograms. Applications of binomial, normal, t and chi square distributions. Statistical tests. Confidence intervals. Simple regression and correlation. Prerequisite: MA 102.

MA 232† Statistical Methods II 2:3:3
Analysis of variance 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. Prerequisite: MA 223.

Additional offerings in the area of statistics may be found under 500-number courses

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 LaPlace differential equations. Dirichlet and Neuman problems. Legendre polynomials and Bessel functions, some numerical techniques. Prerequisites: MA 103 and MA 104.

MA 341 Discrete Computational Structures I 3:0:3
Discrete mathematics and its implications in computing. Graphs, set theory, relations and functions, networks, finite groups, combinatorics, mathematical logic. Prerequisite: junior status or permission of instructor.

MA 342 Discrete Computational Structures II 3:0:3
Continuation of MA 341 with applications of combinatorial mathematics, algorithms involving discrete optimization, queueing theory in computer science. Prerequisite: MA 341.

MA 358 Introductory Numerical Analysis 3:0:3
Numerical solution of equations, difference tables, finite differences, operator methods, numerical differentiation and integration, numerical solution of ordinary differential equations, systems of linear equations, solution by direct and iterative methods. Prerequisites: MA 104, MA 153 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 discussion and presentation by participating students. Prerequisite: department adviser's permission.

GRADUATE COURSES

MA 531-532† Applied Mathematics in Engineering and Science I, II each 2½:0:3
Vector algebra and vector analysis. Determinants and matrics. 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 for graduate credit in Department of Mathematics. MA 531 prerequisites: MA 103 and MA 104. MA 532 prerequisite: 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 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: calculus.

MA 552† Applied Statistics II (Experimental Design) 2½:0:3
Statistical principles useful in designing comparative and descriptive experiments and their application. Randomized block designs, latin square, factorial, saturated, response surface designs, sequential experimentation. 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 fractional factorial 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 por individual. Regression and correlation. Simple multiple and partial correlations. Problems of discrimination and classification, elements of factor analysis. Applications to analysis and interpretation 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 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 acceptable for graduate credit in Department of Mathematics. Prerequisite: MA 561.
Also listed under OR 608

MA 565† Intermediate Differential Equations 2½:0:3
Solution of ordinary differential equations. Applications to geometry and physics. Oscillation theory. Introduction to geometric theory, elementary critical points. Prerequisites: 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 153 or equivalent.

LOGIC AND FOUNDATIONS

MA 603 Symbolic Logic 2½:0:3
Formal, manipulative, symbolic logic. Russell's theory of types, existence 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. Designed to provide high school teachers with modern concepts to enrich their classrooms. 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
Designed to modernize overall viewpoint of secondary school teachers of mathematics. Implication for secondary school curriculum derived from study of sets, topology, transformations, types of geometries. Discussions of symbolic logic and deduction, algebraic structures, analysis, probability and statistical inference, selected related topics. 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-Nikodyrh 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 variable. Complex number system, differentiation and integration, analytic and meromorphic functions, residue theory, introduction to Riemann 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, measurable transformations, measures in locally compact topological spaces, measure and topology in groups, Haar measure, measures in functional spaces. MA 625 prerequisite: MA 624 or instructor's permission. MA 626 prerequisite: MA 625.

MA 630 Elements of Complex Variables 2½:0:3
Emphasis on analytic functions of single complex variable. Complex numbers, differentiation and integration, line integrals, Cauchy integral theory, power series, residues, brief introduction to multiple-valued functions. Acceptable for graduate credit only in departments other than mathematics. Prerequisites: MA 103 and MA 104.

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. Existence 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 equations in two variables, characteristics and classification, hyperbolic, parabolic and elliptic systems, wellposedness. Prerequisite: MA 645.

MA 649-650 Topics in Ordinary and Partial Differential Equations 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 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. Prerequisite: 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 asymptotic 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 operators 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. Extensions 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 cannonical 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 prerequisites: 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 MA 620.

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 770 Metric Differential Geometry 2½:0:3
Elements of metric geometry of curves and surfaces in Euclidean space. Plane and space curves, first and second differential forms of a surface, lines of curvature, asymptotic lines, geodesics, theorems of Meusinier, Euler, Gauss, Codazzi, special classes of surfaces, mapping problems. Prerequisites: MA 103 and MA 104.

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 786 Selected Topics in Topology 2½:0:3
Complex spaces (several complex variables), calculus of variations in the large (Morse theory), global differential geometry. Differential topology, homotopy theory. Prerequisites: 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, 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 805-806 Tensor Analysis I, II each 2½:0:3
Study of tensors beginning with their algebra in affine coordinates in ordinary Euclidean three-dimensional space. General concept of geometric objects in n-dimensional space, including co- and contra-variant tensors, densities, capacities and their classification. Calculus of tensor fields, metrics, differential operators, covariant derivative, curvature tensor, differential geometry of Riemannian spaces, parallel displacement, linear connections. Applications to mechanics of continuous media and theory of relativity. Prerequisites: MA 535 and MA 703.

MA 812-815, 817, 818 listed below under Probability, Statistics, Operations Research.

MA 819-820 Theory of Approximation **each 2½:0:3**
Theory and application of methods of fitting mathematical curves or surfaces to experimental data in two or three variables, including method of least squares, method 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 821-822 Numerical and Approximate Analysis I, II **each 2½:0:3**
Approximation of functions by polynomials. Interpolation. Numerical integration. Linear algebraic equations and eigenvalue-eigenvector problems. Numerical solution of equations. Numerical solution of ordinary and partial differential equations. Primarily intended for students in applied fields. MA 821 prerequisite: MA 153. MA 822 prerequisite: MA 821, MA 358 or equivalent.

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. Prerequisites: MA 821 and MA 153.

MA 825 Numerical Linear Algebra **2½:0:3**
Review of direct and iterative solutions of linear equations. Perturbation theory. Error analysis. LR and OR algorithms. Review of recent algorithms and publications. Prerequisite: MA 153.

MA 833 Partial Differential Equations of Mathematical Physics **3¾:0:4½**
First- and second-order partial differential equations and systems of equations. Initial and boundary value problems. Fundamental solutions and Green's functions. Theory of characteristics. Eigenvalue problems. Rayleigh-Ritz and Ritz-Galerkin methods. Approximate and asymptotic methods. Nonlinear equations and applications. Prerequisite: MA 202, or MA 212 or MA 620 or equivalent.

MA 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 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 632.

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, minimax theorems for eigenvalues of hermitian pencils. Illustrations drawn from continuum mechanics, electromagnetic theory, ordinary differential equations. 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 operators on metric, Banach and Hilbert spaces. Applications of functional analysis concepts to integral and differential operators of mathematical 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 problem for deterministic systems with various constraints. Solution for both continuous and discrete-time systems using maximum principle and dynamic programming. Hamilton-Jacobi theory as applied to synthesis problem. Optimization problems with state variable constraints. Prerequisites: MA 838 or EL 653 or EL 673.
Also listed under EL 823

MA 846 Fourier and LaPlace Transforms **2½:0:3**
Application of transform methods of partial differential equations of mathematical physics. Includes introduction to Wiener-Hopf technique. Prerequisites: MA 631 or MA 620 or MA 630.

MA 851-855, 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. Prerequisites: 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, post-optimality analysis. Degeneracy. Transportation and assignment problems. Applications, problem formulation, computer solution. Prerequisite: MA 153.
Also listed under OR 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 OR 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 817 Graph Theory **2½:0:3**
Concepts and theoretical considerations in structure and application of linear graphs. Representation of networks, operational configurations, physical structures of graphs. Problems of realizability and enumeration. Prerequisites: MA 153 and MA 223.

MA 818 Nonlinear Programming 2½:0:3
Optimization of nonlinear functions. Classical methods. Constraints and Lagrangian methods. Duality and economic interpretation. Separable programming, feasible directions, gradient projection. Quadratic and convex programming. Industrial and engineering applications. Prerequisite: MA 813.
Also listed under OR 832

MA 821-823, 831-832, 835-839, 841-842, 844, 848, listed above under Applied Mathematics.

MA 851 Probability Theory 3¾:0:4½
Second course in probability, at graduate level. Probability of events, distribution of random variables, joint distribution, characteristic functions, proofs of central limit theorem and laws of large numbers. Prerequisites: MA 103 and MA 104, MA 223 or equivalent.

MA 852 Stochastic Processes 3¾:0:4½
A first course in theory of stochastic processes with attention to epecific processes. Conditioning, normal and stationary processes, Wiener processes, Poisson and renewal processes, Markov chains and processes. Prerequisite: MA 851.

The following sequence, MA 853-855, covers material of MA 851-852 in three courses of three units each.

MA 853 Probability I 2½:0:3
Probability of events, distribution of random variables, joint distribution, transformations. Prerequisites: MA 103 and MA 104, MA 223 or equivalent.

MA 854 Probability II 2½:0:3
Characteristic 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. Prerequisite: MA 853 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 statistics. MA 861 prerequisite: MA 224 or equivalent. MA 862 prarequisite: 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 seta of means. Tests of general linear hypothesis. Some generalizations in analysis of variance. Prerequisite: MA 862 or MA 153.

MA 865-866 Regression and Analysis of Variance I, II each 2½:0:3
Linear regression on one or more independent variables. Least squara estimates of regression coefficients. Gauss-Markov theorem. Confidence regions for and tests of hypothesis about regression coefficients. Test of general linear hypothesis. Multiple classification in analysis of variance. Power of F-test. Alternative models: Models I and II, mixed models, analysis of covariance and components of variance. 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 of 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.

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/SA 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: hypotheses 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 623 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 pathe. Conditional expectation. Martingales. Classes of stochastic proceases, Gaussian processes, Markov processes, others. Second-order properties. Stationary processes. Applications. Prerequisite: MA 872 or equivalent.

MA 881-882 Statistical Analysis of Time Series I, II each 2½:0:3
Careful study of tractable models for statistical analysis of scaler 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 thase models, spectral representation and filtering, estimation of spectral density. Prerequisitas: MA 153, MA 852 and MA 862.

MA 931-932 Selected Topics in the Teaching of Mathematics I, II each 2½:0:3
Advanced or specialized topics relevant for the teaching of mathematics in grades 7-12.

READING, PROJECT, THESIS, DISSERTATION

MA 935 Applied Science Project Related to Public Administration I, II each 2½:0:3
This program is discussed in the catalog section on the Cooperative Program with the NYU Graduate School of Public Administration, see page 205.

MA 941-944 Reading in Mathematics I-IV each 2½:0:3
Coursee intended primerily for students who have completed two years of full-time graduate study and who wish to do research in specialized area. Reading done under guidance of

faculty member and devoted mainly to scholarly papers. Prerequisite: permission of department.

MA 951-952 Topics in Mathematical Biology I, II **each 2½:0:3**
Topic varies at discretion of instructor. Mathematical genetics, mathematics of circulatory system, biological application of stochastic processes, applications of wave equation in biology. Course designed so that visiting professor may lecture on special area of interest.

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 996 Project **each 3 units**
Teaching materials of mathematics in grades 7-12, selected and developed in consultation with a faculty member.

MA 997 Thesis for Degree 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 Degree of Doctor of Philosophy **each 3 units**
Results of independent investigation of some problem in mathematics. Must demonstrate ability to do creative work and include original research of caliber deemed worthy of publication in recognized scientific journals. Oral examination on subject of dissertation and related topics required. Minimum of 24 dissertation units required for degree. Reregistration fee, any part: 3-unit charge. Prerequisite: degree status and qualifying examination.

For statistics course listing, refer to separate section titled "Statistics."

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 Algebra	3 cr.
MA 154	Elements of Abstract Algebra	3 cr.
MA 177	Transformation Geometry	3 cr.
MA 178	Projective Spaces	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.
MA 238	Applied Probability	3 cr.
MA 531-532	Applied Mathematics in Engineering and Science I, II	3 units
MA 561	Elements of Probability	3 units
MA 562	Elements of Mathematical Statistics	3 units
MA 575	Differential Geometry	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 Terzuoli, Professor of Mathematics and Administrative Officer
B.S., Brooklyn College; M.S., New York University
Probability, statistics

George Bachman, Professor of Mathematics
B.E.E., M.S., Ph.D., New York University
Fields and valuations, Banach algebras, topological measure theory

Emeric Deutsch, Professor of Mathematics
B.S., Pedagogical Institute of Timisoara (Romania); M.S., Ph.D., Polytechnic Institute of Brooklyn
Matrix theory, functional analysis

Heinrich Guggenheimer, Professor of Mathematics
Dipl., Dr.Sc., Swiss Federal Institute of Technology, Zurich (Switzerland)
Differential equations, geometry-convexity

Leon H. Herbach, Professor of Mathematics
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

Clifford 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

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

William R. Allen, Associate Professor of Mathematics
B.Ed., Chicago Teachers College; M.S., Northwestern University
Data analysis, experimental design

Burton Lieberman, Associate Professor of Mathematics
B.A., Harvard University; M.S., Ph.D., New York University
Differential equations, stochastic processes

Edward Y. Miller, Associate Professor of Mathematics
B.A., University of Pennsylvania; M.A., Ph.D., Harvard University
Topology

Paul F. Pickel, Associate Professor of Mathematics
B.S., Ph.D., Rice University
Infinite groups, ring theory, algebraic topology

Lesley Sibner, Associate Professor of Mathematics
B.A., CCNY; M.S., Ph.D., New York University
Partial differential equations, global analysis

Hermann Waldinger, Associate Professor of Mathematics
B.A., Pomona College; M.Sc., Brown University; Ph.D., Columbia University
Combinatorial group theory

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

Anne Houtman, Assistant Professor of Mathematics
Lic. Math., University Catholique de Louvain (Belgium); M.A., Ph.D., Princeton University
Statistics

Kathryn Kuiken, Assistant Professor of Mathematics
B.A., M.A., Montclair State College; M.S., New York University; Ph.D., Polytechnic Institute of New York
Group theory

Erwin Lutwak, Assistant Professor of Mathematics
B.S., M.S., Ph.D., Polytechnic Institute of Brooklyn
Convexity

ADJUNCT FACULTY

Neil Bellinson, Lecturer
B.S., Polytechnic Institute of Brooklyn; M.S., Columbia University
Number theory, automorthic forms

Barbara Cain, Lecturer
B.S., Syracuse University; M.S., New York University
Ordinary differential equations

Barry Glotzer, Lecturer
B.S., M.S., Brooklyn College
Group theory, number theory, computer science

Wallace Goldberg, Lecturer
B.A., Yeshiva University; M.S., New York University; Ph.D., Polytechnic Institute of New York
Ordinary differential equations

Daniel Steinitz, Lecturer
B.Sc., Hebrew University, Jerusalem, Israel; M.Sc., New York University
Algebra and logic

EMERITUS FACULTY

Aaron Fialkow, Professor Emeritus
B.S., M.S., CCNY; Ph.D., Columbia University
Differential geometry, network theory

Ronald M. Foster, Professor Emeritus
B.A., Harvard; D.Sc. (Hon.), Farleigh Dickinson University
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 of these two degrees is offered at both the Brooklyn and the Farmingdale 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/fluids/energy field, 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 application of such principles to the problems of their profession. The sophistication of aerospace systems is such that students must necessarily master some of the more powerful analytic techniques in order to evolve an efficient design. 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, as well as assuming leadership roles in the aerospace industry.

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 emphasis is primarily on principles and concepts in fundamental and basic sciences.

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

The undergraduate program leads to the degree of bachelor of science in aerospace engineering and is accredited by the Accreditation Board for Engineering and Technology.

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 in mechanical engineering.

A valuable feature of the program is the availability of technical electives in each of the last four semesters. In consultation with a faculty adviser, the student may construct a minor in one of many technical areas outside traditional mechanical engineering. Alternatively, the student 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 programs lead to the degree of bachelor of science in mechanical engineering and are accredited 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 100AE	Intro. to Programming	2	0	2	AM 111	Mechanics I	3	0	3
HU 101	College Composition	3	0	3	HU 200	Intro. to Literature	3	0	3
SS 104	Contemp. World Hist.	3	0	3		Hum./Soc. Sci.[h]	3	0	3
PE 101	Physical Education	0	2	0	PE 102	Physical Education	0	2	0
				15					17

Sophomore Year

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	Structure of Metals	2	0	2
	Hum./Soc. Sci.[h]	3	0	3		Hum./Soc. Sci.[h]	3	0	3
PE 103	Physical Education	0	2	0	PE 104	Physical Education	0	2	0
				17					17

Junior Year

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.[h]	3	0	3		Hum./Soc. Sci.[h]	3	0	3
				18					18

Senior Year

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 electives[i]	9	0	9
AM 343	Aircraft Design II	2	3	3					16
	Free elective[f,r]	3	0	3					
				18					

Total credits required for graduation: 136

---

[f]Free electives are subject to a departmental adviser's approval.

[r]ROTC 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 131, 142, 143, 146, may be used to substitute for the free elective(s) which exist in the aerospace and mechanical engineering programs.

[i]Approved technical electives are listed as follows: AM 234, AM 262 and AM 282. The choice of any of the above electives or possible other technical electives must be accompanied by a departmental adviser's approval.

[h]Requirements in humanities and social sciences—the student 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).

In addition, the student is strongly urged to select an area 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 elect two or three courses in this concentration, in consultation with the departmental adviser. A modern language may be chosen as a suitable concentration but a student without prior knowledge of the language must plan to devote at least 12 credit hours to the subject.

For the remaining credits in the humanities/social sciences requirement, the student should select courses in areas other than that of the concentration. Additional courses in the humanities and social sciences may be taken 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 100ME	Intro. to Programming	2	0	2	CM 101	General Chemistry I	2½	0	2½
HU 101	College Composition	3	0	3	CM 111	General Chemistry Lab. I	0	1½	½
SS 104	Contemp. World Hist.	3	0	3	HU 200	Intro. to Literature	3	0	3
PE 101	Physical Education	0	2	0		Hum./Soc. Sci.[h]	3	0	3
				15	PE 102	Physical Education	0	2	0
									17

Sophomore Year

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	Structure of Metals	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		Hum./Soc. Sci.[h]	3	0	3
	Hum./Soc. Sci.[h]	3	0	3	PE 104	Physical Education	0	2	0
PE 103	Physical Education	0	2	0					17
				17					

Junior Year

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[f,r]	3	0	3		Free elective[f,r]	3	0	3
				16					18

Senior Year

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[s]	3	0	3		Technical elective[s]	3	0	3
	Hum./Soc. Sci.[h]	3	0	3		Hum./Soc. Sci.[h]	3	0	3
				18					18

Total credits required for graduation: 136

See footnotes on previous page.

[s]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 a student 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 ye r 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 basis. The fifth and sixth years are interchangeable as are the seventh and eighth. Thus, a student may graduate in eight years.

Course of Study for the Evening Program in Mechanical Engineering

First Year

First Semester			Hours/Week		Second Semester			Hours/Week	
No.	Subject	Cl.	Lab.	Cr.	No.	Subject	Cl.	Lab.	Cr.
HU 101	College Composition	3	0	3	MA 102	Calculus II	4	0	4
MA 101	Calculus I	4	0	4	PH 101	Introductory Physics I	3	0	3
				7	SS 104	Contemp. History	3	0	3
									10

Second Year

HU 200	Intro. to Literature	3	0	3	AM 101	Graphics (81-82, 83-84) *or*	1	3	2
MA 103	Calculus III	3	0	3	CS 100	Intro. to Programming (82-83, 84-85)	2	0	2
PH 102	Introductory Physics II	3½	1½	4	MA 104	Applied Diff. Equations	3	0	3
				10	PH 103	Introductory Physics III	2½	1½	3
									8

Third Year

AM 116	Engineering Mechanics I	2	0	2	AM 117	Engineering Mechanics II	2	0	2
CM 101	General Chemistry I	2½	0	2½	AM 101	Graphics (81-82, 83-84) *or*	1	3	2
CM 111	General Chemistry Lab. I	0	1½	½	CS 100	Intro. to Programming (82-83, 84-85)	2	0	2
	Hum./Soc. Sci. elective	3	0	3	CM 102	General Chemistry II	2½	0	2½
				8	CM 112	General Chemistry Lab. II	0	1½	½
									7

Fourth Year

AM 118	Engineering Mechanics III	2	0	2	MT 302	Structure of Metals	2	0	2
AM 121	Mechanics of Materials	3	0	3		Science elective	3	0	3
	Hum./Soc. Sci. elective	3	0	3		Hum./Soc. Sci. elective	3	0	3
				8					8

Fifth Year* (81-82, 83-84)

MA 333	Partial Diff. Equations	3	0	3	AM 231	Fluids I	3	0	3
AM 201	Thermodynamics I	3	0	3	AM 252	Dynamic System Response	3	0	3
	Hum./Soc. Sci. elective	3	0	3		Hum./Soc. Sci. elective	3	0	3
				9					9

Sixth Year* (82-83, 84-85)

AM 271	Fund. Stress Analysis I	3	0	3	AM 272	Stress Anal. of Mech. Comp.	3	0	3
AM 302	Anal. & Design of Mach. El.	3	0	3	AM 301	Synth. of Mech. Systs.	3	0	3
	Free elective	3	0	3		Free elective	3	0	3
				9					9

Seventh Year† (81-82, 83-84)

AM 202	Thermodynamics II	3	0	3	AM 232	Fluids II	3	0	3
AM 261	Vibrations	3	0	3	AM 321	Instrumentation & Control	3	0	3
AM 351	ME Laboratory I	½	1½	1	AM 352	ME Laboratory II	½	1½	1
				7		Technical elective	3	0	3
									10

Eighth Year† (82-83, 84-85)

AM 203	Heat Transfer	3	0	3	AM 204	Design of Energy Transfer	3	0	3
AM 331	Comp. Meth. in Design	2	3	3	AM 353	ME Laboratory III	½	1½	1
AM 361	Project Proposal	0	6	2	AM 362	ME Project	0	6	2
				8		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 PROGRAMS

Programs of study are offered leading to the degrees of master of science, engineer, and doctor of philosophy in mechanical engineering, in aeronautics and astronautics and in applied mechanics. In mechanical engineering the student may specialize in either (1) the mechanical analysis and design option or in (2) the thermal/fluids/energy option. A bachelor's degree in mechanical, aerospace, civil or chemical engineering is 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'S DEGREE

Core Courses:

A. For mechanical engineering (mechanical analysis and design option) and for applied mechanics

AM 601-02	Stress Analysis I & II	6
AM 651-52	Advanced Dynamics I & II	6
or		
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 740	Principles of Fluid Dynamics	3
AM 710	Convection	3
AM 971-72	Seminar in Mechanical and Aerospace Engineering	0
		9

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 603-04	Elasticity I & II	6
AM 613-14	Theory of Plates and Shells	
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 & Shells	6
	Electives[1]	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	Conduction 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—Aeronautics 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 a student 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 the student in departmental courses (including thesis or project) at Polytechnic.

The department limits to nine the total of transfer, readings (guided studies), and validation credits that can be offered for the master's degree. The certification of validation credits is administered by the departmental graduate advisers.

A student must establish an overall B average in those departmental courses submitted in partial fulfillment of the degree requirements. All courses submitted for the degree must have been completed within the four-year period prior to the awarding of the degree.

[1]Either the core courses or the electives must include AM 651-52, Advanced Dynamics I & II.

REQUIREMENTS FOR THE ENGINEER DEGREE

A master's degree in mechanical, aerospace, civil or chemical engineering that meets one of the department specialization area requirements is generally required. Applicants with master's degrees not meeting these requirements may be conditionally admitted with deficiencies as evaluated by a departmental graduate adviser. Each candidate must complete a program of study of at least 36 units beyond the master's degree as approved by an appropriate departmental graduate adviser. This program of study will normally include at least 24 units of work within the department; part of this work will include a project of 6 but not more than 12 units. Course work may be substituted for the project if the applicant's background includes 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.

A student must establish an overall B average in those departmental courses submitted toward fulfillment of the degree requirements.

REQUIREMENTS FOR THE DOCTOR'S DEGREE

A master's degree in mechanical, aerospace, civil or chemical engineering that meets one of the department's area requirements is generally required. Applicants with degrees not meeting these requirements may be admitted with credit for previous work as evaluated by a departmental graduate adviser.

Each candidate for the Ph.D. must complete a minimum of 36 units of approved courses beyond the master's degree. In addition, registration for a minimum of 24 units of dissertation research is required at the rate of a minimum of three units per term, continuously, until the dissertation is completed and accepted. Satisfactory attendance in 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 of the degree.

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 student's major.

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 analysis of trusses, frames and machines. Friction, impending motion. Method of virtual work. Potential energy and stability of equilibrium. Prerequisites: PH 101 and **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 analysis of trusses, frames and machines. Friction, impending motion. Prerequisites: PH 101 and **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
Method 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
Basic energy concepts. Fundamental laws of thermodynamics. Properties of working substances. Open and closed systems. General applications to various engineering systems. Prerequisites: MA 103 and PH 102.

AM 202 Thermodynamics II 3:0:3
Continuation of AM 201. Applications of laws of thermodynamics to power-producing cycles and to refrigeration cycles. Properties of mixtures. Energy and equilibrium aspects of chemical reactions. Introduction to kinetics of combustion. Prerequisite: AM 201.

AM 203 Heat Transfer 3:0:3
Introduction to conduction, convection and radiation heat transfer. Steady-state and transient analysis 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. Application of first and second laws of thermodynamics to design and evaluation of energy conversion cycles. Detailed heat exchanger or energy system design required of student. Prerequisites: AM 202 and AM 203.

AM 211 Statistical Thermodynamics* 3:0:3
Review of elementary probability theorems, 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. Calculation of transport properties. Senior elective. Prerequisite: AM 201.

AM 212 Air Conditioning and Refrigeration* 2:0:2
Application of thermodynamics and other sciences needed for rational approach to solution of engineering problems in air conditioning and refrigeration. Senior elective. Prerequisite: AM 201.

AM 213 Transport Processes* 3:0:3
Extension of principles developed in AM 201, AM 203 and AM 231. Detailed study of 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
Introduction to fluids, kinematics, hydrostatics, thermodynamics. Derivation of continuity, momentum and energy equations. Flux concepts and relation with divergence theorem. Control volume equations and applications. Differential equations and applications. Bernoulli equation. Discussion of vorticity and stream function. Potential flows over simple geometric configurations. 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 oblique 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. Introduction to turbulent boundary layer theory. Prerequisite: AM 232.

AM 234 Fluids IV 3:0:3
Review of fluid dynamic equations. Incompressible airfoil theory, circulation, lift, Kutta condition. Finite wing theory. Acoustic motion. Method of characteristics. Compressible airfoil theory. Oblique shocks and expansion fans. Prerequisite: AM 232.

AM 241 Propulsion 3:0:3
Basic principles of 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. Prerequisites: AM 233 and AM 311.

AM 242 Rocket Propulsion* 3:0:3
Introduction to 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 end 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 333.

AM 252 Dynamic Systems Response 3:0:3
Basic dynamic behavior of mechanical, fluid, thermal and electrical elements from 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
Review of mechanics of vibrating systems. Equations of motion, Lagrange's equation 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 response 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. Introduction to analysis of nonlinear oscillatory systems. Prerequisite: AM 261.

AM 271 Fundamentals of Stress Analysis I 3:0:3
Stress and strain in two dimensions. Equilibrium equations, compatibility, superposition. Cylindrical coordinates: thick-walled cylinders. Plane stress, plane strain. St. Venant's principle. Stress concentrations. Torsion of mechanical elements: solid sections. Pure bending; bending of thin-walled, unsymmetric, open-section beams. Shear center. Initial curvature and axial load effects on bending. Prerequisites: 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 columne, 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
Introduction to matrix algebra. Matrix analysis of framed structures: truss, beam, frame, grid. Static and kinematic indeterminacies. Flexibility and stiffness coefficients, reciprocal rela-

tions, symmetry. Displacements in determinate structures. Flexibility and stiffness methods applied to statically indeterminate structures. Current programming techniques. Prerequisite: AM 281.

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 mechine 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, stability derivations, longitudinal and lateral-directional 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 feedback principles to machine systems. Use of classical and transform methods for transient and steady-state solutions. Prerequisite: AM 321.

AM 331 Computer Methods in Design 2:3:3
Introduction to computer as design tool. Discussion of visual displays. Drawing and design capability of modern computing systems. Iteration, parametric studies and optimization of mechanical engineering designs. Studies and design projects from thermal, fluid and mechanical systems. Efficient numerical computational techniques. Prerequisites: CS 100 and junior status.

AM 341 Introduction to Aerodesign 2:3:3
Consideration of the nature of design synthesis and analysie as it pertains to aerospace. Qualitative and quantitative aspects of feasibility, design methodology, modeling, use of computers, iteration and optimization in terms of design project. 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 analysis, airload estimation. Prerequisite: AM 341.

AM 343 Aircraft Design II 2:3:3
Structural design of airplane based on specification and aerodynamic requirements. Discussion of construction materials, forming, fasteners, fittings. Structural arrangement of landing gear, fuselage, stress analysis. Prerequisite: AM 342.

AM 344 Spacecraft Design 2:3:3
Design of hypervelocity vehicles. Trajectory and orbit analysis, 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. Prerequisites: **AM 201** and **AM 112.**

AM 352 ME Laboratory II ½:1½:1
Experiments related to thermodynamics, fluid properties, systems dynamics, vibrations. 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.

AM 381-382 Senior Honors Work in Mechanical Engineering 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 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 theorem 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. Torsion of prismatic bars, open and closed thin-walled structures, and multi-cellular structures.

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. Prerequisite: adviser's approval.

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 load-carrying 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 field, 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, thermo-elasticity, plasticity, 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 equilibrium considerations. Equilibrium equations and boundary conditions derived from energy principles. Exact and approximate solutions (series, Rayleigh-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: adviser's approval.

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. Application to problems of technical interest associated with structures and vehicles. Prerequisite: adviser's approval.

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, platea and shells under static and dynamic loads. Emphasis on problems involving analysis of systems with many unknowns. Prerequisite: adviser's approval.
Also listed under CE 616

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 structurel analysis. Particular attention to continuum techniques such as Fourier, Ritz, Galerkin, least square and collocation methods. Prerequisite: adviser's approval.

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. 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. Prerequisite: adviser's approval.
Also listed under CE 623

AM 626 Advanced Topics in Experimental Stress Analysis* 1½:2½:3
Course orientation is toward advanced research. Introduction to modern optics followed by analysis of optical image formation. Theory of holography and wave propagation in anisotropic media; advanced topics in three-dimensional photoelasticity, moire analysis of tree-dimensional 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. Prerequisite: adviser's approval.

AM 632 Piping Analysis 2½:0:3
Free thermal deformations and stresses in piping branches. Free deformations due to weight, wind and seismic loading. Support reactions. Matrix methods for load transfer, axes transformation and deformation transfer. Flexibility and stiffness matrices. Elastic center analysis. Flexibility and stiffness methods. Prerequisite: AM 601.

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.

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. Prerequisite: adviser's approval.

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 formulations, applications. Variational principles including Hamilton's principle and simple applications to optimization. Prerequisite: adviser's approval.

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. Prerequisite: adviser's approval.

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
Theory of vibration of multidegree of freedom systems. Normal mode expressions of undamped and damped systems. Lagrange's equation. Response of continuous systems. Emphasis on methods suitable for analysis of large complex systems by digital computer. Prerequisite: adviser's approval.
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. Prerequisites: 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: adviser's approval.

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. Prerequisite: adviser's approval.

AM 672 Kinematic Synthesis of Mechanisms* 2½:0:3
Kinematic analysis of planar motion. Geometric and algebraic methods in linkage synthesis for path and function generation. Errors in dimensional synthesis. Euler-Savary equation and the cubic of stationary curvature. Cognate linkages, Roberts-Chebyshev theorem. Synthesis of spatial linkages. Prerequisite: adviser's approval.

AM 675 Mechanical Servomechanisms I* 2½:0:3
Analysis of linear control and feedback systems. Feedback loops, transfer functions and block diagrams. Proportional, rate, integral control. Root-locus method, Bode and Nyquist plots, stability criteria. Prerequisite: adviser's approval.

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 for 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 653.

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. Prerequisite: adviser's approval.

AM 685 Noise and Acoustics I* 2½:0:3
Survey of mathematical methods, random signals, acoustic fields, room acoustics, subjective criteria, environmental criteria. Prerequisite: adviser's approval.

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. Estimation of road noise. Problems of subway noise. Techniques of measurement. Environmental impact. Prerequisite: AM 685.

AM 687 Acoustic Radiation from Submerged Structures* 2½:0:3
Wave equation and elementary solutions. Helmholtz integral formulation. Radiation from submerged plates and shells and associated sound radiators; scattering of sound by rigid and elastic scatterers; creeping waves. Prerequisite: adviser's approval.

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 2½:0:3
Critical study and review of classical thermodynamics. Availability functions, general thermodynamic relations, equations of state, general thermodynamic equilibrium criteria. Prerequisite: adviser's approval.

AM 702 Thermodynamics II* 2½:0:3
Continuation of AM 701. Application of thermodynamic equilibrium criteria to various problems, including chemical reactions. Prerequisite: AM 701.

AM 703 Combustion* 2½:0:3
Thermodynamics and chemical kinetics of reacting gases. Calculation of equilibrium and transport properties. Gas dynamics of multiphase flow. Prerequisite: AM 701 or adviser's approval.

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 709 Special Topics: Thermodynamics and Combustion* 2½:0:3
Topics of particular current interest in thermodynamics and combustion. Prerequisite: adviser's approval.

AM 710 Convection 2½:0:3
Development and applications of laminar hydrodynamic and thermal boundary layer equations for fluid media. Mechanics of turbulence; formulation and analysis of turbulent hydrodynamic and thermal boundary layer equations. Coupled hydrodynamic and thermal applications: natural convection and film evaporation and condensation. Prerequisite: AM 740 or equivalent.

AM 711 Convective Heat Transfer* 2½:0:3
Theory of free and forced convective systems. Equations for heat transfer coefficients in compressible and incompressible fluids are developed from boundary layer concepts. Applications to internal and external laminar and turbulent flows. Prerequisite: AM 710.

AM 712 Conduction 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. Equation of transfer, radiative heat flux 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: 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: advisers approval.
Also listed under NU 715

AM 716 Reactor Heat Transfer* 2½:0:3
Heat transfer problems and solution techniques associated with nuclear reactors including BWR, PWR, LMFBR and HIGR's. Representative core geometries and primary loop components. Flow boiling phenomena, liquid metal heat transfer, combined convection and radiation gas flow. LOCA and ECCS considerations. Prerequisite: AM 715 or AM 203.
Also listed under NU 716

AM 717 High-Performance Heat Exchangers* 2½:0:3
Heat exchanger requirements including need for augmentation. Review of 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.

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, 710, 740 or adviser's approval.

AM 729 Special Topics: Heat Transfer* 2½:0:3
Topics of particular current interest in heat transfer. Prerequisite: adviser's approval.

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

AM 732 Computational Methods in Thermal and Fluid Mechanics 2½:0:3
Review of 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: adviser's approval.

AM 740 Principles of Fluid Dynamics 2½:0:3
Conservation laws of mass, momentum and energy. Elements of potential theory end gas dynamics. Application of inviscid flow to simple internal and external geometries; control volume and differential approach to fluid dynamic problems. Prerequisite: adviser's approval.

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

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

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

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 chennels including effects of viscosity, heat transfer, mass transfer. Prereq-uisites: AM 741 and AM 742.

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

AM 746 Fluid Dynamics of Rotating Machinery* **2½:0:3**
Methods of analysis of flow in rotating machines. Cascades, performance, radial equilibrium, secondary flows, viscous flows. Supersonic and transonic flows in compressors and turbines. Prerequisite: 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-density flows of neutral and ionized gases. Selected applications to flight problems, heat transfer and vacuum technology. Prerequisite: 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: 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: 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.
Also listed under CE 763

AM 752 Aerodynamics of Urbsn 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.
Also listed under CE 764

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. Determination 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. Application to measurements of forces, pressures, heat transfer, velocity and electron density. Schlieren, interferometry, laser, Raman scattering, etc. Prerequisites: AM 741 and AM 742.

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 conversion 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 tamperature processes. Direct, diffuse and ground-reflected solar radiation, sun angles, active and passive solar heating systems, fundamentals of heat transfer applied to 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: undergraduate engineering degree.

AM 764 Soler Thermal Engineering II **2½:0:3**
Extension of AM 763 to more advanced solar heating topics plus cooling and dehumidification. 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: undergraduate engineering degree.

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 artificial atmospheres on human performance. Energy requirements and alternatives. Prerequisite: adviser's approval.

AM 769 Special Topics: Energy Conversion* **2½:0:3**
Topics of particular current interest in energy conversion. Prerequisite: adviser's approval.

AM 801 Trajectories and Orbits* **2½:0:3**
Two-body problem, formulas for orbital motion, optimum orbit transfer and rendezvous problem, interplanetary trajectories. Re-entry trajectories, maximum acceleration and heat transfer, effect of aerodynamic lift. Prerequisite: adviser's approval.

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, particle motion in central force field, launch and re-entry trajectories. Land and seaborne vehicles: automobile, tracked vehicles, ship and GEM vehicles. Prerequisite: adviser's 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. Prerequisite: AM 803.

AM 806 Physics of the Atmosphere* **2½:0:3**
Origin of solar system, planets, atmospheres. Structures, composition 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 dynamics, mesosphere, thermosphere. Prerequisite: graduate status or instructor's permission.
Also listed under EL 683

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, thermochemistry of solid and liquid rocket engines. Engineering parameters in engine design. Prerequisite: 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: 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: adviser's approval.

AM 819 Special Topics: Aeronautics and Astronautics* **2½:0:3**
Topics of particular current interest in aeronautics and astronautics. Prerequisite: 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 department 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. Discussion 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 member. Project title to be 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 candidate. Continuous registration required until satisfactory project completed. Minimum of 6, maximum of 12 units counted toward degree. 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 units per semester required until dissertation completed. Reregistration fee: 3-unit charge. Prerequisite: degree status.

FACULTY

Richard S. Thorsen, Department Head Mechanical and Aerospace Engineering
B.M.E., CCNY; M.M.E., Ph.D., New York University
Heat transfer, nuclear reactor safety, solar energy

Vito D. Agosta, Professor
B.M.E., Polytechnic Institute of Brooklyn; M.S., University of Michigan; Ph.D., Columbia University
Propulsion, heat power, heat transfer

Anthony E. Armenakas, Professor
B.S., Georgia Institute of Technology; M.S., Illinois Institute of Technology; Ph.D., Columbia University
Vibration, dynamic analysis of structures, fracture

William Blesser, Professor
B.M.E., Rensselaer Polytechnic Institute; M.E.E., Polytechnic Institute of Brooklyn
Bioengineering, instrumentation, control systems

Martin H. Bloom, Institute Professor
B.M.E., M.S., Ph.D., Polytechnic Institute of Brooklyn
Fluid and thermal studies, aerospace engineering, energy conversion

Robert J. Cresci, Professor and Director of Aerodynamics Laboratories
B.Ae.E., M.Ae.E., Ph.D., Polytechnic Institute of Brooklyn
Gas dynamics, heat and mass transfer, industrial aerodynamics

John R. Curreri, Professor
B.M.E., M.E.E., Polytechnic Institute of Brooklyn; M.S., Adelphi University
Nonlinear vibrations, stress analysis, earthquake response of structures

Burton Erickson, Professor
B.Ae.E., M.S., Polytechnic Institute of Brooklyn
Experimental stress analysis, mechanics

Murray Imber, Professor
B.S., University of Illinois; M.S., Eng. Sc.D., Columbia University
Energy conversion, heat transfer, applied mathematics

Joseph Kempner, Professor
B.Ae.E., M.Ae.E., Ph.D., Polytechnic Institute of Brooklyn
Structural analysis, shell theory, structural dynamics

Jerome M. Klosner, Professor
B.C.E., CCNY; M.S., Columbia University; Ph.D., Polytechnic Institute of Brooklyn
Structural dynamics, fluid-structure interaction, thermal stress analysis

Samuel Lederman, Professor
Dipl.Ing., Technical University of Munic (Germany); M.E.E., Polytechnic Institute of Brooklyn
Wind and shock tunnel testing, diagnostics of fluids, microwaves, spectroscopy, lasers, plasma

Morris Morduchow, Professor
B.A., Brooklyn College; B.Ae.E., M.Ae.E., D.Ae,E., Polytechnic Institute of Brooklyn
Fluid dynamics, solid dynamics, numerical analysis

Gino Moretti, Professor
Ph.D., University of Turin (Italy)
Fluid mechanics, numerical techniques

Wheeler K. Mueller, Jr., Professor
B.S., Iowa State College; M.S., Ph.D., University of Illinois
Heat transfer, thermodynamics, and energy conversion

Sebastian V. Nardo, Professor and Administrative Officer, Farmingdale
B.M.E., M.Ae.E., Ph.D., Polytechnic Institute of Brooklyn
Structural mechanics, dynamics, solar energy

Huo-Hsi Pan, Professor
B.S., National Southwest Associated University (China); M.S., Texas A&M; M.S., Kansas State University; Ph.D., University of California (Berkeley)
Solid mechanics, rational design, applied mathematics

Sharad A. Patel, Professor
B.Sc., Banares Hindu University (India); M.Ae.E., Ph.D., Polytechnic Institute of Brooklyn
Solid mechanics, creep, structural analysis

Frank J. Romano, Professor and Administrative Officer, Brooklyn
B.M.E., M.S., Ph.D., Polytechnic Institute of Brooklyn
Solid mechanics, structures, shell theory, thermodynamics

Pasquale M. Sforza, Professor
B.Ae.E., M.S., Ph.D., Polytechnic Institute of Brooklyn
Theoretical and experimental fluid dynamics, fluid power engineering

Bernard W. Shaffer, Professor
B.M.E., CCNY; M.S., Case Institute of Technology; Ph.D., Brown University
Rational design, elasticity and plastic stress analysis

Simon Slutsky, Professor
B.C.E., CCNY; M.S., Columbia University; Ph.D., Polytechnic Institute of Brooklyn
Urban noise, engine noise, vibrations of systems

Gordon H. Strom, Professor
B.Ae.E., M.S., Ph.D., University of Minnesota
Applied aerodynamics, subsonic wind tunnels, atmospheric pollution

William P. Vafakos, Professor
B.M.E., M.M.E., Ph.D., Polytechnic Institute of Brooklyn; J.D., Brooklyn Law School
Solid mechanics, structures

Philip Abrami, Associate Professor
B.M.E., M.S., Polytechnic Institute of Brooklyn
Mechanical analysis and design, sport product engineering

Philip Chaikin, Associate Professor
B.S., CCNY; B.M.E., New York University
Graphics, computer programming

Robert Corry, Associate Professor
A.B., Columbia College; B.S., M.S., Ph.D., Columbia University
Applied instrumentation, servomechanisms

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

Bernard Grossman, Associate Professor
B.S., Ac.E., M.S., Ph.D., Polytechnic Institute of Brooklyn
Computational fluid mechanics, aerodynamics

Morris P. Isom, Associate Professor
A.B., Harvard University; M.S., Massachusetts Institute of Technology; Ph.D., Princeton University
Acoustics, gas dynamics, applied mathematics

August R. Krenkel, Associate Professor
B.S., M.S., Massachusetts Institute of Technology
Atmospheric flight dynamics, applied aerodynamics, aircraft design

Jack E. Werner, Associate Professor
B.S., M.S., Massachusetts Institute of Technology; Ph.D., The Johns Hopkins University
Low-speed aerodynamics, shock waves, fluid mechanics

Barry M. Wolf, Associate Professor
B.M.E., Cooper Union; M.S., University of Pennsylvania; Eng. Sc.D., Columbia University
Vibrations, stress analysis, biomechanics

ADJUNCT FACULTY

Jack Como, Adjunct Professor
B.M.E., M.E.E., New York University; M.B.A., Adelphi University
Vibrations, systems analysis

Mansuk Lee, Industry Professor
B.S., M.S., Massachusetts Institute of Technology; M.E., Columbia University
Computer graphics

Irving Ojalvo, Adjunct Professor
B.M.E., CCNY; S.M., Massachusetts Institute of Technology; ScD., New York University
Applied mechanics, numerical methods

Clifford Wojan, Adjunct Professor
B.M.E., M.M.E., Polytechnic Institute of Brooklyn; M.I.E., New York University
Thermodynamics, energy conversion

Tio C. Chen, Adjunct Associate Professor
B.S., National Taiwan University (Taiwan); M.S., University of Kansas; Sc.D., Columbia University
Energy conversion, environmental impact

Beauvais Fox, Adjunct Assistant Professor
B.S., Lehigh University
Graphics, engineering economics

Je Chul Kim, Adjunct Associate Professor
B.S., Masachusetts Institute of Technology; M.S., Northeastern University; Ph.D., Purdue University
Thermodynamics, heat transfer

Edward Pinnes, Adjunct Associate Professor
B.M.E., M.S., New York University; Ph.D., Polytechnic Institute of New York
Thermodynamics, heat transfer

Donald J. Render, Adjunct Associate Professor
B.S., University of Illinois; M.S., Massachusetts Institute of Technology; Ph.D., New York University
Fluid mechanics, heat transfer

Arthur Rubel, Adjunct Associate Professor
B.M.E., CCNY; M.M.E., Ph.D., New York University
Fluid dynamics, numerical analysis

Robert DiMarco, Adjunct Lecturer
B.S.Ae.E., Polytechnic Institute of Brooklyn; M.S., Long Island University
Computer graphics

Richard LaRosa, Adjunct Lecturer
B.E.E., M.S., D.E.E., Polytechnic Institute of Brooklyn
Solar energy

Michael London, Adjunct Lecturer
B.S., M.S., Ph.D., New York University
Flight mechanics, stability and control

Anil Padhye, Adjunct Lecturer
B.S., Indian Institute of Technology (Bombay); M.S., Polytechnic Institute of New York
Thermodynamics, laboratories

Bernard Roth, Adjunct Lecturer
B.M.E., M.S., CCNY
Graphics, mechanics

John Sposito, Adjunct Lecturer
B.S.Ae.E., M.S., Polytechnic Institute of Brooklyn
Aircraft design, mechanics

Steven Vitale, Adjunct Lecturer
B.M.E., M.M.E., M.C.E., Polytechnic Institute of New York
Fluid mechanics, heat transfer

METALLURGY: PHYSICAL AND ENGINEERING

Human civilization dawned with the transition from the stone to the iron age. Ever since, metallic materials have been the pacesetters of our technological advancement. Metallurgists are specialists in the most effective utilization of metals and alloys. 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 two decades, we have witnessed an increasing demand for such familiar materials as high-strength steels, aluminum, magnesium and copper alloys, and the utilization of some less common metals such as titanium, beryllium and molybdenum. Yet we have utilized only a fraction of the theoretical potentials of metallic materials. Thus a challenge remains for imaginative individuals to probe, understand and use metallic materials in fields ranging from electronic devices, to new energy production processes, to chemical production and space environment. The broad field of metallurgy may be divided into several areas of specialization. The most important of these are physical and engineering metallurgy, which are emphasized at Polytechnic.

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 behavior of metals and alloys. Chemical composition, atomic bonding, crystal structure and microscopic imperfections are correlated with the strength and other physical and chemical properties 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 nonmetallic materials such as ceramics and glasses, semiconductors, ionic solids and even polymers.

Engineering Metallurgy

In engineering metallurgy, attention is focused directly on the engineering application of metallic materials. Metallurgical engineers play a vital role in materials selection and process optimization. They have a thorough knowledge of existing metallic materials, their properties and limitations. Borrowing fundamental knowledge from physical metallurgy, they are constantly in search of a new and better material to improve a process or a product. Some of the areas in which a metallurgical engineer works are prevention of corrosion and environmental degradation, welding, brazing and joining of metals and alloys, failure analysis and product reliability and safety, quality control, materials characterization, and alloy development.

Metallurgists may work in research and development, plant operations or consulting. Further, metallurgists contribute to the progress in oceanography, medical prosthetics, dental materials, environmental protection and electronic devices.

Programs of study in this department lead to the degrees of bachelor of science, master of science and engineer in metallurgical engineering and to the degree of doctor of philosophy in physical metallurgy, materials science and metallurgical engineering and materials science. The undergraduate program is accredited by the Accreditation Board of Engineering and Technology.

UNDERGRADUATE PROGRAM

The program of full-time day 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 aim, providing the capability to solve present problems and the ability to keep pace with the technological advancements and increasingly complex problems of the future.

Specifically, the curriculum consists of 33 credits in mathematics, physics and chemistry, 24 credits in the humanities and social sciences, 60 credits in engineering sciences, material sciences, engineering design and systems, 9 credits of technical electives, 3 credits of free electives and 7 credits of thesis.

Students will have an opportunity to select physical metallurgy or metallurgical engineering technical electives. The materials science oriented student may choose the former program, while the student interested in the industrial aspects of materials may select the latter. The technical elective structure also

allows students to branch out into interdisciplinary fields by taking courses in bioengineering, polymeric materials, physics or chemistry.

Humanities and social science requirements for all engineering students are given on page 23.

The freshman and sophomore years of the metallurgical engineering curriculum may be taken at the Farmingdale campus. The junior and senior metallurgy courses are only offered on the Brooklyn campus. Any of the non-metallurgy courses listed in the last two years may also be taken at the Farmingdale campus provided they are offered.

Typical Course of Study for the Bachelor of Science Degree in Metallurgy

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	College Composition	3	0	3	HU 200	Intro. to Literature	3	0	3
SS 104	Contemp. World Hist.	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 111	Intro. to Computers	3	0	3
PE 101	Physical Education	0	2	0	PE 102	Physical Education	0	2	0
				16					17

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. Physics III	2½	1½	3	AM 121	Mechs. of Materials	3	0	3
MA 103	Calculus III	3	0	3	MA 104	Appl. Ord. 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	3
				15		Elective*	3	0	3
									16

Junior Year

MT 402	Mechan. Metallurgy I	3	3	4	CM 161	Physical Chemistry I	3	0	3
MT 401	Physical Metallurgy I	3	0	3	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 Thermodynamics	3	0	3	MT 407	Metallurgy Transport	3	0	3
	Hum./Soc. Sci. elective	3	0	3	MT 408	Phys. Metallurgy Lab.	0	6	2
	Elective*	3	0	3	MT 495	Thesis	0	3	1
				18		Hum./Soc. Sci. elective	3	0	3
									18

Senior Year

MT 421	Metal. Failure Anal.	1	6	3	MT 411	Fabrication Technology	3	0	3
MT 416	Electrometal. & Corrosion	3	0	3	MT 413	Process Metallurgy	3	0	3
MT 412	X-Ray Diffraction	2	3	3	MT 423	Ceram. & Refrac. Mat.	3	0	3
MT 410	Solid-State Metallurgy	3	0	3	MT 497	Thesis	0	9	3
MT 496	Thesis	0	9	3		Hum./Soc. Sci. elective	3	0	3
	Elective*			3		Elective*	3	0	3
				18					18

Total credits required for graduation: 136

*The 12 credits of electives taken during the last three years comprise 9 credits of technical electives and 3 credits of free electives.

GRADUATE STUDY

The Department of Physical and Engineering Metallurgy prepares students for the degrees of master of science and engineer in metallurgical engineering and doctor of philosophy in physical metallurgy, in materials science and in metallurgical engineering and materials science. The courses of study and research leading to these degrees are designed for students holding baccalaureate degrees in metallurgical engineering but are open to those holding baccalaureate degrees in related disciplines if undergraduate deficiencies are removed.

Both fundamental and applied research are carried on within the department. Excellent facilities are available for work in electron microscopy, X-ray diffraction, deformation and fracture and other fields. Fundamental research is being carried out on alloy hardening, deformation and fracture, phase transformations, thermomechanical working and other topics. In applied research, the department is involved in studies of metallurgical materials for medical and dental applications, electronic applications and energy-related applications. The rules governing admittance to graduate studies are applicable to all students.

REQUIREMENTS FOR THE MASTER'S DEGREE

No.	Required Subjects	Units
MT 760-761	Seminar (attendance required two semesters)	3
MT 996	Project (part-time students only)	6
Nine units from the following:		
MT 600	Structure-Property Relationships in Materials	3
MT 610	Thermodynamics of Metals and Alloys	3
MT 620	Plastic Deformation and Fracture	3
MT 630	Theory of Metals	3
MT 640	Reactions in Solids	3
MT 650	Advanced Engineering Metallurgy	3
Selected electives in science, mathematics, economics or engineering, in consultation with department adviser up to		18
or		
MT 997 Thesis		12
	Total	36

In order to be admitted to the master's program, an applicant must have the equivalent of a bachelor's degree in metallurgy or materials science. An applicant with a bachelor's degree in a field of science or engineering other than metallurgy or materials science may have to remove some undergraduate deficiencies as determined by the department adviser.

A graduate student enrolled in the master's program may elect to do a six-unit project, a 12 unit thesis, or under special circumstances take a series of recommended courses and pass an oral examination. A total of 36 units is required for the degree.

Part-time students enrolled for the M.S. degree in metallurgical engineering may elect to take the following groups of courses which emphasize engineering metallurgy.

Required Subjects:		Units
Take nine units from:		
MT 600	Structure-Property Relationships	3
MT 610	Thermodynamics of Metals and Alloys	3
MT 620	Plastic Deformation and Fracture	3
MT 630	Theory of Metals	3
MT 640	Reactions in Solids	3
MT 650	Advanced Engineering Metallurgy	3

Metallurgy Department Electives

Take 15 to 18 units from:		
MT 700	Welding Engineering	3
MT 705	Semiconductor Technology	3
MT 715	Corrosion & Oxidation	3
MT 621	Special Topics: Fracture Mechanics	3
MT 651	Special Topics: Non-Destructive Testing	3
MT 726	Nuclear Reactor Materials	3
MT 710	Powder Metallurgy	3

Engineering & Science Electives

Take 6 to 9 units from:		
IE 611	Statistical Quality Control	3
OR 608	Statistics	3
MA 561	Probability	3
MG 600	Management Process	3
MG 601	Organizational Behavior	3
IE 685	Reliability	3

Project

Take 3 to 6 units		
MT 996	Project	3 to 6
		36

REQUIREMENTS FOR THE ENGINEER DEGREE

Applicants for admission to this program must hold a master's degree (or equivalent) comparable in content to that of the department. This must include at least the equivalent of the required courses in the MT 600-650 series listed under the requirements for the master's degree. 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 departmental graduate adviser, are removed during the time that the student is enrolled in the program.

No.	Required Subjects	Units
MT 621-622	Special Topics in Plastic Deformation and Fracture	3
MT 650-652	Special Topics in Advanced Engineering Metallurgy	6
MT 762	Seminar—presented by the student, critically reviewing a technical paper selected by the student with the approval of a faculty adviser	—

Selected electives in science, mathematics, economics, or engineering, in consultation with department adviser, up to	18
or	
MT 998 Project	6
Total	36

REQUIREMENTS FOR THE DOCTOR'S DEGREE

The requirements for the doctor's degree conform to the regulations stated in this catalog under "Doctor's Degree." Specific doctoral requirements are available from the departmental secretary in the publication *Guide for Doctoral Students in Metallurgy.*

A typical program consists of 30 units in the major field of physical metallurgy, a minor field in X-ray crystallography, a minor field in chemical physics, chemistry, theoretical mechanics, or other acceptable disciplines and 36 units of research for the doctoral dissertation.

UNDERGRADUATE COURSES

REQUIRED

MT 401 Physical Metallurgy I **3:0:3**
Introduction to physical metallurgy. Relation of properties to microstructure in pure metals. Recovery, recrystallization and grain growth. Phase diagrams. Solidification. Iron-carbon alloy system. Ferrous alloys. Prerequisites: PH 103, PH 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. Effect 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 transformations. 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 nonferrous alloys. Macroetching and sulphur prints. Temperature measurement: thermocouple and pyrometry. Photomicrography and photographic techniques. Replica electron microscopy. Sample preparation techniques for electron microscopy. Prerequisite: MT 401 and **MT 403.**

MT 405 Metallurgical Thermodynamics **3:0:3**
Laws of thermodynamics. Free energy of heterogeneous reactions. Gibb's phase rule. Solutions. Quasichemical theory of solutions. Thermodynamics of surfaces and interfaces. Thermodynamics of 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 polycrystailine materials. Impurity effects and yield point phenomena. Elements of dislocation theory. Dislocation reactions, multiplication, 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 mass, momentum and energy transport concepts from both macroscopic and microscopic points of view. Determination of transport coefficients from kinetic theory. Introduction to irreversible thermodynamics. 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 properly relationships. Prerequisite: MT 403.

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 semiconductor 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 theory 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. Structure and crystal orientation. Stress analysis and phase diagram determination by x-ray techniques. Qualitative and quantitative chemical analysis 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 421 Metallurgical Failure Analysis **1:6:3**
Integrated knowledge of metallurgical principles applied to analysis of in-service failures of materials. Discussion 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 treatment to obtain ceramic products. Glasses, glazes and enamels on metals. Introduction to physical ceramics. Equilibria and reactions between ceramics. Recrystallization, grain growth and microstructure of ceramics. Plastic and viscous deformation in ceramics. Physical properties of ceramics.

MT 495-497 Bachelor's Thesis in Metallurgical Engineering **MT 495 1 credit**
MT 496-497 each 3 credits
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.

TECHNICAL ELECTIVE COURSES

MT 409 Materials Selection **3:0:3**
Knowledge of metallurgy and materials science applied to engineering materials selection. Value engineering approach and organization for materials selection. Elementary statistics

applied to specifications, quality standards, quality control. Prerequisite: MT 403.

MT 414 Metallurgical Kinetics 3:0:3
Statistical and empirical approaches to kinetics. Diffusion in metals and alloys. Theory of nucleation and growth. Kinetics of recrystallization, precipitation, martensitic transformation. Prerequisite: MT 405.

MT 415 Metallurgy of Magnetic Materials 3:0:3
Macroscopic concepts of magnetism. Magnetization curve. 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 416 Electrometallurgy and Corrosion 3:0:3
Fundamental principles of electrometallurgical processes. Electrode potential and over-voltage. Electrode kinetics. Electroplating. Corrosion and stress corrosion. Corrosion protection. Prerequisite: MT 403.

MT 417 Welding Metallurgy 3:0:3
Metallurgical aspects of welding. Theory and applications of arc, gas, resistance and Thermit welding processes. Modern methods of procedure, control, tests, inspection. Examinations of micro- and macro-structure of welds and adjacent areas. Applications of welding. Weldability criteria. Prerequisite: 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
Theory 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 interpretation of tests on mechanical properties of materials. Engineering properties of ferrous and nonferrous alloys. Laboratory experiments on properties, microstructure, fractography. Interdepartmental course for mechanical engineering students.

MT 302 Metallurgy for Engineers 2:0:2
Introduction to atomic, microscopic and macroscopic structure of engineering materials. Effect of grain size and boundaries, work hardening and heat treatment on behavior of solids. Discussion of inelastic behavior, creep, fatigue, brittle and ductile fracture of metals. For aerospace engineering students.

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.

MT 304 Materials Science 2:3:3
Plastic behavior of single and polycrystalline materials. Deformation mechanisms. Effect of temperature and deformation on rate of plastic flow. Strain hardening. Dislocation theory. 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 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 or MT 410 or equivalent.
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 material arranged by faculty steering committee.

MT 420 Engineering Materials 3:0:3
Structure, properties and uses of polymers and metals as engineering materials. Crystal structure, defects, heat treatment, corrosion and its prevention. Manufacture and processing of polymers. Mechanical behavior of polymers and their thermal and electrical properties. Prerequisites: CM 161, CM 162, CM 123 and CM 124.
Also listed under CH 271

GRADUATE COURSES

MT 600 Structure-Property Relationships in Materials 2½:0:3
Dependence of properties, e.g., mechanical and electrical, on structure of material. Crystalline vs. amorphous structure, occurrence and role of defects. Bonding and structure. Anisotrophy 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 2½:0:3
Nature and use of electron microscope; theory of electron diffraction, including indexing of diffraction patterns. Kinematical theory of electron diffraction. Imaging of precipitates and Burger's vector determinations. Use of Kikuchi patterns in quantitative electron miscroscopy. Prerequisite: MT 600.

MT 610 Thermodynamics of Metals and Alloys 2½:0:3
Review of fundamentals of classical and statistical thermodynamics with emphasis on solid state, phenomenology of metallic surface, 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
Review of elasticity theory. Dislocation concepts of mechanical

behavior of metals. Theories of plastic flow, work hardening, strength, ductility. Movement 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 Theory 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, influence 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 theory of metals. Prerequisite: MT 630.

MT 640 Reactions in Solids **2½:0:3**
Study of mechanisms and kinetics of diffusion-controlled and diffusionless phase transformations in solid metallic systems; diffusion in multiphase, multicomponent metallic systems; theories of precipitation, of grain boundary migration and grain growth, of eutectoid transformations and of martensitic transformation. Prerequisite: MT 414.

MT 641-642 Special Topics in Reactions in Solids I, II* **each 2½:0:3**
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 design and design 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 700 Welding Metallurgy **2½:0:3**
Analysis of process variables affecting joining techniques. Study of arc characteristics, heat flow, gas-metal interactions, solidification mechanics, residual stress effects, distortion control. Application of solid-phase bonding, electron and laser welding. Weldability criteria for ferrous and nonferrous alloys. Prerequisite: instructor's consent.

MT 705 Semiconductor Technology **2½:0:3**
Review of electrical transport properties of semiconductors. Preparation of semiconductor materials. Impurity diffusion, diffusion mechanisms, concentration profiles and their measurement, diffusion procedures used for silicon, germanium and compound semiconductors. Surface preparation and contacts. Integrated circuits, design of circuit components, techniques used in fabrication, various limitations on performance. Prerequisite: graduate status.
Also listed under EL 644

MT 706 Magnetism and Magnetic Materials* **2½:0:3**
Origin of magnetism in atoms and solids. Diamagnetic vs. paramagnetic behavior. Ferromagnetic domain theory. Antiferromagnetism and ferrimagnetism. Structure and properties of magnetic materials. Prerequisite: MT 410.

MT 707 Thin Film Technology **2½:0:3**
Preparation, structure, evaluation and properties of thin films: metallic, semiconductor and dielectric film techniques, nucleation and growth considerations, epitaxy, and metastable configurations. Prerequisite: instructor's consent.

MT 710 Powder Metallurgy **2½:0:3**
Fundamental treatment of powder metallurgy covering theoretical and practical aspects of subject. Production of metal parts from powder, review of commercial applications. Theories of metal synthesis, compacting, consolidation and sintering. Important patents and commercial processes. Colloquium. Prerequisite: instructor's consent.

MT 715 Corrosion and Oxidation Mechanisms in Metals **2½:0:3**
Electrochemical principles applied to corrosion. Analysis of corrosion mechanisms. Study of preventive methods. Effects of temporature, environmental and metallurgical factors. High-temperature oxidation and metal-gas interactions. Testing. Analysis of use of cathodic protection, water treatment, cathodic and anodic coatings. Prerequisite: MT 405 or instructor's consent.

MT 725 Noble Metal Metallurgy **2½:0:3**
Crystal structure and phase equilibria for noble metal alloy systems. Mechanical, electrical, magnetic and optical properties for various alloy systems. Criteria for corrosion and tarnish resistance. Fabrication, joining and application of noble metal alloys. Prerequisite: instructor's consent.

MT 726 Metallurgy of Nuclear Reactor Materials **2½:0:3**
Study of material requirements for basic parts of nuclear reactors. Metallurgy of fuels, moderator, control and construction materials. Description of handling and fabricating techniques. Prerequisite: instructor's consent.
Also listed under NU 726

MT 727 Bioengineering Metallurgy* **2½:0:3**
Selection and application of metals and alloys for use in body environment. The body as corrosive environment. Examination of major problem areas. Principles and techniques for preparation of dental amalgams and other alloys. Design of alloys for bioengineering applications. Prerequisite: instructor's consent.
Also listed under BE 741

MT 740† Survey of Metallurgical Principles* **2½:0:3**
Survey of metallurgical principles. Crystal structure, alloying, phase diagrams, diffusion phenomena, mechanical deformation of metals and alloys, recrystallization, age hardening. Prerequisite: instructor's consent.

MT 760-761 Seminar in Metallurgical Engineering **each 0:2½:1½**
Recent progress in field of metallurgical engineering given in lectures by engineers from industry, research and educational institutions. One or more seminar topics from current literature in metallurgical field assigned each student for presentation. Students taking course expected to read in each of assigned topics so as to be conversant with topic 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 student of seminar on some topic of metallurgical engineering, in which student critically reviews technical paper selected by student with approval of faculty adviser. For students enrolled in engineer in metallurgical engineering degree program.

MT 763-764 Seminar in Metallurgy and Materials Science each 0:2½:0
Preparation and presentation by student of seminar on some topic of physical metallurgy, metallurgical engineering, or materials science in which student critically reviews technical paper selected by student with approval of faculty adviser. For students enrolled in doctoral program.

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 guidence of depertmental adviser. Report includes critical analysis and interpretetion of pertinent literature and should represent worthwhile contribution to the field. Oral final examination and project report required.

MT 997 Thesis for the Degree of Master of Science 3-12 units
Extension of project study to thesis level with approval of division head. Regular conference 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 member. Candidate 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 area of physical metallurgy. Work must demonstrate originality and creativity and should be worthy of publication in recognized scientific journal. Candidate must take oral examination on thesis subject and related topics. Minimum of 36 units required.

FACULTY

George Fischer, Professor of Metallurgy and Head of Physical and Engineering Metallurgy
B.Met.E., M.Met.E., Polytechnic Institute of Brooklyn
Corrosion and welding metallurgy

Irving Cadoff, Professor of Metallurgy
B.M.E., CCNY; M.M.E., D. Eng.Sc., New York University
Electronic materials, liquid metal embrittlement, thin film epitaxy

Louis S. Castleman, Professor of Metallurgy
S.B., Sc.D., Massachusetts Institute of Technology
Diffusion in solids, biomaterials

Carmine D'Antonio, Professor of Metallurgy
B.Met.E., M.Met.E., Polytechnic Institute of Brooklyn
Mechanical properties, thin films, failure analysis

Harold Margolin, Professor of Metallurgy
B.Eng., M.Eng., D.Eng., Yale University
Plastic deformation and fracture, titanium metallurgy, fatigue of metals and alloys

Homi S. Daruvala, Associate Professor of Metallurgy
M.A., M.Sc., L.L.B., Bombay University (India); B.S.E., M.S.E. (Chem. Eng.), M.S.E. (Met.), University of Michigan; D. Ch.E., Polytechnic Institute of Brooklyn
Electrochemistry, materials processing and unit operations, ordering reactions

Henry H. Hausner, Research Professor of Metallurgy
E.E., Dr.Eng., Technical University (Vienna, Austria)
Powder metallurgy, powder technology

ADJUNCT FACULTY

Simon D. Strauss, Distinguished Visiting Professor of Metallurgy and Fellow of the Polytechnic
Metals and mineral economics

Devendra Gupta, Adjunct Professor of Metallurgy
B.Sc., Delhi University (India); B.Sc., Banaras Hindu University (India); M.S., New York University; Ph.D., University of Illinois
Diffusion, solid-state transformations, mass transport in thin films

Robert Rosenberg, Adjunct Professor of Metallurgy
B.S., Drexel University; M.S., Ph.D., New York University
Metallurgy and materials science

George Stern, Adjunct Professor of Metallurgy
B.Ch.E., CCNY; M.S., University of Michigan
Metallurgy of nuclear materials

John R. Weeks, Adjunct Professor of Metallurgy
M.S., Colorado School of Mines; M.S., Ph.D., University of Utah
Metallurgy of nuclear materials, liquid metal technology, stress-corrosion cracking

Ernest Levine, Adjunct Associate Professor of Metallurgy
B.Met.E., Rensselaer Polytechnic Institute; Ph.D., New York University
Electron microscopy

Sankar Sastri, Adjunct Associate Professor of Metallurgy
B.S., Indian Institute of Science; M.S., M.E., Columbia University; Ph.D., Polytechnic Institute of New York
Mechanical behavior of metals

James Lloyd, Adjunct Instructor of Metallurgy
B.S., M.S., Ph.D., Stevens Institute of Technology
Thermodynamics of metals and alloys

Anthony J. Vecchio, Lecturer of Metallurgy
M.Met.E., Polytechnic Institute of Brooklyn
Industrial metallurgy

EMERITUS FACULTY

John P. Nielsen, Professor Emeritus of Metallurgy
M.E., Ph.D., Yale University
Precious metals and alloys, grain growth and recrystallization, dental materials

MILITARY SCIENCE

Through the Reserve Officers Training Corps (ROTC), the U.S. Army gains officers with diverse educational backgrounds and contemporary ideas. ROTC graduates have the chance to use their ideas in positions of leadership and enable the Army to remain aligned with our ever changing society.

ROTC 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 U.S. Army while earning their college degrees.

OFFICER EDUCATION PROGRAM

The four-year Army ROTC 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 the second year. Subjects cover the following areas: management principles, national defense, leadership development, mountaineering, orienteering and marksmanship.

Various social and professional enrichment activities are available in conjunction with the military science program. Necessary textbooks and materials are furnished without cost to the student. Students who participate in the basic course may be excused from physical education requirements.

After completing the basic course, students who have demonstrated officer potential and meet Army physical fitness standards are eligible to enroll in the advanced course.

Advanced Course—The advanced course is normally taken in the final two years of college. Instruction includes further leadership development, organization and management, 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 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 or field environment.

Allowances—All cadets in the advanced course receive uniforms, necessary military science textbooks, pay for the advanced camp ($500), and 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 will not receive the $1,000 per year 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 the professor of military science.

4. Successfully pass a prescribed medical examination.

5. Successfully pass an educational-level examination.

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 Army ROTC during their first two years and have two years remaining in school. Students can take advantage of this opportunity by successfully completing a paid six-week basic camp after their sophomore year and enrolling in the ROTC advanced course in their junior and senior years, provided they otherwise meet enrollment requirements.

OBLIGATIONS

On graduation students can elect to serve on active duty for a three-year period or enter the Army Reserve or National Guard as a commissioned officer. Scholarship students incur a four-year active duty obligation. The professor of military science may designate outstanding cadets as distinguished military graduates. Students so designed may apply for a commission in the Regular Army of the United States.

ARMY ROTC SCHOLARSHIPS

Army ROTC 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 an ROTC program.

Students who attend the basic camp of the two-year program may also compete for two-year scholarships.

The scholarships pay for tuition, textbooks, lab fees, plus a living allowance of up to $1,000 each year the scholarship is in effect.

TYPICAL COURSES FOR STUDY IN MILITARY SCIENCE

Freshman Year

No.	Title	Sem.
MS 101	Intro. to Military Science I	1
MS 102	Intro. to Military Science II	2

Sophomore Year

MS 117	Military Skills	1
MS 121	Leadership & Motivational Theory	2
MS 120	Wilderness Training	1
MS 123	Dynamics of National Defense	2

Junior Year

MS 137	Military Tactics	1
MS 134	Leadership Skills I	1
MS 131	Military History[2]	2
MS 135	Leadership Skills II	2

Senior Year

MS 142	Military Justice	1
MS 144	Applied Leadership I	1
MS 146	Management Techniques	1
MS 143	Senior Seminar	2
MS 145	Applied Leadership II	2

PROFESSIONAL ACTIVITIES

ROTC also offers a variety of social and professional activities. Scabbard and Blade is the advanced course national honor fraternity. The Pershing Rifles promotes military ideals as exemplified by General John J. Pershing. The Society of American Military Engineers promotes the national engineering potential for defense.

The National Association of Rigorous Training Units (Sappers) offers instruction in adventure training, such as mountaineering, rappelling, ranger, airborne and orienteering. These activities offer leadership opportunities that improve proficiency and military skills and enhance confidence.

HOW TO ENROLL

Students should visit the Department of Military Science during the registration period so that the 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 ROTC, telephone (212) 643-2105, 2106, or, at the Farmingdale campus, (516) 694-5500, ext. 118.

[2]An equivalent academic course may be substituted. Substitution requires department approval.

CREDITS TOWARD POLYTECHNIC DEGREES

The number of military science credits that are applicable toward Polytechnic degrees depends on the student's academic major and on which courses the student chooses to replace with ROTC courses. The table and notes (left) outline both the requirements for commissioning and substitutes for ROTC courses.

BASIC COURSES

MS 101 Introduction to Military Science I **1:0:0**
This course is a practical introduction to the ROTC program. Areas of study include the organization of the ROTC, its programs and the organization of the Army. A large percentage of the classes is devoted to map reading and land navigation in order to develop a working knowledge of topographic maps. Emphasis is placed on how to use different types of maps and how to navigate on the ground with the use of maps and compass.

MS 102 Introduction to Military Science II **1:0:0**
Continuation of MS 101. Development of skills in first aid and orienteering are emphasized. First aid consists of basic life saving measures, burn treatment, splinting and first aid for heat and cold injuries. The orienteering portion of the course consists of familiarization with the techniques and methods of the sport of orienteering and its related equipment.

MS 117 Military Skills **1:0:0**
Knowledge of the skills of mountaineering and marksmanship are developed during this course. The mountaineering portion consists of theoretical and practical applications of military mountaineering tactics, techniques and concepts. Emphasis placed on the individual student's ability to comprehend and apply the instruction in a mountainous region of New York State. Marksmanship consists of familiarization with various military weapons, including the M-16 and .22 caliber rifles. The instruction also includes basic aspects of good marksmanship and live weapons firing. Course includes classroom and mandatory fieldwork.

MS 120 Wilderness Training **1:0:0**
This course is designed to develop a sense of confidence in the student when subjected to living under field conditions. Subjects included in this course are navigation using dead reckoning and terrain association, identification and preparation of edible planta and animals, improvised shelters and field craft. Instruction includes a mandatory two-day field exercise.

MS 121 Leadership and Motivational Theory **2:0:0**
Consortium of subjects related to the functioning of a leader, consisting of leadership styles, ethics, counseling. Concentration on aspects of leadership as function of line managament. Power, communication, professionalism, organizational development, motivational theory, subordinate/superior relations, alienation.

MS 123 Dynamics of National Defense **1:0:0**
Survey course in the development and organization of the present U.S. Defense establishment. An explanation of the roles of the various government offices/agencies and their relationships to the defense policy. Topics include: society and the military, the military-industrial complex and current defense trends.

MS 128 Ranger Operations **1:0:0**
Instructions and practical field training in small unit tactics, techniques and leadership. Course consists of the planning, preparation and conduct of ranger-type patrols under simulated combat conditions. Requisite: Participate with the National Association of Rigorous Training Units.

MS 129 Precison Drill Competition **1:0:0**
Designed for students interested in participating in intercollegiate drill competitions with the ROTC Pershing Rifles drill team. Requisite: Participate with the Pershing Rifles Drill Team.

ADVANCED COURSES

MS 131 American Military History **2:0:2 or nc as arranged**
Survey course stressing interrelationships between the American military establishment and American society and how these relationships have influenced the growth of American military system and conduct of American wars. Role of technology in evolution of tactics and strategy.

MS 134 Leadership Skills I **2:0:0**
Coursework is designed through a progressive physical conditioning program coupled with a well-rounded curriculum of related military subjects to develop in the cadet the physical and mental leadership traits of initiative, judgment, courage, endurance, knowledge and enthusiasm, in order to be able to properly motivate and lead subordinates. Prerequisite: MS III standing.

MS 135 Leadership Skills II **2:0:0**
Continuation of MS 134 with a one-week field proficiency test. Prerequisite: MS III standing.

MS 137 Military Tactics and Organization **1:0:0**
Course in basic knowledge of military tactics at small-unit level together with principles of military operations and organizations. Introduction to infantry weapons, small unit tactics, principles of military organizations, fundamentals of offensive and defensive operations, troop leading procedures, techniques of battle drill.

Advanced Summer Camp **nc**
All candidates for commission through the ROTC program are required to successfully complete ROTC advanced camp, held at Fort Bragg, North Carolina. Stress placed on leadership and command responsibility, implemented by command rotetion 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 134 and MS 135.

MS 142 Philosophy and Structure of Military Justice System **2:0:2 or nc as arranged**
Topics selected from history of military law, place of law in society, Constitution, Uniform Code of Military Justice, recent court decisons, procedural safeguards for servicemen, criticism of military justice system, military crimes, international laws of war, rules of conduct in hostilities.

MS 143 Senior Seminar **2:0:2 or nc as arranged**
Course designed for student about to finish school and enter the work world. Emphasis is on preparing students for transition into the Officer Corps. Topics include effective communications, interpersonal relations, professional ethics, personal affairs and career planning. Prerequisites: senior standing and cadet status.

MS 144 Applied Leadership I **1:0:0**
Cadet officers acting in capacities as troop commanders and staff officers instruct lower classmen in military skills. Senior (MS IV) cadets enrolled in this course exercise acquired leadership and management skills through planning of field training exercises, administration of the cadet batallion and presentation of formal classroom and field instruction. Prerequisite: MS IV standing.

MS 145 Applied Leadership II **1:0:0**
Continuation of MS 144. Prerequisite: MS IV standing.

MS 146 Management Techniques **2:0:2 or nc as arranged**
Basic considerations and techniques involved in work simplification and scheduling skills. Course is designed to develop skills in work planning and analysis, and provides a logical framework for simplifying any job. Skills in basic scheduling techniques are developed, such as, the critical path method.

FACULTY

LTC Ronald F. Trauner, Professor and Head of the Department of Military Science
B.S., United States Military Academy, West Point; M.S., Purdue University

MAJ Robert Lo Pinto, Assistant Professor of Military Science
B.S., Polytechnic Institute of New York; M.E., Manhattan College

CPT Joseph P. Donnelly, Assistant Professor of Military Science
B.S., Norwich University; M.S., Polytechnic Institute of New York

CPT James R. Lingvai, Assistant Professor of Military Science
B.S., University of Toledo; M.S., Polytechnic Institute of New York

CPT Herrick E. Marden, Assistant Professor of Military Science
B.S., University of Maine

SGM William H. Brown III, Chief Instructor

MSG Spencer W. Putnam, Principal Drill Instructor

NEW YORK UNIVERSITY/ POLYTECHNIC COOPERATIVE PROGRAM

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.

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. These may include atmospheric chemistry and pollution control, energy policies, operations research, dynamic systems modeling and a host of other areas where technical competence and an understanding of public administration become complementary. The decision-maker, in that portion of the public sector where science and technology play a major role, must have a level of technical competence achieved by graduate study in the engineering or scientific discipline. At the same time, the scientist interested in such a career must be able to work with people whose background is in the legal, fiscal, administrative or sociological areas, and must understand the special problems of public administration. The joint graduate program described herein, leading simultaneously to both the master of public administration and master of science degrees, has been designed to be the ideal solution for both persons.

POLYTECHNIC AND NYU/GPA

The Polytechnic Institute of New York is now the most important engineering and science institution in the New York Metropolitan area. Similarly, The New York University Graduate School of Public Administration, located in the nation's greatest metropolis, is an unexcelled focal point for work in public administration. The two schools are separated by a ten-minute subway ride, so that students have ready access to the resources of both institutions and to the city at large.

COOPERATING SCIENCE AND ENGINEERING PROGRAMS AT THE POLYTECHNIC

The M.S. degree will be awarded by the Polytechnic Institute of New York in one of the following program areas. This degree will be awarded simultaneously with the M.P.A. degree from New York University on successful completion of the program.

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

PROGRAM ELIGIBILITY AND DURATION

The program is open to qualified students with an acceptable undergraduate background in mathematics, science or engineering; some departments will accept students from quantitatively-oriented social science programs. Students must be admitted through one of the cooperating departments at the Polytechnic Institute of New York 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, with a minimum of sixty graduate credits required for the award for both master's degrees. It should be noted that the joint program provides for a significant time saving compared with sequential study for the two master's degrees, which would require at least 36 credits for the M.S. and 44 credits for the M.P.A.

It is assumed that the student has an undergraduate science or engineering background that is essentially equivalent to a Polytechnic degree. Students with deficiencies in their undergraduate preparation may be required to take additional credits for the completion of the degree. Students are expected to be familiar with elementary digital computational procedures and with a programming language such as FORTRAN or PL/1. Students without this background should take OR 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. A brochure summarizing them is 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:

P11.1013 American Public Administration and Its Political Environment
P11.1016 Organization Theory 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.

(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 will 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 will 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 policy. Participation will be required of all students in the program.

Typical Project Topics—The following list of possible project topics is illustrative only; actual topics will be determined by the students and their advisers.

Water resource evaluation and management in the New York area

Determination of pollution standards and abatement feasibility for air, water, thermal or noise pollution

Waste disposal

Transportation needs and allocations

High speed mass transit systems

Air traffic and airport planning and design

Road traffic control and improvement

Administration in public services with large scientific and engineering inputs

Influence of community values on transportation planning and development

Fire hazards and storage of combustibles

Oil slick control

Conflict of community and technical goals in electric power generation

The role of the engineer in public policy planning

Effects of technological change on personnel administration

Energy policy in the metropolitan area

Admission Details—Applications for admission to the combined program are available from the program coordinator. Applicants should complete the application form for Polytechnic—clearly indicating the desired Polytechnic program—and that for NYU/GPA, and send them to the program coordinator (see address below), enclosing separate checks for the two application fees; only one set of transcripts and references is required. The admission to both schools will then be 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 the application form.

Registration—Students will 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, a student will be assigned a Polytechnic adviser with whom the overall program should be planned. In addition, students will be assigned an adviser from NYU/GPA by the liaison officer of that school.

Further Information—Additional information may be found in the NYU/GPA catalog. A brochure and application forms are available from the program director:

Prof. Joachim I. Weindling
POLY/NYU Program Director
Polytechnic Institute of New York
333 Jay Street
Brooklyn, New York 11201

NUCLEAR ENGINEERING

Nuclear engineering is the branch of the engineering profession concerned with the practical applications of nuclear energy, that is, the energy emanating from the atomic nucleus. Nuclear engineers today are in the forefront of efforts to solve the nation's mounting energy problems. By 1985 upward of 20 percent of the United States' electric power output will originate in nuclear power plants. In the years ahead, mobile nuclear plants will also be needed in increasing numbers for the propulsion of naval vessels and merchant ships. Nuclear fusion, the energy source of the sun and hydrogen bombs, is under development by nuclear engineers and other technologists with the expectation that commercial nuclear fusion plants may become a reality in the early part of the next century.

Quite apart from the domain of nuclear power, nuclear engineers are involved in any and all problems related to nuclear radiation, its use and control. Thus nuclear engineers are called upon to design facilities for radiation processing, the manufacture and utilization of radiopharmaceuticals and the numerous applications of radioactive substances in industry and commerce.

The Department of Nuclear Engineering offers programs of study leading to the bachelor of science, master of science, engineer and doctor of philosophy degrees.

Undergraduate Program

The undergraduate curriculum in nuclear engineering provides the students with a firm foundation in the fundamental sciences and engineering upon which the nuclear engineering profession is based. At the same time, the students receive sufficient training in nuclear engineering per se, either to embark directly upon an industrial career or to continue their education in graduate school. (See "Typical Course of Study" on the following page.)

Graduate Program

Requirements for the Master's Degree—A minimum of 36 units is required, including either the sequence NU 601-602 or NU 701-702 and the sequence NU 603-604, NU 606 and NU 607.

Requirements for the Degree of Nuclear Engineer—A minimum of 36 units of work beyond the master's degree is required. The student must satisfactorily complete the sequences NU 701-702-703, NU 603-604, NU 606 and NU 607 or equivalents. In general, a project in nuclear engineering should also be completed. A maximum of 12 units, to be included within the overall unit requirement, may be devoted to the project. In special cases, where the student has previously completed work which would constitute a satisfactory project but which was accomplished in a non-academic setting, the project requirement may be waived.

Requirements for the Doctor's Degree—The student must complete 90 units of graduate work, of which at least 24 units are devoted to completion of a thesis and at least 66 units to course work. The student must satisfactorily complete the sequences NU 701-702-703, NU 603-604, NU 606 and NU 607.

The student should demonstrate proficiency in translating technical articles into English from one foreign language commonly used in international journals. Generally, French, German or Russian will be acceptable for fulfillment of this requirement. Another language may be substituted only with approval of the department.

To be considered a doctoral candidate, a student must pass an examination, usually both written and oral. This examination will ordinarily precede starting of the thesis. On completion of the thesis, the student will be required to defend it satisfactorily at an oral examination.

While the specific course requirements for graduate degrees are minimal, every student should choose a program together with a departmental adviser. Students with differing interests and backgrounds may take substantially different programs in addition to the core courses.

UNDERGRADUATE COURSES

NU 301 Introduction to Nuclear Engineering I 3:0:3
Introductory survey of nuclear engineering. Review of atomic and nuclear physics, interaction of radiation with matter, neutron chain reactions, nuclear reactor types. Prerequisite: PH 232 or equivalent.

NU 302 Introduction to Nuclear Engineering II 3:0:3
Continuation of NU 301. Elementary nuclear reactor design, reactor kinetics and control, heat removal from reactors. Prerequisite: NU 301.

NU 303 Nuclear Engineering Lab I 2½:1½:3
Study of radiation detection instruments: GM counters, proportional counters, ionization chambers, health physics in-

Typical Course of Study for the Bachelor of Science Degree in Nuclear 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[m]	4	0	4	MA 102	Calculus II[m]	4	0	4
PH 101	Introductory Physics I	3	0	3	PH 102	Introductory Physics II	3½	1½	4
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	Gen. Chemistry Lab. II	0	1½	½
HU 101	College Composition[h]	3	0	3	CS 111	Intro. to Programming	3	0	3
SS 104	Contemp. World Hist.[h]	3	0	3	HU 200	Intro. to Literature[h]	3	0	3
PE 101	Physical Education[d,r]	0	2	0	PE 102	Physical Education[d,r]	0	2	0
				16					17

Sophomore Year

MA 104	Diff. Equations[m]	3	0	3	MA 103	Calculus III[m]	3	0	3
MT 301	Mech. Behavior of Materials	3	0	3	PH 232	Modern Physics	2½	1½	3
PH 103	Physics III	2½	1½	3	CE 202	Mech. of Materials	3	0	3
AM 115	Eng. Mech.	4	0	4	EE 370	Prin. of Elec. Eng.	3	0	3
	Hum./Soc. Sci.[h]	3	0	3	EE 374	Instrumentation Lab.	0	3	1
PE 103	Physical Education[d,r]	0	2	0		Hum./Soc. Sci.[h]	3	0	3
				16	PE 104	Physical Education[d,r]	0	2	0
									16

Junior Year

MA 260	Vec. Anal./Par. Diff. Eq.	4	0	4	MA 358	Numerical Analysis	3	0	3
AM 201	Thermodynamics I	3	0	3	NU 302	Intro. to Nuclear Eng. II	3	0	3
AM 231	Fluids I	3	0	3	NU 306	Radiation Protection	3	0	3
NU 301	Intro. to Nuclear Eng. I	3	0	3		Hum./Soc. Sci.[h]	3	0	3
	Hum./Soc. Sci.[h]	3	0	3		Free elective			3
				16		Technical elective			3
									18

Senior Year

MA 201	Applied Analysis I	3	0	3	MA 202	Applied Analysis II	3	0	3
AM 203	Heat Transfer	3	0	3	NU 304	Nuclear Eng. Lab II	2½	1½	3
NU 303	Nuclear Eng. Lab. I	2½	1½	3	NU 308	Nuclear Eng. Design	3	0	3
NU 307	Licensing, Safety, Env.	3	0	3	NU 336	Atomic/Nuclear Physics II	3	0	3
NU 335	Atomic/Nuclear Physics I	3	0	3		Technical elective			3
	Hum./Soc. Sci.[h]	3	0	3		Free elective			3
				18					18

Total credits required for graduation: 135

[h]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. 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).

At least 6 additional credits must be taken from outside the area of modern languages. It is recommended that students intending to go on for the doctorate take at least one language from among French, German and Russian.

[m]Students with a strong background in mathematics may wish to substitute the sequence MA 111-114 for MA 101-104.

[d]Day students only.

[r]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 131, 142, 143, 146, for six credits of technical electives.

All elective courses are to be chosen in consultation with the department adviser.

Note that because of possible scheduling conflicts between courses given in different departments, the student may find it advisable to switch the order in which certain courses are taken. This should always be done in consultation with the department adviser to avoid possible difficulties with prerequisites.

struments, scintillation spectrometry, activation analysis, cross-section and shielding measurements, macroscopic properties of reactor materials. Corequisite: **NU 301.**

NU 304 Nuclear Engineering Lab. II 2½:1½:3
Continuation of NU 303. Macroscopic properties of reactors: Fermi age, diffusion length, buckling, thermal utilization, resonance escape probability, delayed neutrons, criticality measurements; static and dynamic behavior of critical reactors. Prerequisite: NU 303.

NU 306 Principles of Radiation Protection 3:0:3
Fundamentals of health physics and radiation protection. Interaction of ionizing radiation with matter, biological effects of radiation, dosimetry, radiation shielding, radiation codes. Prerequisite: NU 301.

NU 307 Reactor Licensing, Safety and the Environment 3:0:3
Governmental authority and responsibility, reactor licensing, nuclear power plant safety, dispersion of effluents from nuclear facilities, radiation doses from nuclear power plants, reactor siting, reactor accidents, accident risk analysis, environmental radiation doses. Prerequisites: NU 302 and NU 306.

NU 308 Nuclear Engineering Design 3:0:3
A design course in which students address the full range of problems involved in the design of a practical nuclear facility. Each student must prepare and defend orally a design report on the facility. Prerequisite: NU 307.

NU 335-336 Atomic and Nuclear Physics I, II each 3:0:3
Introduction to electronic and nuclear structure of the atom. Relativity, wave mechanics, natural and artificial radioactivity, fission and cosmic rays. Fundamental experiments and postulates of wave and particle atomic physics. NU 335 prerequisite: PH 232. NU 336 prerequisite: NU 335.

GRADUATE COURSES

NU 601 Introduction to Nuclear Engineering I 3:0:3
Introductory survey of nuclear engineering. Review of atomic and nuclear physics, interaction of radiation with matter, neutron chain reactions, nuclear reactor types. Prerequisite: PH 232 or aquivalent.

NU 602 Introduction to Nuclear Engineering II 3:0:3
Continuation of NU 601. Elementary nuclear reactor design, reactor kinetics and control, heat removal from reactors. Prerequisite: NU 601.

NU 603 Nuclear Engineering Laboratory I 2½:1½:3
Study of radiation detection instruments, GM counters, proportional counters, ionization chambers, health physics instruments, scintillation spectrometry, activation analysis, cross-section and shielding measurements, macroscopic properties of reactor materials. Prerequisite: **NU 601** or equivalent.

NU 604 Nuclear Engineering Laboratory II 2½:1½:3
Continuation of NU 603. Macroscopic properties of reactors: Fermi age, diffusion length, buckling, thermal utilization, resonance escape probability, delayed neutrons, criticality measurements; static and dynamic behavior of critical reactors. Prerequisite: NU 603.

NU 606 Principles of Radiation Protection 3:0:3
Fundamentals of health physics and radiation protection. Interaction of ionizing radiation with matter, biological effects of radiation, dosimetry, radiation shielding, radiation codes. Prerequisite: NU 601 or equivalent.

NU 607 Reactor Licensing, Safety and the Environment 3:0:3
Governmental authority and responsibility, reactor licensing, nuclear power plant safety, dispersion of effluents from nuclear facilities, radiation doses from nuclear power plants, reactor siting, reactor accidents, accident risk analysis, environmental radiation doses. Prerequisites: NU 602 and NU 606.

NU 619 Introduction to Thermonuclear Power 3:0:3
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.
Also listed under EL 657

NU 701 Nuclear Reactor Theory I* 3:0:3
Intermediate course in nuclear reactor theory. Review of neutron interactions, flux, current and neutron diffusion. Prerequisite: NU 602 or equivalent.

NU 702 Nuclear Reactor Theory II* 3:0:3
Continuation of NU 701. Neutron slowing down with and without absorption and fission; Fermi age and group theories of critical systems. Prerequisite: NU 701.

NU 703 Nuclear Reactor Theory III* 3:0:3
Continuation of NU 702. Heterogeneous reactors, reactor kinetics, temperature coefficients, fission product poisoning, reactor lifetime calculations, control rods, perturbation theory. Prerequisite: NU 702.

NU 705-706 Advanced Nuclear Engineering Laboratory I, II* each 2½:1½:3
Selected advanced experiments chosen to reflect the interests of the students, subject to the availability of necessary laboratory equipment. Prerequisite: NU 604.

NU 712 Radiation Shielding* 3:0:3
Theory and practice of neutron and gamma ray shielding. Prerequisite: NU 606.

NU 715 Heat Transfer 2½:0:3
Comprehensive treatment of 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. Classical analytical techniques and experimental methods. Analogies between heat, mass and momentum transfer. Dimensional analysis and boundary layer considerations. Fins and heat exchangers. Condensation and boiling. Prerequisite: adviser's approval.
Also listed under AM 715

NU 716 Reactor Heat Transfer 2½:0:3
Study of heat transfer problems and solution techniques associated with various test, power and propulsion nuclear reactors including BWR, PWR, LMFBR and HTGR. Core geometries and primary loop components. Introduction to flow boiling phenomena, liquid metal heat transfer, combined convection and radiation gas flow. Behavior during loss of coolant accidents and emergency core cooling systems. Prerequisite: NU 715 or equivalent.
Also listed under AM 716

NU 721 Economics of Nuclear Power 3:0:3
Economic considerations in design of stationary nuclear power plants. Prerequisite: NU 602.

NU 726 Metallurgy of Nuclear Reactor Materials* 3:0:3
Study of material requirements for basic parts of nuclear reactors. Metallurgy of fuels, moderator, control and construction materials. Description of handling and fabricating techniques. Prerequisite: adviser's approval.
Also listed under MT 726

NU 731 Nuclear Chemical Engineering* **3:0:3**
Applications of chemical engineering principles to processing of nuclear engineering materials. Fuel cycles of nuclear reactors, chemistry of uranium, plutonium, fission products, theory of isotope separation processes. Prerequisite: NU 602.

NU 801 Radiation Transport Theory I* **3:0:3**
Linear transport equation, applications of conservation principles, geometrical attenuation, solution methods with application to classical albedo, Milne and criticality problems. Prerequisite: instructor's permission.

NU 802 Radiation Transport Theory II* **3:0:3**
Continuation of NU 801. Further discussion of solution techniques, diffusion boundary conditions, energy-dependent neutrons, radiative transfer. Prerequisite: NU 801.

NU 811 Control of Nuclear Reactor Plants I* **3:0:3**
Introduction to control systems and nuclear reactor dynamics. State space representation of dynamical systems, input-output relations, Laplace transform, state transition function, transfer function. Analysis of linear systems, stability of linear systems. Derivation of reactor dynamics equations, feedback reactivity, linear reactor dynamics. Introduction to nonlinear dynamical systems, Lyapunov function, stability of nonlinear systems. Prerequisite: NU 703.

NU 812 Control of Nuclear Reactor Plants II* **3:0:3**
Continuation of NU 811. General derivation of reactor dynamics equations. Nonlinear reactor dynamics, reactor stability criteria. Optimal control of nuclear reactor systems. Stochastic systems, reactor noise, optimization of stochastic systems. Introduction to distributed-parameter systems, space-dependent reactor dynamics, xenon spatial oscillation, neutron wave propagation. Reactor safety. Prerequisite: NU 811.

NU 902-903 Seminar in Nuclear Engineering **nc**
Recent developments in the field of nuclear engineering through lectures given by scientists and engineers from industry, research and educational institutions, and by staff members and qualified graduate students.

NU 911 Projects in Nuclear Engineering **3:0:3**
Project course of advanced nature, conducted by assigning individual investigations to be performed by student under supervision of staff member. Consists of theoretical and experimental engineering of interest to student.

NU 927 Energy Policy Issues **2½:0:3**
See Energy Program for details.

NU 928 Energy Resource Distribution and Conversion Technology **2½:0:3**
See Energy Program for details.

NU 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.

NU 961-962 Thesis for Degree of Master of Science **each 3 units**
Independent investigation of problem in nuclear engineering. Acceptance of student by faculty adviser required before registration. Registration fee, any part—3-unit charge. Prerequisite: degree status.

NU 971-972 Project for Degree of Engineer **each 3 units**
Independent project in nuclear engineering. Acceptance of student by faculty adviser required before registration. Registration fee, any part—3-unit charge. Prerequisite: candidacy for engineer degree.

NU 981-988 Thesis for Degree of Doctor of Philosophy **each 3 units**
Original investigation in some aspect of nuclear engineering or science. Candidate required to defend thesis at oral examination. Acceptance of student by faculty adviser required before registration. Registration fee, any part—3-unit charge. Prerequisite: candidacy for Ph.D. degree.

FACULTY

John R. Lamarsh, Professor of Nuclear Engineering and Head, Department of Nuclear Engineering
B.S., Ph.D., Massachusetts Institute of Technology
Nuclear reactor theory, nuclear weapons proliferation

Raphael Aronson, Professor of Nuclear Engineering and Physics
B.S., University of Minnesota; M.A., Ph.D., Harvard University
Transport theory

KunMo Chung, Research Professor of Nuclear Engineering
B.S., Seoul National University (Korea); Ph.D., Michigan State University
Thermonuclear power, international nuclear power development

Walter Kiszenick, Associate Professor of Physics and Nuclear Engineering
B.S., Brooklyn College; M.S., Ph.D., Polytechnic Institute of Brooklyn
Electron microscopy, x-ray diffraction

Richard S. Thorsen, Associate Professor of Mechanical, Aerospace and Nuclear Engineering and Head, Department of Mechanical and Aerospace Engineering
B.M.E., CCNY; M.M.E., Ph.D., New York University
Heat transfer, energy conversion, nuclear reactor safety

Chern H. Tsai, Research Associate Professor of Nuclear Engineering
B.S., University of Arizona; M.S., New York University; Ph.D., Iowa State University
Nuclear reactor safety, system design

ADJUNCT FACULTY—Brooklyn Campus

Robert W. Kupp, Adjunct Professor of Nuclear Engineering
B.S., Wayne State University
Economics of nuclear power

David C. Purdy, Adjunct Professor of Nuclear Engineering
B.S., Webb Institute of Naval Architecture; Oak Ridge School of Reactor Technology
Reactor heat transfer

George Stern, Adjunct Professor of Metallurgy and Nuclear Engineering
B.Ch. E., CCNY; M.S., University of Michigan
Nuclear metallurgy

ADJUNCT FACULTY—Brookhaven National Laboratory

Robert A. Bari, Adjunct Professor of Nuclear Engineering
A.B., Rutgers—The State University; Ph.D., Brandeis University
Nuclear reactor safety

Ralph J. Cerbone, Adjunct Professor of Nuclear Engineering
B.S., Boston College; M.S., Ph.D., Rensselaer Polytechnic Institute
Nuclear reactor safety, radiation shielding

David J. Diamond, Adjunct Professor of Nuclear Engineering
B.E.P., Cornell University; M.S., University of Arizona; Ph.D., Massachusetts Institute of Technology
Nuclear reactor theory and safety

Frank B. Hill, Adjunct Professor of Nuclear Engineering
B.Ch.E., Catholic University of America; Ph.D., Princeton University
Nuclear chemical engineering

Melvin M. Levine, Adjunct Professor of Nuclear Engineering
B.S., Ph.D., Massachusetts Institute of Technology
Nuclear reactor safety

David C. Rorer, Adjunct Professor of Nuclear Engineering
B.S., Massachusetts Institute of Technology; M.S., University of Illinois; Ph.D., Duke University
Experimental reactor physics

John R. Weeks, Adjunct Professor of Nuclear Engineering and Metallurgy
Met.E., Colorado School of Mines; M.S., Ph.D., University of Utah
Nuclear metallurgy

Wolfgang Wulff, Adjunct Professor of Nuclear Engineering
B.S.M.E., Institute of Technology Winterthur (Switzerland); M.S., Ph.D., Illinois Institute of Technology
Heat transfer

William G. Shiffmacher, Adjunct Lecturer in Nuclear Engineering
B.E.E., Manhattan College; M.S., Long Island University
Economics of nuclear power

Frank J. Vitale, Adjunct Lecturer in Nuclear Engineering
B.E.E., Polytechnic Institute of Brooklyn; M.S., C.W. Post College
Economics of nuclear power

OPERATIONS RESEARCH

The Division of Management offers programs in the area of operations research at the bachelor's, master's and doctoral levels.

Because of the vital importance of economics in operations research and related fields, the division has developed substantial strength in this area; master's and doctoral-level programs are offered in economic systems.

The field of 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 an increasing use of mathematical models in nearly all fields of endeavor. There is a need for trained professionals who can play an important role in the development of quantitative models and solution techniques for a broad array of challenging problems.

Operations researchers address themselves to such problems as production, distribution and marketing, allocation of urban resources, industrial and government operation 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 on society and industry.

Operations researchers concern themselves with systems in which the mission is imprecisely specified, in which limited resources are available, or where there is great variability in input and output demands. They are involved in decision-making in the face of incomplete information and conflicting objectives—objectives that frequently cannot be adequately defined, that are subjective and that are difficult to quantify. They 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 the orientation.

UNDERGRADUATE PROGRAM

The undergraduate program leads to the degree of bachelor of science in operations research. The program is built on the essential scientific and mathematical foundations underlying its field.

The undergraduate program 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 that build on the core requirements. Some possible elective sequences are listed after the curricula; these are mere suggestions, not required sequences of study.

The student wishing to enter this field should normally prepare to continue studies beyond the bachelor's level. Accordingly, undergraduate training places heavy emphasis on mathematics and the basic physical and social sciences that are necessary for graduate study in this area.

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 131, 142, 143, 146, for six credits of technical electives.

Graduate Courses may be taken as electives by qualified juniors and seniors with at least a B average, who 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.

Requirements for the Bachelor of Science

		Credits:
Mathematics:	MA 101,[1] MA 102,[1] MA 103,[1] MA 104,[1] MA 153, MA 223, MA 224, MA 555[1]	26
Science:	CM 101, CM 102, CM 111, CM 112, CS 100, 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
Major:	IE 254, IE 300, IE 314, IE 319, IE 327, IE 328, IE 346, IE 380	24
Electives:[2]	Chosen by student in consultation with department adviser	42
	Total	128

Typical Four-Year Operations Research Program

A typical program sequence covering eight semesters is shown below and on the following page. Students may rearrange courses and increase or decrease load per semester to suit their educational needs, provided prerequisites are not violated.

Typical Course of Study for the Bachelor of Science Degree in Operations Research

Freshman Year

First Semester			Hours/Week		Second Semester			Hours/Week	
No.	Subject	Cl.	Lab.	Cr.	No.	Subject	Cl.	Lab.	Cr.
CS 100	Intro. to Computer Progrmg.	2	0	2	HU 200	Intro. to Literature[1]	3	0	3
HU 101	College Composition	3	0	3	MA 102	Calculus II[1]	4	0	4
MA 101	Calculus I[1]	4	0	4	PH 102	Introductory Physics II	3½	1½	4
PH 101	Introductory Physics I	3	0	3	SS 252	Economics II: Macro-Econ.	3	0	3
SS 251	Economics I: Micro-Econ.	3	0	3	PE 102	Physical Education	0	2	0
PE 101	Physical Education I	0	2	0		Electives[2]			3
				15					17

Sophomore Year

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
IE 254	Industrial Management	3	0	3	MA 103	Calculus III[1]	3	0	3
MA 104	Appl. Differential Eqns.[1]	3	0	3	MA 153	Elem. of Linear Algebra	3	0	3
PH 103	Introductory Physics III	2½	1½	3	SS 104	Contemp. World Hist.[1]	3	0	3
PE 103	Physical Education III	0	2	0	PE 104	Physical Education IV	0	2	0
	Electives[2]			4		Electives[2]			4
				16					16

Junior Year

IE 327	Operations Research I	3	0	3	IE 300	Eng. Economic Analysis	3	0	3
MA 223	Intro. to Probability	3	0	3	IE 328	Operations Research II	3	0	3
SS 189	Intro. to Psychology	3	0	3	IE 380	System Simulation	3	0	3
	Electives[2]			7	MA 224	Intro. to Math. Statistics	3	0	3
				16		Electives[2]			5
									17

Senior Year

IE 314	Modeling of Social Syst.	3	0	3	IE 346	Oper. Des. of Public Syst.	3	0	3
IE 319	Prodctn. Planng. & Control	3	0	3		Electives[2]	0	0	13
MA 555	Design of Experiments[1]	2	3	3					16
	Electives[2]			7					
				16					

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. The adviser may approve substitution of another applied statistics course for MA 555.

[2]The 42 credits of electives are to be distributed as follows:
- 8 credits of courses in operations research and industrial engineering
- 13 credits of technical electives: engineering or science.
- 12 credits of humanities and social science.
- 9 credits of free electives: normally any course that does not duplicate others.

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 the student has completed 64 credits equivalent to MA 101-104, PH 101-103, CM 101-102, CM 111-112, CS 100, HU 200, SS 104, SS 189, SS 251-252, plus 14 credits of acceptable electives, the student can complete the requirement as follows:

EVENING PROGRAM

The degree requirements for part-time evening students in the operations research program are in all respects identical to those for full-time students. The evening program is structured for eight years without summer work.

A suggested sequence is shown below; students may change this sequence and increase or reduce the number of credits per term to suit their needs or available time, provided they do not violate the prerequisites.

Requirements 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	Industrial Management	3	0	3	IE 300	Eng. Economic Analysis	3	0	3
IE 327	Operations Research I	3	0	3	IE 328	Operations Research II	3	0	3
MA 223	Intro. to Probability	3	0	3	IE 380	System Simulation	3	0	3
	Electives[2]			6	MA 153	Elements of Lin. Algebra	3	0	3
				15	MA 224	Intro. to Math Statistics	3	0	3
									15

Senior Year

IE 314	Modeling of Social Systems	3	0	3	IE 346	Oper. Design of Public Syst.	3	0	3
IE 319	Prodctn. Planng. & Control	3	0	3		Electives[2]			14
MA 555	Design of Experiments	3	0	3					17
	Electives[2]			8					
				17					

See notes under typical course of study, page 213.

Suggested Sequence of Study for Evening* Students

First Year

First Semester			Hours/Week		Second Semester			Hours/Week	
No.	Subject	Cl.	Lab.	Cr.	No.	Subject	Cl.	Lab.	Cr.
HU 101	College Composition	3	0	3	CS 100	Intro. to Computer Progr.	2	0	2
MA 101	Calculus I[1]	4	0	4	MA 102	Calculus II[1]	4	0	4
					PH 101	Introductory Physics I	3	0	3

Second Year

MA 103	Calculus III[1]	3	0	3	MA 104	Appl. Diff. Equations[1]	3	0	3
PH 102	Intro. Physics II	3½	1½	4	PH 103	Introductory Physics III	2½	1½	3
					SS 104	Contemp. World Hist.[1]	3	0	3

Third Year

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 200	Intro. to Literature[1]	3	0	3	MA 223	Intro. to Probability	3	0	3
IE 254	Industrial Management	3	0	3		Elective[2]			3

Fourth Year

IE 327	Operations Research I	3	0	3	IE 328	Operations Research II	3	0	3
MA 224	Intro. to Math. Statistics	3	0	3	SS 252	Economics II: Macro-Econ.	3	0	3
SS 251	Economics I: Micro-Econ.	3	0	3					

Fifth Year

IE 314	Modeling of Social Systems	3	0	3	IE 300	Eng. Economic Analysis	3	0	3
SS 189	Intro. to Psychology	3	0	3	MA 153	Elem. of Linear Algebra	3	0	3
	Elective[2]			3					

Sixth Year									
IE 319	Prodctn. Planning & Control	3	0	3	IE 380	System Simulation	3	0	3
	Elective[2]			6		Electives[2]			6
Seventh Year									
MA 555	Design of Experiments	3	0	3	IE 346	Oper. Design for Pub. Syst.	3	0	3
	Electives[2]			3		Electives[2]			4
Eighth Year									
	Electives[2]			9		Electives[2]			8

*See notes under typical course of study, page 213.

SUGGESTED ELECTIVE SEQUENCES

Students often seek guidance in using the permitted electives to develop a meaningful sequence for concentration. Some suggested groupings are shown below from which the student may select his electives. Courses numbered 600 or above are graduate courses requiring a B or better average and the adviser's special permission. Since these suggestions are addressed to both industrial engineering and operations research students, some of the electives may duplicate required courses. These are merely suggestions, not required sequences of study.

Behavioral Science		**Credits**
SS 175	Introduction to Sociology	3
SS 185	Anthropology I	3
SS 191	Social Psychology	3
SS 192	Experimental Psychology I	3
SS 193	Experimental Psychology II	3
SS 198	Psychology of Human Dev.	3
SS 199	Organizational Behavior	3

Bioengineering		
BE 201	Syst. Apprch. to Biomed. I	2
BE 202	Syst. Apprch. to Biomed. II	2
CM 122	Organic Chemistry I	3
CM 164	Phys. Chem. of Living Systems	3
LS 105	General Biology I	3
LS 106	General Biology II	3
LS 115	General Biology Lab. I	7
LS 116	General Biology Lab. II	1

Computer Science		
CS 203	Computer Programming II	3
CS 204	Intro. to Data Structures	3
CS 205	Assem. & Mach. Lang. Prog.	3
CS 206	Compilers	3
CS 236	Switch. Circuits & Dig. Syst.	3
CS 237	Intro. to Comp. Architecture	3
CS 238	Computer Systems	3
CS 297	Computer Laboratory I	2
CS 299	Computer Laboratory II	2

Control Systems		
EE 101	Electrical Systems I	3
EE 102	Electrical Systems II	3
EE 103	Electrical Systems III	3
EE 104	Feedback Syst. Theory w. Applic.	4
EE 107	Control System Design	3
EE 111	Solid-State Dev. & Circ. I	3
EE 141	Signal Processing	3

Economics		
SS 255	Contemp. Amer. Policy	3
SS 257	History of Economic Thought	3
SS 258	Comp. Economic Systems	3
SS 259	Economic Development	3
SS 263	Labor Economics	3
SS 264	Urban Economics	3
SS 265	Money and Banking	3

Management		
IE 252	Cost Fundamentals	3
MG 300	Management Process	3
MG 612	Human Resources Management	3
MG 664	Legal Environment of Business	3
MG 606	Managerial Finance	3
MG 607	Marketing Management	3
SS 199	Organizational Behavior	3

Mathematics, Applied		
MA 153	Elements of Linear Algebra	3
MA 201	Applied Analysis I	3
MA 202	Applied Analysis II	3
MA 217	Complex Variables	3
MA 260	Vector Anal. & Part. Diff. Equa.	4
MA 358	Intro. Numerical Analysis	3

Operations Research, Advanced		
MA 153	Elements of Linear Algebra	3
OR 618	Inventory Models	3
OR 631	Linear Programming	3
OR 632	Nonlinear Programming	3
OR 650	Queuing Systems I	3
OR 665	Microeconomic Models	3

Statistics and Probability		
IE 311	Statistical Quality Control	3
MA 232	Statistical Methods II	3
MA 238	Applied Probability	3
MA 554	Applied Decision Theory	3
MA 556	Correl. & Multivar. Mod.	3
MA 557	Sampling	3
OR 852	Regression & Anal. of Variance	3
OR 853	Design of Experiments	3

Transportation Systems		
TR 360	Traffic Planng. & Opertns.	3
TR 361	Transportation Models	3
TR 362	Public Transit Tech. & Oper.	3
TR 670	Planng. & Design of Termls.	3
TR 715	Urban Goods Movement	3

Urban Systems

IE 346	Oper. Des. of Urban Systems	3
LS 140	Environmental Biology	3
SS 180	Sociology of Urbanization	3
SS 182	Man and the Environment	3
SS 264	Urban Economics	3
TR 630	Urban Planning Principles	3
TR 631	Urban Planning Methods	3

GRADUATE STUDY

The division offers master of science and doctor of philosophy degree programs in the areas of operations research and economic systems. Within these degree programs, students may pursue graduate studies in such specialized areas as information science, system simulation, management science, experimental design, industrial economics, 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 a desire to develop techniques for problem-solving and decision-making in a technological world.

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.

GRADUATE PROGRAMS

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, and 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.

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 advanced studies.

A bachelor's degree and competence in calculus (equivalent to MA 103) are required for admission to the program. Applications should be made to the Division of Management with operations research indicated as the area of specialization.

Students entering the program without a three credit minimum in probability (not including statistics) are urged to take such a course during the summer preceding their first term.

The program in operations research leads to the degrees of master of science in operations research and doctor of philosophy.

Economic Systems—The program in economic systems is intended to develop individuals proficient in the construction and implementation of economic models, both at the level of the individual firm and of the entire economy. Such models provide engineering managers with important tools for decision-making.

Starting with fundamental courses in engineering economics, microeconomic and macroeconomic decision models, the student is encouraged to complement the program with related courses in methodology and practice. This may include work in production planning, application of linear programming theory or courses in management and social sciences.

An undergraduate degree in engineering or science usually provides the necessary prerequisites for admission to the program. Further, undergraduates in economics and other quantitative social sciences are also encouraged to enter the program if their interests are in economic systems. If competence in mathematics through calculus (MA 103) has not been attained, appropriate courses to remove this deficiency will be required on admission to the program. Application should be made to the Division of Management with economic systems indicated as the area of specialization.

The graduate program in economic systems leads to the degrees of master of science and doctor of philosophy.

MASTER OF SCIENCE DEGREES

Operations Research
Requirements for the master of science in operations research degree:

A. Basic Required Courses[1]

MA 153	Elements of Linear Algebra[4]
MA 561	Probability[5]
OR 601	Intro. to Digital Computing
OR 608	Statistics
OR 627	Oper. Res.: Deterministic Models[4]
OR 628	Oper. Res.: Stochastic Models[4]

B. Required Courses . . . . . 9 units

IE 600	Engineering Economic Analysis
OR 631	Linear Programming
OR 650	Queuing Systems I

C. Major Electives:[2] Select 4 . . . . . 12 units

IE 611 }	Statistical Quality Control
OR 685 }	Reliability I
OR 614 }	Modlg. of Social Systems I
OR 680 }	System Simulation I

networks. Applications include production-inventory problems, plant location-allocation problems, regional transportation and traffic assignments, manufacturing processes. Prerequisites: MA 561 and either OR 627 or OR 631.
Also listed under IE 636

OR 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: OR 608.

OR 651 Queuing Systems II* 2½:0:3
Applications of queuing theory with emphasis on communications and vehicular traffic. Customer behavior, switching networks, overflow traffic, alternate routing, feedback, priorities, control. Formulation of standards based on cost-benefit viewpoint. Prerequisite: OR 650 or MA 815.

OR 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: SA 607 and either SA 627 or SA 631 or permission of instructor.

OR 666 Macroeconomic Models 2½:0:3
Measures of economic activity, national income accounting. Input-output analysis, Leontief's static model, inter-industry relationships, applications to regional planning, economic forecasting and environmental problems. Dynamic models and growth, models of national economy. Portfolio selection. Prerequisites: MA 561 and either OR 627 or OR 628.

OR 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: OR 608.
Also listed under MG 671

OR 673 Time Series: Forecasting and Control 2½:0:3
Strict and weak stationarity. Autocorrelation and correlogram. Moving average (MA), autoregressive (AR) and mixed ARMA 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: OR 608.

OR 674 Econometric Models and Methods* 2½:0:3
Single equation estimation vs. simultaneous-equation systems estimation. Regression techniques. Instrumental and lagged variables. Problems of identification in simultaneous-equation methods. Two-stage, three-stage and limited information estimation. Applications to macroeconometric models, economic systems structural analysis, short-term and long-term forecasting, etc. Prerequisite: OR 608.
Also listed under SS 713

OR 680 System Simulation I 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 SIMSCRIPT, introduction to other languages. Students program, code and run several simulation models. (Not open to students who have taken IE 380.) Prerequisites: OR 601 and MA 561 or instructor's permission.
Also listed under IE 680

OR 681 System Simulation II* 2½:0:3
Advanced concepts of discrete simulation. Statistical aspects of simulation design, run length, efficiency. Methods for generation of nonuniform random variables, including probability integral transform, rejection, composition techniques. Monte Carlo variance reducing techniques, including importance sampling, control variates and antithetic variates. Application to physical problems. Prerequisites: OR 608 and OR 680.
Also listed under IE 681

OR 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: MA 223 or MA 561 or equivalent.
Also listed under EL 617 or IE 685

OR 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 components reliability. Prerequisite: MA 223 or MA 561 or equivalent.
Also listed under EL 618 and IE 686

OR 700 System Effectiveness* 2½:0:3
Evaluation methodology in system analysis for decision-making process in selection of preferred solutions from set of competing alternatives. Discussions center on origin and need of performance effectiveness, requirements and criteria, basic concepts, models, applications to real-world problems, computer methods. Prerequisites: OR 601, OR 627 and OR 628, or instructor's permission.
Also listed under IE 700

OR 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: OR 601 and either OR 627 or OR 631.
Also listed under IE 720

OR 727 Case Studies in Management Science* 2½:0:3
Application of scientific and analytical methods of solving management decision-making problems drawn from current practice and literature. Prerequisites: OR 627 or OR 631 and OR 628 or OR 650.
Also listed under IE 727 and MG 727

OR 730 Mathematical Economics* 2½:0:3
Contributions of mathematical analysis to traditional economic problems. Review of basic mathematical tools. Multiplier and accelerator models, economic stabilization, capital theory, economic growth, static equilibrium, individual behavior, welfare economics and subjects of special interest to students. Prerequisite: OR 665 or instructor's permission.
Also listed under SS 730

OR 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: OR 619.
Also listed under IE 778

OR 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, governmental service systems. Cost-benefit viewpoint in social welfare context. (Not open to students who have taken IE 346 except with instructor's permission.) Prerequisite: OR 627 or TR 837 or equivalent.
Also listed under IE 846

OR 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 Markow 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.

OR 852 Applied Regression and Analysis of Variance 2½:0:3
Analysis of observed data by means of regression and analysis of variance and covariance. 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. Prerequisites: MA 153 and OR 608.
Also listed under IE 852

OR 853 Design of Experiments 2½:0:3
Basic designs for scientific and industrial experiments: single-factor and multiple-factor completely randomized designs, randomized blocks, incomplete blocks, orthogonal contrasts, general regression approach, Latin and higher squares, quantitative factors-orthogonal polynomials, complete and fractional factorial experiments including confounding methods. Introductions to statistical packages: SPSS and BMDP. Prerequisite: OR 608.
Also listed under IE 853

OR 870 Games and Decisions 2½:0:3
Rectangular games and strategies, payoffs, values and the minimax theorem. Continous 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: OR 608.

OR 911-912 Selected Topics in Operations Research I, II* each 2½:0:3
Lectures beyond areas covered in other courses. Specific topics vary according to instructor, who may be visiting professor. Topics and prerequisites announced during term prior to offering.

OR 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.
Also listed under IE 920

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
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 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 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: completion of qualifying examination and guidance committee's approval.

The following courses listed under industrial engineering are also considered in-program courses for operations research:

IE 600 Engineering Economic Analysis
IE 606 Work Design and Measurement
IE 611 Statistical Quality Control
IE 612 Advanced Quality Control
IE 716 Commercial Data-Processing System Design
IE 765 Human Factors in Engineering Design
IE 775 Industrial Safety Engineering
IE 776 Material Requirement Planning
IE 777 Manufacturing Improvement Curves
IE 779 Advanced Work Systems Design

FACULTY

Norbert Hauser, Professor of Industrial Engineering and Management Science and Dean of Management
B.M.E., Cooper Union; M.I.E., Eng.Sc.D., New York University
Modeling of social systems, computer simulation, quality control

John T. Chu, Professor of Operations Research
B.S., University of Chekiang (China); M.S., Ph.D., Iowa State University
Managerial decisions, behavioral approaches, national and international problems

Walter Helly, Professor of Operations Research
B.A., Cornell University; M.S., University of Illinois; Ph.D., Massachusetts Institute of Technology
Urban systems, stochastic modeling, vehicular traffic

John H.K. Kao, Professor of Industrial Engineering
B.S., National Central University (China); M.S., D.Eng.Sc., Columbia University
Applied statistics, quality control and reliability, operations research in nuclear engineering

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 (N.Y., PA.)
Mathematical programming, optimum design, 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, industrial management, project management

Seymour Kaplan, Associate Professor of Operations Research and Director of Economic Systems Program
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 Director of Industrial Engineering Program
B.S., Banaras Hindu University (India); M.S., Ph.D., University of Illinois
Production planning, operational control systems, facility location and layout

A. George Schillinger, Associate Professor of Management and Operations Research
B.E.E., C.C.N.Y.; M.S., Eng.Sc.D., Columbia University
Technology management, policy studies, stochastic systems

ADJUNCT FACULTY

Geoffrey Gordon, Adjunct Professor
B.Sc. (Physics), B.Sc. (Mathematics), M.Sc. (Mathematics), University of London (England)

Samuel Gorenstein, Adjunct Professor
B.B.A., City College of New York; Ph.D., New York University

Peter M. Meier, Adjunct Professor
B.S., Swiss Federal Institute of Technology (Zurich); M.Sc., Ph.D., University of Massachusetts

Arnold Ockene, Adjunct Professor
B.E.E., City College of New York; M.S., Columbia University

Lawrence W. Parks, Adjunct Professor
B.S., M.S., Ph.D., Polytechnic Institute of New York

Robert Marose, Adjunct Assistant Professor
B.S., University of Notre Dame; M.S., Stevens Institute of Technology; Ph.D., Polytechnic Institute of New York

Andrew Sipos, Adjunct Assistant Professor
Engineering Diploma, Technical University, Budapest; M.S.C.E., University of Pennsylvania (P.E.)

Moira LeMay, Adjunct Associate Professor
B.S., Queens College of City University of New York; M.S., Ph.D., Pennsylvania State University

Young W. Yoon, Adjunct Associate Professor
B.A., Yonsei University; M.B.A., New York University; Ph.D., Polytechnic Institute of New York

Michael P. London, Lecturer
B.S., M.S., New York University

Martin Sternberg, Lecturer
B.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, agility and endurance. The program teaches skills in interesting lifetime sports: tennis, golf, badminton, etc., and gives the students healthful activities that may be pursued with family and friends.

Athletics

The student athlete attending Polytechnic may compete in a far-reaching intercollegiate athletic program that encompasses every phase of sport. All full-time undergraduate students in good academic standing are eligible to try out for positions on the seven varsity teams that carry the blue and white colors of Polytechnic in N.C.A.A. competition. Intercollegiate sports are baseball, basketball, cross-country, fencing, soccer, tennis and wrestling.

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 a sound program of instruction and participation for all students in physical education.

Each undergraduate student is 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 one hour a week of CPR where the students will learn principles and techniques of how to maintain breathing and circulation in a victim suffering from cardiac arrest. In the second hour each student participates in an individual weight-training program.

PE 103 Disco Dance **0:2:0**
Theory and application of popular dance techniques.

PE 104 Weight Training **0:2:0**
Individual weight-training programs developed to produce increased strength and endurance through the use of isotonic and isometric exercises.

FACULTY

Joseph Martini, Director of Physical Education and Athletics
B.S., Long Island University; M.S., Brooklyn College

Edward J. Collins, Instructor

Marilyn Washington, Instructor
B.S., Long Island University

Louis Zinser, Instructor
B.S., University of Baltimore; M.S., Hofstra University

PHYSICS

Physics is the basic science of the natural world—the science of matter, energy and motion. It is indispensable in the preparation for any engineering or scientific career.

The training of physics majors at both the undergraduate and graduate levels is basic and general. This broad training makes them less subject to the risks of obsolescence produced by the rapidity of technological change in modern life. The curriculum is designed to provide a background 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 any one of many different levels. And physics graduates at all levels are employed in private industry, government agencies and research foundations for fundamental research and engineering. In addition, training in physics serves as valuable preparation for a great variety of 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 industry, the chemical industry and the fields of 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 the master's or doctor's degree. For many others, it means professional work in industry, government or in high school teaching. In addition, some students use their major in physics as preparation for work in other fields such as mathematics, chemistry, biology, medicine, engineering, law, history of science, writing or business.

Our program's emphasis on fundamental knowledge, on thorough analytic training and on the universal logic of science enables our physics students to take these different paths.

The structure of the undergraduate program is fourfold: formal instruction in the sciences, instruction in humanities and social sciences, informal instruction and additional activities.

Formal instruction in the sciences is described by the program of courses. This program includes—after the freshman year with its beginning courses in physics, chemistry and mathematics—a spiral 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 or nuclear physics or in 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 thirty-two credit hours of courses in the humanities and social sciences required of all physics majors. Our department urges its students to choose additional courses in these areas. We believe that the natural curiosity that 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. Each student meets regularly with members of the physics faculty in informal conferences to discuss the student's 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 seminars, students prepare talks on aspects of advanced topics in physics and present them to the critical audience of their peers and professors.

Many students spend some time in research, either assisting in the various research programs carried on by the faculty or working on a relatively independent research project assigned after consultation with a guidance professor. Undergraduate participation in research alongside graduate students and professors is becoming so important that it will probably soon enter the department's formal educational 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 the opportunity for individual reading and advanced study under professorial guidance and will accept satisfactory performance in a regular course examination as fulfillment of a course requirement.

Physics students have at their disposal 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 on page 13.

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. We believe that such interaction, leading to a college experience built around studying physics, talking physics, thinking physics and doing physics, is the most valuable preparation for any career in physics. We also feel that this blending of experiences leads to real appreciation of the intellectual impact of physics and to an understanding of why so many of mankind's important thinkers have been attracted to physics and have added to its accomplishments.

REQUIREMENTS FOR THE BACHELOR OF SCIENCE

The program requires 128 credits, including 46 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 and free electives. (See "Typical Course of Study" on the following page.) The distribution is as follows:

	Credits
PH 101-103, 111, 210, 232, 240, 303-304 313-314, 321, 335-336, 343, 390	46
CM 101, 102, 111, 112, 180, EE 370, 374 MA 101-104, CS 111	30
HU 101, 200, SS 104 or IS 140, 141	9
Language (or equivalent)	12
Electives (7 MA, 3 PH, 11 Hum./Soc. Sci.)	21
Free electives	10
	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 to be chosen in consultation with the departmental adviser. Seven elective credits must be in mathematics and three in physics. The remaining electives are free.

GRADUATE STUDY

The Department of Physics prepares properly qualified graduates for careers in research and college teaching, granting the M.S. and Ph.D. degrees in physics. It offers a program of advanced and specialized education in theoretical and experimental physics with concentrations in particular fields of physics, emphasizing early participation in seminars and research. Programs of research are carried on which aim to extend the knowledge and techniques in particular fields of specialization.

A special formal program in chemical physics, described below, and a master's program having emphasis in energy policy are also given.

In addition, the Department of Physics participates in a cooperative program with the New York University's Graduate School of Public Administration, leading to the joint degree of master of science in physics and master of public administration.

Areas of current theoretical research are primarily in solid-state physics and statistical mechanics within the theoretical condensed matter group, and also include field-matter interactions, image restoration and nuclear theory. Our major experimental research programs are in the fields of solid-state physics, x-ray physics, radiation physics, quantum optics, surface physics and medical physics. Each of these is centered in well-equipped laboratories with modern facilities. The department maintains a large facility for surface and thin films preparation, and is serviced by a precision machine shop. The x-ray diffraction laboratory, one of the largest, allows the full range of techniques for crystal structure analysis and has unique facilities for multiple beam interferometric interactions at high resolution.

The importance of the informal aspects of physics education, already stressed in the discussion of the undergraduate program, is carried over fully into our approach to graduate training. There is much interaction between students and faculty. Outstanding students are advised to apply for financial aid in the form of research fellowships, teaching fellowships or partial tuition remission.

Typical Course of Study for the Bachelor of Science Degree in Physics

Freshman Year

First Semester			Hours/Week	
No.	Subject	Cl.	Lab.	Cr.
CS 111	Introduction to Computing	3	0	3
	Hum./Soc. Sci. elective[h]	6	0	6
MA 101	Calculus I	4	0	4
PH 101	Introductory Physics I	3	0	3
PH 111	Freshman Seminar in Current Physics	1	0	1
PE 101	Physical Education	0	2	0
				17

Second Semester			Hours/Week	
No.	Subject	Cl.	Lab.	Cr.
CM 101	General Chemistry I	2½	0	2½
CM 111	General Chemistry Lab I	0	1½	½
	Hum./Soc. Sci. elective[h]	6	0	6
MA 102	Calculus II	4	0	4
PH 102	Introductory Physics II	3½	1½	4
PE 102	Physical Education	0	2	0
				17

Sophomore Year

CM 102	General Chemistry II	2½	0	2½
CM 112	General Chemistry Lab II	0	1½	½
	Hum./Soc. Sci. elective[h]	3	0	3
MA 103	Calculus III	3	0	3
PH 103	Introductory Physics III	2½	1½	3
PH 210	Elementary Mechanics	3	0	3
PE 103	Physical Education	0	2	0
				15

MA 104	Applied Differential Eqs.	3	0	3
PH 232	Intro. to Modern Physics	2½	1½	3
PH 240	Optics	3	0	3
EE 370	Princ. of Electrical Eng.	3	0	3
	Hum./Soc.Sci. elective[h]	3	0	3
EE 374	Instrumentation Lab	0	3	1
PE 104	Physical Education	0	2	0
				16

Junior Year

PH 303	Physical Meas. I	1	3	2
PH 335	Atomic & Nuclear Physics I	3	0	3
	Hum./Soc. Sci. elective[h]	3	0	3
	Electives	0	0	6
				16

PH 304	Physical Meas. II	1	3	2
PH 321	Electricity and Magnetism	4	0	4
PH 336	Atomic & Nuclear Physics II	3	0	3
	Hum./Soc. Sci. elective[h]	3	0	3
	Electives	0	0	3
				15

Senior Year

PH 313	Intro. to Theo. Phys. I	3	0	3
PH 343	Thermodynamics & Kin. Theo.	4	0	4
	Hum./Soc. Sci. elective[h]	3	0	3
	Electives	0	0	6
				16

CM 180	Structural Chem. for Physicists	3	0	3
PH 314	Intro. to Theo. Phys. II	3	0	3
PH 390	Senior Seminar	2	0	2
	Hum./Soc. Sci. elective[h]	5	0	5
	Electives	0	0	3
				16

Total credits required for graduation: 128

---

[h]In the humanities and social sciences, the student is to fulfill the following minimum 32-credit requirements:

1. Required courses (21 credits) HU 101 and either HU 200, SS 104, or IS 140, 141 (9 credits)
ML 1 × 1 through 1 × 4 (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.

2. 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.

REQUIREMENTS FOR THE MASTER'S DEGREE

For admission to graduate study in physics, a bachelor's degree in physics is assumed with preparation equivalent to intermediate or advanced courses in mechanics, electromagnetic theory, optics, thermodynamics and atomic physics (including wave mechanics). Applicants with a degree in physics of different emphasis or in other fields may be admitted with undergraduate deficiencies if approved by the departmental adviser.

All applicants are required to take the Graduate Record Examination.

The program of study for the degree of master of science in physics offers three options, each requiring 36 units. One option, including early formal research, consists of a 12-unit thesis (PH 999) and 24 units of required and elective courses. In another option, candidates with suitable research experience may substitute a six-unit project (PH 999) 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. Either thesis or project is completed by a satisfactory defense in an examination. The third option does not include a thesis but emphasizes a strong formal training in courses.

The arrangements for a thesis or project and the choice of elective courses require approval of the departmental adviser.

The detailed program of study for the degree of master of science in physics is given in tabular form below. Students offering the equivalent of any required courses may substitute additional units of electives.

No.	Subject	Units
PH 901-902	Physics Colloquium I, II	None
PH 953-954	Graduate Seminar I, II	3
PH 667	Quantum Mechanics I	3
PH 999	Thesis (12 units) + 18 elective units	
or		
PH 999	Project (6 units) + 24 elective units	30
or	30 elective units	
	Total	36

REQUIREMENTS FOR THE DOCTOR'S DEGREE

The requirements for the Ph.D. in physics conform to the general regulations. A major and one minor course sequence are required. The major offering consists of 54 units in physics. The minor of 18 units may be taken in such fields as mathematics, chemistry or electrical engineering. With permission of the department and the candidate's guidance committee, a limited number of graduate course credits in the history and philosophy of science may be offered to satisfy the major requirements.

The doctoral candidates must pass both written and oral qualifying examinations for which they should register with the approval of the department. The candidates may then ask for the appointment of a guidance committee and the formalization of the dissertation topic and adviser. Note that if doctoral research is continued in the same area of specialization as the M.S. thesis, credits will usually be transferred toward the Ph.D. research requirement. About three months before completion of the dissertation, a doctoral candidate submits a written summary of work to the department and is examined on the general area of the dissertation in a precis examination by the guidance committee. The candidate must also demonstrate a reading knowledge of German, Russian or French. Details on examination content and regulations may be obtained from the department.

CHEMICAL PHYSICS PROGRAM

(See page 57.)

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**
Introductory course, including topics in both classical and modern physics. Emphasis on development of physics as a dynamic cumulative process through the interplay of experiment and theory. Prerequisites: **MA 091-092.**

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. Prerequisite: **MA 101.**

PH 102 Introductory Physics II **3½:1½:4**
Continuation of PH 101. Thermodynamics and kinetic theory of gases. Electromagnetic fields and forces and their interactions with particles. Principles and instruments of classical and modern measurements. Lab fee required. Prerequisites: PH 101 and **MA 102.**

PH 103 Introductory Physics III **2½:1½:3**
Continuation of PH 102. Propagation of waves, particularly as illustrated by the study of physical and geometrical optics. Lab fee required. Prerequisite: PH 102.

PH 111 Freshman Seminar in Current Physics **1:0:1**
Analysis and discussion of selected topics of current interest in physics emphasizing concepts and the underlying framework of physical understanding. Topics are discussed from various areas of current research such as astrophysics, atomic and nuclear physics, the solid state and biophysics. Lectures and discussion. Readings in literature. Visiting scientists.

PH 210 Elementary Mechanics **3:0:3**
Statistics by virtual work and potential energy methods. Stabili-

OR 618 } Inventory Models
OR 619 } Production Planng. & Control
OR 632 } Nonlinear Programming
OR 720 } Optimum Seeking Methods
OR 665 } Microeconomic Models
OR 674 } Econometric Models & Methods
OR 851 } Stochastic Processes
OR 852 } Applied Regression & ANOVA

D. Other Relevant Electives[3] . . . . . 15 units
Minimum total 36 units

Economic Systems
Requirements for the Master of Science degree:
A. Basic Required Courses[1]
IE 600 Engineering Economic Analysis
MA 153 Elements of Linear Algebra[4]
MA 561 Probability[5]
OR 601 Intro. to Digital Computing
OR 608 Statistics[6]
OR 627 Oper. Res.: Deterministic Models[4]

B. Required Courses . . . . . 9 units
OR 665 Microeconomic Models
OR 666 Macroeconomic Models
OR 674 Econometric Models & Methods

C. Major Electives: Select 4 . . . . . 12 units
MG 700 Managerial Accounting
OR 614 Modeling of Social Systems I
OR 628 Oper. Res.: Stochastic Models[4]
OR 631 Linear Programming
OR 671 Bus. & Econ. Forecasting
OR 673 Time Series: Forecasting & Control
OR 852 Applied Regression & ANOVA

D. Other Relevant Electives[3] . . . . . 15 units
Minimum Total 36 units

DOCTOR OF PHILOSOPHY DEGREES

The Division of Management offers programs leading to the degrees of doctor of philosophy in the major areas of operations research and economic systems.

The general Polytechnic requirements for the doctor of philosophy degree are stated in this catalog under Degree Requirements. Specific requirements for each of these doctoral programs may be found in the division's doctoral brochure.

Entrance to a doctoral program is contingent on passing the program's qualifying examination. This will consist 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 will select a thesis adviser and prepare a formal proposal for the dissertation research. A thesis committee will be appointed to judge the merit of the proposed research. After approval of this proposal, the doctoral candidate shall register for research. On completion of the dissertation, the candidate must pass an examination in its defense.

CERTIFICATE PROGRAMS

The division offers several certificate programs designed for the professional with work experience. A certificate program requires five courses which are selected in line 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 individual is issued a certificate. Students who choose to work toward a master's degree are able, on admission, to apply all courses taken toward a certificate to the degree program. Additional information may be obtained from the division.

UNDERGRADUATE COURSES

All undergraduate courses in operations research are listed under Industrial Engineering.

---

[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 will be increased accordingly.

[2]Only one of each bracketed pair of courses will be 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 departments. Because of substantial overlap with OR courses, no credit will be given for MG 630, MG 602, and MG 605.

[4]Certain introductory courses will be waived if the student takes specified advanced courses, for which full credit will be given.
For OR 627: OR 631 and either OR 632 or OR 665
For OR 628: OR 650 and either OR 618 or OR 619
For MA 153: MA 703 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 OR 608 or an equivalent course during the summer preceding their first term.

GRADUATE COURSES

OR 601 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 101 or equivalant.)
Also listed under CS 531 and IE 601

OR 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

OR 614 Modeling of Social Systems I 2½:0:3
Social systems 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 or related areas individually chosen. (Not open to students who have taken IE 314.) Prerequisites: knowledge of calculus and computer programming.
Also listed under IE 614

OR 615 Modeling of Social Systems II* 2½:0:3
Continuation of OR 614, with greater emphasis on underlying theory. More complex systems are analyzed, and control algorithms are designed and tested to improve performance. Prerequisite: OR 614.
Also listed under IE 615

OR 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 OR 627 or OR 631.
Also listed under IE 618

OR 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 or equivalent.) Prerequisite: OR 627 or OR 631.
Also listed under IE 619

OR 620 Project Planning and Control* 2½:0:3
Network planning and techniques for project management and resource allocation. Emphasis on PERT, LOB, CPM and probabilistic generalized networks. Heuristic models for multiproject 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 IE 620 and MG 610

OR 621 Facility Layout and Location* 2½:0:3
Development of quantitative models for analysis of facility layout and location problems. Solutions by both mathematical optimization and heuristic algorithms. Location of single and multiple facilities in existing and new layout design. Other topics include computerized layout planning, minimax location and discrete vs. continuous location planning. (Not open to students who have taken IE 321.) Prerequisite: OR 627 or OR 631.
Also listed under IE 621

OR 624 Computer-Augmented Case Studies in Management Science 2½:0:3
Cases involving problems in forecasting, inventory, scheduling, line balancing, maintenance, queuing and in similar industrial engineering and operations research disciplines are assigned. Students may write their own computer programs or may use existing packages to analyze the cases and design improved alternatives. Written reports are required. Prerequisites: IE 600, OR 627 and OR 628.
Also listed under IE 624

OR 627 Operations Research: Deterministic Models 2½:0:3
Development of mathematical models for solving decision problems of deterministic nature. Classical optimization, Lagrange multipliers. Linear programming, transportation method, network procedures, games. Dynamic programming. (Not open to students who have taken IE 327 or equivalent.) Prerequisite: calculus.

OR 628 Operations Research: Stochastic Models 2½:0:3
Mathematical models for solving decision problems of stochastic nature. Queuing, Markov processes, inventory models, reliability, dynamic programming. OR 628 and OR 627 constitute standard one-year survey course in operations research. (Not open to students who have taken IE 328 or equivalent.) Prerequisite: MA 561.

OR 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

OR 632 Nonlinear Programming* 2½:0:3
Optimization of nonlinear functions. Classical methods. Constraints and Lagrangian methods. Duality and economic interpretation. Separable programming, feasible directions, gradient projection. Quadratic and convex programming. Industrial and engineering applications. Prerequisite: OR 631.
Also listed under MA 818

OR 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: OR 631.
Also listed under MA 814

OR 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 OR 627 or OR 631.

OR 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 OR 631.

OR 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

ty 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, photoelectric 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 232 Introduction to Modern Physics 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 240 Optics 3:0:3
Principles of reflection, refraction, photometry, interference, diffraction, polarization, dispersion, scattering; application to lenses, optical instruments, interferometers, resolving power, spectra. Prerequisite: PH 103.

PH 281 Astronomy and Astrophysics* 3:0:3
Historical development. Traditional and modern observational techniques. Theories of planets, stars, galaxies. High points of current advances in astrophysics and cosmology. Given on demand. Prerequisite: PH 103.

PH 303-304 Physical Measurements I, II* each 1:3:2
Precision measurements in mechanics, heat, electricity, optics, modern physics. Lab fee required. Given alternate years. PH 303 prerequisites: PH 232 and **PH 335**. PH 304 prerequisites: PH 303 and **PH 336**.

PH 313-314 Introduction to Theoretical Physics I, II* each 3:0:3
Provides a foundation for more advanced graduate courses by developing mathematical methods used in classical theoretical physics. Topics include Lagrange's equations, rigid body motion, normal modes of motion, Hamilton's equations, vibrating strings and membranes, flow of fluids, flow of heat, electrostatics, electrodynamics, Maxwell's equations. PH 313 prerequisites: PH 210 and PH 321. PH 314 prerequisite: PH 313.

PH 321 Electricity and Magnetism 4:0:4
Properties of the electrostatic, magnetostatic and electromagnetic field in vacuum and in material media. Maxwell's equations with applications to elementary problems. Prerequisite: MA 104.

PH 335-336 Atomic and Nuclear Physics I, II each 3:0:3
Introduction to electronic and nuclear structure of the atom. Relativity, wave mechanics, natural and artificial radioactivity, fission, cosmic rays. Fundamental experiments and postulates of wave and particle physics. PH 335 prerequisite: PH 232. PH 336 prerequisite: PH 335.
Also listed under NU 335-336

PH 343 Thermodynamics and Kinetic Theory 4:0:4
Discussion of experimental basis or 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. Introduction to principles of kinetic theory of gases. Boltzmann distribution H-theorem, viscosity, thermal conductivity. Prerequisite: PH 336.

PH 372 X-Ray Diffraction 2:3:3
Production and properties of x-rays. Elements of crystallography. Stereographic projection. Powder and single crystal diffraction techniques. Structure and crystal orientation. Stress analysis and phase diagram determination by x-ray techniques. Qualitative and quantitative chemical analysis by x-ray techniques. Prerequisites: MA 104 and PH 103.
Also listed under MT 412

PH 381-382 Reading Course in Physics I, II each 2 credits
Reading course in special topics in physics, supervised by an appropriate staff member. Prerequisites: physics major, junior standing and departmental approval.

PH 390 Senior Seminar 2:0:2
Topics of general interest prepared, reported and discussed by the students. Prerequisite: PH 336.

PH 391-394 Bachelor's Thesis in Physics each 2 credits
An individual investigation involving theoretical, experimental and bibliographic study of some problem of interest to physicists. Students may register for thesis in parts as noted. Total credits determined in consultation with adviser.

PH 399 Senior Honors Work in Physics* credit to be arranged
Independent work undertaken by qualified honor students in physics. Course material arranged by a faculty steering committee.

GRADUATE COURSES

PH 601-602 Physics for Chemists I, II* each 3¾:0:4½
For doctoral candidates in chemistry with only a general physics background, gives 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
Concerned with a range of specialized techniques and processes of modern experimental physics. Depending on requirements of thesis student and recommendation of adviser, concentration on advanced laboratory skills in areas such as vacuum techniques, thin films, preparation of samples for solid-state studies, crystal growing, cryogenics and instrument design. Emphasis on intensive training in those particular skills required in student's research endeavors. Permission of student's adviser and of director of the course required. May be taken for a maximum of two semesters. Prerequisite: concurrent thesis registration.

PH 607 Mathematical Methods of Physics I* 2½:0:3
Review of vector and tensor analysis. Introduction to complex variable theory. Special functions of mathematical physics. Differential equations of mathematical physics. Emphasis on unifying role of mathematics in physics on physical concepts and problems. Prerequisites: PH 321 or equivalent and **PH 313** or equivalent.

PH 606 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. Introduction to integral equations. Emphasis on unifying role of mathematics in physics and on physical concepts and problems. Prerequisite: PH 607 or equivalent.

PH 612† 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 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 theory of mechanics including the Hamilton-Jacobi and Poisson bracket formulation. Lagrangean formulation of mechanics of continuous media. Prerequisite: PH 615.

PH 623 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 624 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 anisotropic 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**
Survey of 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 particles, their modes of decay, interactions, classifications and invariance laws. PH 633 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 safety levels, effects of accoustical, microwaves and thermal radiation. Prerequisite: PH 335 or equivalent.
Also listed under BE 605

PH 643-644† Physical Optics I, II* **each 2½:0:3**
Classical electromagnetic theory of geometrical and physical optics as applied to propagation, reflection, refraction, dispersion, optics of crystals, interference, diffraction. Quantum and statistical optics of coherence and partial coherence as applied to masers and lasers, and nonlinear effects. PH 643 prerequisite: PH 314. PH 644 prerequisite: PH 643.

PH 651-652† Introduction to Solid-State Physics I, II **each 2½:0:3**
Survey of phenomena and introduction to 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 matter and to thermal radiation. Kinetic theory. Non-equilibrium 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. Discussion of many-body problems. Prerequisites: PH 663 and PH 667, or equivalent.
Also listed under EL 652

PH 667-668 Quantum Mechanics I, II **each 2½:0:3**
Quantum mechanics with applications to atomic systems. The use of Schroedinger's equations. Angular momentum and spin. Problems and approximation methods. Semiclassical theory of field-matter interaction.
Also listed under EL 655-656

PH 669-670 Quantum Mechanics III, IV* **each 2½:0:3**
Theory of measurement and connection with classical dynamics. The Dirac formulation, transformation theory, scattering theory and introduction to the theory of radiation. Candidates for the Ph.D. in physics may receive credit only on completion of the full sequence of four courses. 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**
The interpretation of x-ray powder data. Theory and methods of crystal structure analysis, crystallite size determination, scat-

tering by amorphous substances, crystal perfection, small angle scattering. Prerequisite: PH 671.

PH 673† X-Ray Diffraction Techniques I* **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. Lab fee required. Prerequisite: **PH 671.**

PH 674† X-Ray Diffraction Techniques II* **0:4:3**
Continuation of PH 673. Study of single crystals using rotation, oscillation, Weissenberg, precision and diffractometer techniques. Determination of space groups. Intensity measurements. Stress-strain analysis, small-angle scattering and scattering by amorphous materials. Lab fee required. Prerequisites: **PH 672** and PH 673.

PH 676 Methods of Crystal Structure Determination* **2½:0:3**
The theory of crystal structure analysis. Trial and error methods, the 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 alectrical, 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**
Discussion of the particular physical properties of crystals arising from anisotropy of matter constants. Topics include thermal, electrical, optical and elastic properties and effects arising from coupling of these properties. Interpretation 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 Lagrangian formalism of classical fields. Quantization of fields, scattering and the S-matrix theory. Feynman diagrams and renormalization theory. Application 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**
Summary of present knowledge of fundamental properties of nuclei followed by advanced quantum mechanical treatment of nuclear forces, nuclear reactions, nuclear structurea, nuclear radiation and the theory of beta-decay. Emphasis on 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 invarience laws of particle physics. Topics include 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. Discussion of the higher symmetry schemes of SU (3), SU (6), etc. Field theory and second quantization introduced as necessary. PH 765 prerequisite: PH 670. PH 766 prerequisite: PH 765.

PH 767-768 Group Theory and Symmetry Principles in Physics I, II* **each 2½:0:3**
Invariance principles of physics and corresponding groups of transformations. Introduction to group theory with emphasis on Lie groups. PH 767 prerequisite: PH 670. PH 768 prerequisite: PH 767.

PH 780 Special and General Theory of Relativity* **2½:0:3**
Introduction to Einstein's theory of relativity, Minkowski geometry, relativistic mechanics and electrodynamics, applications of theory with special reference to high-energy physics; gravitation and 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 ponderomotive equations. Prerequisite: PH 616 and PH 624 or equivalent.

PH 801-802 Selected Topics in Advanced Physics I, II* **each 2½:0:3**
Current or advanced topics of particular interest to graduate students. Subject matter changes each year determined by student and faculty interest. 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**
Presentation of topical subjects of experimental and theoretical physics by the staff and outside lecturers. Fee required. Required of all master's and doctoral candidates.

PH 927 Energy Policy Issues* **2½:0:3**
See Energy Program for details.

PH 928 Energy Resource Distribution and Conversion Technology **2½:0:3**
See Energy Program for details.

PH 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.

PH 953-954 Graduate Seminar I, II **each 2:0:1½**
Prepared presentation by participating students and discussion of topics in physics of current interest and from the literature. Required of all degree students.

PH 955-956 Reading in Physics I, II **each 2½:0:3**
Individual reading of 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 961-962 Seminar in X-Ray Diffraction I, II **each 2:0:0**
Topics from current literature and reports on current research by staff and outside lecturers. Required of all students with minors in crystallography. Fee required.

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 carried out under the direction of a member of the Department of Physics. Chemical physica majors should register for appropriate CM courses. Minimum research registration requirements for these degrees:
M.S. 12 units; M.S. (project option) 6 units; Ph.D. 36 units.
Registration for research is required each semester consecutively until student has completed adequate research project or acceptable thesis and has passed the required oral examination. Doctoral students should expect in general some registration beyond the minimum. The number of research credits registered for each semester should reflect realistically the time to be devoted to research. Prerequisites: degree status and graduate adviser's and research director's consent.

FACULTY

Ronald D. Parks, Professor and Head of Physics
B.S., Kansas State University; M.S., Ph.D., Stanford University
Surface and low-temperature 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
Solid-state and surface 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

Daniel C. Mattis, Thomas Potts Professor of Physics
B.A., Massachusetts Institute of Technology; M.S., Ph.D., University of Illinois
Theoretical physics, condensed matter

Benjamin Post, Professor of Physics
B.S., CCNY; M.S., Ph.D., Polytechnic Institute of Brooklyn
X-ray physics, crystallography, solid-state chemistry

Nathan Wainfan, Professor of Physics
B.E.E., M.S., New York University; Ph.D., University of Southern California
X-ray physics, gas discharges

Stephen Arnold, Associate Professor of Physics
B.S., University of Toledo; M.A., Ph.D., CCNY
Experimental condensed matter, radiation physics

Hilda Bass, Associate Professor of Physics
B.A., Hunter College; M.A., Smith College
Physics education

Oliver B. Keyes, Associate Professor of Physics
B.S., M.S., Fordham University
Physics education

Walter Kiszenick, Associate Professor of Physics and Nuclear Engineering
B.S., Brooklyn College; M.S., Ph.D., Polytechnic Institute of Brooklyn
Electron microscopy, x-ray diffraction

Meir Menes, Associate Professor of Physics
B.S., Cooper Union; Ph.D. New York University
Experimental solid-state physics, gaseous electronics

Donald B. Scarl, Associate Professor of Physics
B.A., Lehigh University; Ph.D., Princeton University
Quantum optics, solar energy technology, high-energy physics

Laxmi Chaud Gupta, Visiting Associate Professor of Physics
B.S., University of Delhi; Ph.D., University of Bombay
Experimental solid-state physics

Peter Hanggi, Assistant Professor of Physics
B.S., College of Mathematics and Natural Sciences, Basil; M.S., Ph.D., University of Basil (Switzerland).
Statistical mechanics

Peter Riseborough, Assistant Professor of Physics
B.S., Ph.D., Imperial College (England)
Theoretical condensed matter

ADJUNCT FACULTY

Hubert W. Schleuning, Adjunct Research Professor of Physics
M.A., New York University; M.E., Polytechnic Institute of Brooklyn
Vacuum technology

Benjamin Bloch, Adjunct Assistant Professor of Physics
B.S., Columbia University; Ph.D., Polytechnic Institute of Brooklyn
Theoretical atomic physics

Lawrence Mendelsohn, Adjunct Research Professor of Physics
B.S., Brooklyn College; M.S., Columbia University; Ph.D., New York University
Theoretical atomic physics

EMERITUS FACULTY

John J. Dropkin, Professor Emeritus
B.A., Columbia University; M.S., Ph.D., Polytechnic Institute of Brooklyn
Solid-state physics

Paul P. Ewald, Professor Emeritus
Ph.D., University of Munchen (Germany)
X-ray physics

POLYMER SCIENCE AND ENGINEERING

For many years, Polytechnic Institute has had a traditional commitment to a strong polymer program of worldwide renown. At the present time, the Departments of Chemical Engineering and Chemistry jointly offer graduate programs leading to the degree 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 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 master of science degree is designed to meet the need for engineers and chemists well versed in the fundamental principles of polymer science and engineering.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE IN POLYMER SCIENCE AND ENGINEERING

Candidates for the degree master of science in polymer science and engineering are to plan their programs in accordance with the following required courses:

No.	Subjects	Units
CH 917	Introduction to Polymeric Materials	3
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
Electives—chosen* from such courses as CH 862, CH 923, CH 933, CH 940-941, CM 772, CM 781, CM 782, CM 785, CM 905, CM 760, CM 801, AM 603-604, AM 606, AM 625, MT 412 MT 603, MT 620, PH 673-674, PH 676		9

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
		36

The doctor of philosophy in polymer science and engineering program 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.

REQUIREMENTS FOR THE DOCTOR OF PHILOSOPHY IN POLYMER SCIENCE AND ENGINEERING

Programs of study are planned individually with each candidate by members of 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 dean of graduate studies for each candidate. The program is planned to give the student a thorough polymer science and engineering background accompanied by study in a minor field chosen by the candidate. The student must pass a comprehensive qualifying examination in polymer science and engineering, exhibit a reading knowledge in a foreign language and present a doctoral dissertation.

Each candidate for the doctorate must complete a minimum of 90 units of academic work beyond the bachelor's degree, including a minimum of 30 units of dissertation research. Although the student may elect to take more than 30 units of Ph.D. thesis, only 30 units of Ph.D. thesis can be counted in the required 90 unit minimum, and these must be taken at Polytechnic. Once the student has started the dissertation, registration must be continuous, (excluding the summer session), 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

*All electives are to be chosen in conference with the graduate adviser.

the bachelor's degree (not including Ph.D. thesis) in polymer science and engineering subjects will be required, of which at least 18 units must be taken at Polytechnic. A minor is required within a science or engineering department and should consist of at least 12 units.

Attendance is required at the chemical engineering or polymer science and engineering seminars for at least four semesters. Each student must maintain an overall B average in those courses submitted for the doctoral degree.

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 Subjects	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 917	Introduction to Polymeric Materials	3
CH 921	Polymer Processing	3
CH 922	Polymer Processing Laboratory	3
CH 926	Engineering Properties of Polymers	3
		24

Students interested in the Ph.D. program should obtain a brochure outlining procedures and requirements, which is available from the office of the department head.

GRADUATE COURSES POLYMER SCIENCE AND ENGINEERING

CH 862 Rheology of Non-Newtonian Fluids* **2½:0:3**
Classification of non-Newtonian viscoelastic fluids. Derivation of rheological equations of state from continuum mechanics point of view. Molecular viscoelastic theories: random-coil theory and network theory. Experimental characterization of non-Newtonian fluids; steady and dynamic experiments, measurements of normal stress differences in shear flow. Engineering applications to polymer processing operations. Prerequisites: CH 631, MA 531 and MA 532 or equivalent.

CH 917 Introduction to Polymeric Materials **2½:0:3**
Principles of technological aspects of polymerization, compounding and processing of polymeric materials, their properties and applications. Thermoplastic materials such as polyethylene, polypropylene, poly vinyl chloride, polystyrene, acrylics and engineering plastics will be 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. Study of non-Newtonian polymeric systems. Extrusion theory and applications. Discussions and problem-solving in compression, transfer and injection molding, thermoforming and plasticization, 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**
Laboratory study of 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, etc. Prerequisite: CH 921.

CH 923 Industrial Polymerization Processes* **2½:0:3**
Analytical study of principal processes used to synthesize polymers, including polymer engineering operations, equipment, polymerization control, instrumentation, process economics. Emphasis on development and solution of polymer plant engineering problems. Prerequisite: CM 771.

CH 926 Engineering Properties of Polymers **2½:0:3**
Study of mechanical properties and structure of solid polymers. Viscoelastic theory and response 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 917, CM 771.

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 as announced in advance of particular 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 Synthesis of High Polymers **2½:0:3**
Organic aspects. Chemistry of monomer and polymer formation. Modern mechanistic analysis of reactions. Stereochemistry of polymer structure and forces of stereoregulation. Condensation, free radical (bulk, suspension, emulsion, solution), ionic, ring-opening and nonclassical polymerization reactions.

CM 781 Solution Properties of High Polymers **2½:0:3**
Application of osmometry, light scattering, equilibrium ultracentrifugation, electrophoresis, viscosity, diffusion, ultracentrifuge sedimentation, flow birefringence, polarimetry, spectroscopy and other techniques to the characterization of dissolved macromolecules. Properties of polyelectrolytes, association in solutions containing macro-molecules and reaction kinetics in macromolecular solutions also discussed. The course is designed to cover both synthetic and biological macromolecules. Prerequisites: CM 161, CM 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 in 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.

PROJECT, THESIS AND SEMINAR

CH 930 Guided Studies in Polymer Science and Engineering 6 units, each 2 units
Selection, analysis, solution and presentation of a comprehensive report of some problem involving polymer science and engineering, such as polymer synthesis, processing, evaluation, equipment design, etc. Conducted under supervision of staff member. Conferences scheduled. Candidates for master's degree 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 investigation of a problem in polymer science and engineering. Thesis may involve experimental research, theoretical analysis, or process design, and possibly a combination thereof. Candidates for a 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 Degree of Doctor of Philosophy in Polymer Science and Engineering 30 units, each 3 units
Dissertation must give results of independent investigation of a problem in polymer science and engineering and may involve experimental and/or theoretical work. Thesis must show ability to do creative work and that an original contribution has been made to polymer science and engineering, which is 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 and polymer science and engineering 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.

FACULTY

Chang Dae Han, Professor and Head of Chemical Engineering
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

Frederick Eirich, Distinguished Professor of Polymer Chemistry
Ph.D., University of Vienna
Mechanical behavior of polymers, rheology, colloid chemistry, chemical evolution, biopolymers

Herbert Morawetz, Institute Professor of Polymer Chemistry
B.A.Sc., M.S.Sc., University of Toronto; Ph.D., Polytechnic Institute of Brooklyn
Physical chemistry of polymers in solution and in bulk

Yoshiyuki Okamoto, Professor of Chemistry
B.S., Osaka University of Science and Engineering (Japan); Ph.D., Purdue University
Polymer synthesis and polymer reagents

Eli M. Pearce, Professor and Head of Chemistry
B.S., Brooklyn College; M.S., New York University; Ph.D., Polytechnic Institute of Brooklyn
Polymer synthesis, degradation and structure-property relationships

Martel Zeldin, Associate Professor of Chemistry
B.S., Queens College; M.A., Brooklyn College; Ph.D., Pennsylvania State University
Chemistry of elements in Groups IIIA and IVA, inorganic polymers

Jovan Mijovic, Assistant 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

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

EMERITUS FACULTY

Paul F. Bruins, Professor Emeritus of Chemical Engineering
B.S., Central College, Iowa; M.S., Ph.D., Iowa State University; D.Sc. (Hon.), Polytechnic Institute of New York
Plastics technology, electrochemistry, materials science

Herman F. Mark, Professor Emeritus of Chemistry and Dean Emeritus
B.S., Ph.D., University of Vienna
Synthesis, characterization, and properties of natural and synthetic polymers

SOCIAL SCIENCES

UNDERGRADUATE PROGRAM

The department offers a modern program of study leading to the degree of bachelor of science in social sciences. This curriculum has been conceived as an attempt to meet increasing needs for specialists in the social sciences who have more than just a passing familiarity with the physical sciences, mathematics and the humanities. Thus the program is designed to draw on the rich resources available at Polytechnic; the students are offered specialized training in the social sciences in a setting noted for its scientific and technical excellence.

The degree's presentation is interdisciplinary with emphasis on developing an integrated historical, economic, behavioral and cultural understanding of human society and civilization. Within the general social science curriculum, the student may major in one of three areas: history and history of science and technology, behavioral science (anthropology, psychology, sociology and politics) or economics. Each of these is described in the details below.

More and more occupations and professions require individuals firmly grounded in the social sciences. Accordingly, our graduates can look forward to employment opportunities in governmental agencies, foundations and private industry or to independent professional practice. Specific fields in which a social science background is useful include teaching at all levels: applied social research on problems involving race, poverty, education, urban and national planning, and foreign aid; managerial and personnel operations; and the practice of law and medicine.

The department is also responsible for the social science courses that are an essential part of the general education and professional training of scientists and engineers at Polytechnic. The foundation provided in the social sciences helps prepare students for leadership in industry, education and government. In keeping with the educational ideals of Polytechnic, it is also the aim of the department to prepare students for active roles of responsible citizenship in a complex society.

HISTORY AND HISTORY OF SCIENCE AND TECHNOLOGY

Courses in history emphasize the elements of social and economic change in various areas and periods since the Renaissance. Both theoretical discussion and practical response are treated in order to elucidate the deeper meaning of historical movements more clearly than the more traditional political narrative. The methods and conclusions of related work in economics and the behavioral sciences are applied to this historical analysis.

The basic sequence on the history of Western civilization familiarizes students with political, economic, social, cultural and intellectual developments in European history since the Middle Ages. It also introduces them to original documents and to a range of scholarly interpretations. An introductory course on the modern world emphasizes the conflict of ideologies in the twentieth century and the history of non-Western societies. Students are also given the best opportunity to analyze and discuss the best historical scholarship in a variety of special subjects: history of science and technology, development of modern Russia, international communism, American civilization, Afro-American and non-Western history, the Renaissance, imperialism, European thought, and twentieth-century thought. Methods of instruction are similarly varied and include formal lectures, class discussion, colloquia, films and tutorials leading to independent research by students.

ECONOMICS

The economics courses of the department guide students in developing a critical understanding of contemporary economic ideas and their roots, institutions and problems. They concentrate on posing, in their theoretical and historical context, the important questions of domestic and international public policy. Majors in economics will receive a thorough grounding in the tools of economic analysis, mathematics and statistical methods. Concentration in economics will therefore prepare students for careers in governmental service, business and graduate work not only in economics, but in any of the social sciences. Finally, this theoretical training is applied to actual economic problems and circumstances.

BEHAVIORAL SCIENCE

Introductory courses in anthropology, politics, sociology, psychology and social psychology are intended to broaden students' understanding of social process and human behavior and to prepare them to meet problems of a professional or administrative nature with insight and sophistication. For the student major-

ing in behavioral science, advanced courses provide more detailed and intensive study. Available courses examine contemporary American society and its impact on the individual, the variety of social and cultural forms that have unfolded in the course of history and their implications for the contemporary world as the "new nations" enter the historical mainstream, and language, learning, and the modification of behavior with experiments in psychophysics, learning theory and communication. Students have an opportunity 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 the student to psychology as the science of behavior and emphasize that learning is an active process that may be empirically investigated. The department offers advanced courses in the areas of social, developmental, personality, comparative, physiological, learning and abnormal psychology. The major focus in the department is experimental, and all majors take a two-semester laboratory sequence, which offers a unique opportunity for undergraduates to master fundamental methods and concepts in the empirical investigation of human and animal behavior. In addition, other psychology courses allow ample opportunity for students to design and carry out individual research projects under the supervision of the instructor. A concentration in psychology enables a student to pursue graduate training in psychology and in other related areas.

REQUIREMENTS FOR THE BACHELOR'S DEGREE IN SOCIAL SCIENCES

Summary	**Credits**
Requirements	
Humanities	24
Social Sciences	24
Mathematics, Science and Technology	20-22
	68-70
Concentrated study	38-42
Electives	12-18
Total credits required for graduation:	126-128

Humanities

Communications/Literature/Arts (HU 101 and two courses in literature; or IS 140, IS 141 and one course in literature; and one course in the arts)	12
Philosophy and Comparative Religion (Any 2 courses from HU 341 to HU 364)	6
Language or Linguistics (one year German, French, Spanish language or HU 381 Language and Society and HU 382 Introduction to Scientific Study of Language)	6
	24

Social Sciences

History (SS 101 History of Western Civilization, SS 104 Main Themes in Contemporary History)	6
Economics (two courses selected from SS 251, SS 252, SS 254)	6
Psychology (SS 189 Introduction to Psychology; psychology elective)	6
Anthropology/Sociology/Politics (two courses selected from the introductory courses SS 185, SS 175, SS 151)	6
	24

Mathematics, Science and Technology

Mathematics (MA 091-092 Principles of Mathematics or MA 101-102)	8
Laboratory Science, one year sequence selected from LS 101-102 Principles of Biology, CM 091-092 Principles of Chemistry, [or CM 101-102 and CM 111-112], PH 091-092 Principles of Physics [or PH 101-102]	6-8
Two courses selected from CS 100 Introduction to Computer Programming, CS 111 Introduction to Programming, MA 231 Statistical Methods, IE 314 Modeling & Simulation of Social Systems, or equivalent courses	6
	20-22

Concentrated Study 38-42

Under guidance of a personal adviser, students are able to plan focused programs, preparatory to their career interests, from a wide range of possibilities.

Students may choose to devote themselves to a single concentration or to divide their time between a major and minor interest. Those who opt for a minor (minimum of 12 credits) may do so in the form of guided reading and/or guided research. Pre-professionally attractive minors are available outside the liberal arts in computer science, operations research, mathematics and management.

Electives 12-18

Students may continue to strengthen their general education and/or intensify their concentrations. It is hoped that in the unique setting of a technological university students find it attractive to explore further the history, philosophy, and practice of mathematics, science and technology.

MAJOR CONCENTRATIONS

(12 credits in one group; all courses are three credits each)

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 History of Socialism and Communism
SS 149 History of Marxism
SS 153 Revolutions in Comparative Historical Perspective
SS 154 Russia, China and the West
SS 179 Sociology of Human Disease
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 161 Politics and the Film
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 Women in Current Perspective
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
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 Public Policy: Growth, Inflation and Employment
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 700 Industrial Organization of the American Economy
SS 711 Advanced Economic Theory
SS 713 Econometrics

[1]History and history of science options may be combined.

GRADUATE STUDY

The Department of Social Sciences offers graduate courses in the history of science and technology, economics and psychology. These are intended for students majoring in social sciences and for graduate students in science and engineering interested in pursuing the interdisciplinary links between their own specialties and the social sciences. Outstanding stu-

dents are advised to apply for financial aid in the form of research fellowships, teaching fellowships or partial tuition remission.

History of Science and Technology—The master's program in the history of science and technology is 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 interaction with human society and values has become increasingly evident. Intense specialization has further heightened the need for deeper understanding between the various branches of science and the humanities. In considering ideas, time, process, transfer and social change in the history of science, the student is afforded the opportunity of understanding the elusive connections that exist between science and engineering and the social sciences and humanities. Prospective teachers of science and engineering subjects will be able to increase their effectiveness through knowledge of the history of their own and related disciplines. The libraries of Polytechnic contain many important and rare works on the history of science that may be used for original research.

A total of 36 units is required for the master's degree. Normally a student will start by taking the introductory courses, SS 600 and SS 601, and then proceed to the more advanced courses and seminars. But in each case the student's program will be constructed in consultation with an adviser, taking into consideration the student's background and interests. The student will be encouraged to take up to nine units of work in related fields outside the program, for example, philosophy, mathematical logic, Renaissance history or one of the sciences or engineering.

To qualify for the degree, the student may elect to write either a comprehensive examination or a thesis embodying an appropriate and substantive piece of research. If the student chooses the former, the examination may be taken in the term in which the course work is being completed. A student choosing the thesis may apply up to 12 units of course work toward the requirements for the degree. Acceptance of a thesis will involve an oral presentation and defense. In addition to the above requirements, the student must demonstrate a reading knowledge of one appropriate foreign language.

Environmental Psychology—The master's program in environmental psychology prepares the student for an interdisciplinary field, which combines efforts and expertise in behavioral and design professions. This program emphasizes the interaction between psychology and the various engineering disciplines to fill a major gap in the training of professionals who work on applied socio-technical problems.

Many aspects of modern engineering and technological development have complex behavioral and social dimensions. Few professionals, however, are conversant with both the technical and social/behavioral aspects of a problem. This program is designed to produce graduates who have such interdisciplinary abilities by providing students who already have a background in the technical and engineering issues with course work and experience in environmental psychology.

Since, as a psychology program, this curriculum does not provide extensive technological training, students who possess an undergraduate degree in a technical or engineering field will be given preference for admission. Applicants with humanities or social science backgrounds will be considered, but may be required to supplement this program with remedial technical and scientific courses to provide the necessary prerequisites for program electives.

Each student will develop, in consultation with an adviser, an individual program consisting of 18 units of core courses plus 12 units of elective courses. This program will be designed to compliment the students' background, training and experience as well as their particular interests, and may include courses from a variety of Polytechnic departments in addition to the Environmental Psychology Program and Department of Social Sciences.

These individual programs may be developed from three broad areas of emphasis:

A. Human Behavior and the Large Scale Environment. Programs may include study in behavioral and social aspects of transportation planning and of energy use and planning.

B. Social Impact Assessment. This area will involve training in the nature of social response to environmental change, and methodology and use of social impact assessment in the broader context of environmental impact assessment.

C. Laboratory Research in Environmental Effects. Programs in this area may emphasize the use of laboratory techniques for analyses of the effects of various environmental stressors (i.e., noise, pollution, crowding) on human behavior.

Students will also be required to complete a master's thesis in the area of interest and pass a comprehensive psychology examination. The thesis may involve field research which stems from practicum experiences.

This 36-unit program may be completed in one year by full-time students or two to three years by part-time students.

Core Courses (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
MA 553	Applied Statistics II

Thesis (6 units)

SS 997 Thesis for degree of Master of Science in the History of Science

Electives (12 units)

Environmental Psychology Elective. One elective must be chosen from available environmental psychology courses:

SS 915 Behavioral and Social Aspects of Environmental Psychology
SS 924 Social Impact Assessment
SS 928 Topics in Environmental Psychology

Free Electives

These courses may be taken from a wide range of courses chosen from the psychology program or other departments in consulation with an adviser to fit an overall program.

Advanced Psychology Courses

SS 910 Learning Theory
SS 911 Psychology of Language and Communication
SS 912 Sensation and Perception
SS 913 Physiological Psychology
SS 914 Comparative Psychology

Doctoral Minor Requirements—The department offers doctoral minors in economics, history of science and psychology. Normally such a minor would entail at least twelve units of course work in the respective field. In each case, however, the prospective student should obtain the sponsorship of a member of the faculty of the Department of Social Sciences and arrange a specific program.

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 I, 1815-1914 3:0:3
Courses SS 101-102 provide an integrated 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 heritage of Western society between approximately 1500 and 1914. May be taken independently.

SS 104 Main Themes in Contemporary World History 3:0:3
Major sources of change, transformation and tension in 20th century. Discussions, readings, lectures, films on war, racism, scientific-technical revolution, socialism, communism, imperialism, the U.S. and revolutionary movements, modernization of underdeveloped societies, cold war, human ecology.

SS 110 The Renaissance and Reformation Era* 3:0:3
Investigation of dynamic changes in intellectual and artistic values, political and economic approaches, social and religious institutions from late Middle Ages to counterreformation. Guided reading and research. Discussion of selected topics. Prerequisite: SS 101 or equivalent.

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, China. Slave trade, European conquest, struggle for independence. Contemporary African states in world politics.

SS 116 History of Latin America* 3:0:3
Early history of Mexico and Andean area. Spanish conquest and establishment of hacienda system 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
Development of Russian state and society from earliest times. Structure and practice of Tsarism. Russia as "underdeveloped" society and special problems of modernization. Russia and West. Culture and literature with special emphasis on 19th century fiction. Political, social, economic causes of breakdown in 1917.

SS 121 History of Soviet Union 3:0:3
Analysis of 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 to Reconstruction 3:0:3
The development of culture, politics and society from early European and Afro-American settlements through the post-Civil War era. Emphasis will be placed on the interpretation of accessible "primary sources," which illuminate the convictions, ideologies and activities of not only leaders but ordinary Americans from the 17th to the mid-19th century.

SS 124 History of the United States: From Reconstruction to the Cold Wars 3:0:3
The emergence of provincial America to global authority. Particular attention to the interweaving of domestic struggles and foreign policies as the United States moved from the "Gilded Age," through the Progressive Era, the World Wars of the 20th century, the New Deal period and on to confrontation with revolutionary upheavals in the post World War II epoch.

SS 126 Afro-American History* 3:0:3
Role of black people in history. African cultural background, slavery as an institution, abolitionist movement, Civil War, reconstruction, segregation, migration, politics, African independence. Black Americans now and the future.

SS 127 American Economic History in the Industrial Era* 3:0:3
Economic history of the United States from late 19th century to present. Rise of industry, closing of frontier, progressive era, great depression and New Deal, world wars and aftermath. Particular attention to economic role of government.

SS 128 A History of Jazz* 3:0:3
History, appreciation and analysis of jazz as unique Afro-American art form in American heritage. 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
Historical examination of growth and unfolding of American constitutional system stressing political and economic fac-

tors shaping the law. Students expected to handle leading court decisions and related legal tests. Prerequisites: SS 123, or SS 124, or instructor's permission.

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 with emphasis on guerrilla as against conventional warfare. Political and economic history of revolution: role of nationalists and libertarians. Aftermath and consequences.

SS 132 Problems of American Foreign Policy* 3:0:3
Major problems in formulation and application of foreign policy from 18th-century origins to post-Cold War thaw: continental and overseas expansion, international rivalries, impact of domestic influences, diplomacy of infant republic, Monroe Doctrine, "manifest destiny," "white man's burden," open-door policy, "dollar diplomacy," involvement in world wars and their settlements, Cold War and aftermath.

SS 135 History of Science and Technology: Antiquity to Galileo 3:0:3
Science and technology from earliest times to Renaissance. Special emphasis on neolithic and medieval technology, achievements of ancient Greeks from pre-Socratics to Euclid, Copernican revolution, role of science and technology in expansion of Europe, influence of science on development of European thought.

SS 136 History of Science and Technology: Galileo to Darwin 3:0:3
Science and technology from the scientific revolution through the period of Lavoisier to the origins of the theory of evolution. Special emphasis on the achievements of Galileo and Newton and on 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 to the Present 3:0:3
Science and technology from the 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, Contemporary Society* 3:0:3
Comprehensive analysis of mutual relationships between technology, science and society, including 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 use of technology and science. Prerequisite: junior or senior standing.

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. Discussion of alternate scenarios. Predictable and unpredictable consequences of innovations. Long-range technology forecasting. Students prepare forecast on topics of their choice. Prerequisite: junior or senior standing or instructor's permission.

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
Investigation of 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.

SS 145 Colloquium in Twentieth-Century Thought 3:0:3
Investigation of contemporary ideas of Europe and America. Reading and evaluation of selected works in political theory, economic theory, philosophy of science, historiography, ethics, aesthetics, mass cultures.

SS 147 Colloquium in Imperialism* 3:0:3
Study of principal theories of imperialism establishing (1) their premises, (2) their internal consistency, (3) their historical validity, especially in light of breakup of world empires since World War II. Course helps students establish their own criteria and judgments. Prerequisite: SS 104 or equivalent.

SS 148 History of Socialism and Communism* 3:0:3
Socialist movement from founding of Second International to collapse in 1914 and revival in interwar years. Communist movement from theoretical controversies within social democracy before World War I to Eurocommunism. Examinations of socialist theories and ideologies, national parties, international organizations. Interpretive materials and sources in translation. Prerequisite: SS 104 or equivalent.

SS 149 History of Marxism* 3:0:3
Analysis of major Marxian 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. Prerequisite: SS 104 or equivalent.

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 in light of norms of democratic society.

SS 153 Revolutions in Comparative Historical Perspective* 3:0:3
Eighteenth-century quest for reason and rights of man. American and French Revolutions compared. Nineteenth-century extension of radical tradition. Bolshevik revolution as culmination and new departure. Twentieth century as age of global revolution in peasant societies of Third World. "Post-scarcity" transformation and possibilities in advanced West. Prerequisites: SS 104 or SS 101-102.

SS 154 Russia, China, 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. Prerequisite: SS 104.

SS 157-158 Topics in Comparative Politics* each 3:0:3
Selected topics for analysis and research, including 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 Society and Film 3:0:3
The film viewed as document and instrument of social structures and relations. The film as facet of mass culture and mass communication and as 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; Wartime Collapse of France—Genesis & Retrospect; Postwar Italy—the Politics of Self-Criticism; Revolutions in the Third World; Cold-war America—Ego Affirmation & Nightmare; Soviet Images of Russia's Past. Film screenings, readings, lectures and discussions. Lab fee required. May be repeated for credit.

BEHAVIORAL SCIENCE

SS 175 Introduction to Sociology 3:0:3
An elementary treatment of the influence of culture and social structure on human behavior. Topics include concepts of sociological analysis, types of human societies, social stratification, urban ecology, the social context of the environment crisis and the human impact of technology.

SS 177 Social Problems 3:0:3
Examination of social disorganization and deviant behavior in contemporary society. Investigation of specific problem areas: crime and juvenile delinquency, mental disorder, drug addiction alcoholism, suicide, family disorganization, poverty and unemployment. Comparison with cultures of other peoples and/or simpler societies. Discussion 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. Position of Spanish-speaking minorities of Puerto Rican and Mexican descent in United States, compared with ethnic and racial relations in Puerto Rico, Cuba, Brazil.

SS 179 The Sociology of Human Disease* 3:0:3
The study of human disease in the context of social and biological adaptation. The disease "profiles" of the three major levels of man's social evolution, viz., hunters and gatherers, low-energy agriculturalists, and states are considered from a broadly conceived human ecological framework. Recommendation: some background in biology and anthropology is desired.

SS 180 Sociology and Urbanization* 3:0:3
Origin and history of urbanization, ecology of contemporary cities and urban-rural relations, urbanism, family patterns, personality development. Urbanism, social-economic stratification, distribution of power, comparative analysis of urbanization in non-Western world. Student projects on urban problems.

SS 182 Man and the Environment 3:0:3
Development of broad ecological understanding of interaction of humans with non-human environment through survey of relevant topics: ecosystem, human interaction with ecosystem, human societies as self-regulating systems, attitudes toward nature, case studies in ecological history, present environmental crisis and attempts at resolution.

SS 185 Anthropology: Physical 3:0:3
The biosocial basis of human conduct seen in evolutionary perspective. The elementary genetic, demographic and ecological models necessary for the 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. A consideration of both variation and developmental trends in several human institutions such as 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. Extensive treatment of basic areas of learning, physiological psychology, sensory systems with introduction to areas of developmental, educational, abnormal and social psychology. Lectures, class discussion, presentation of films, demonstrations of experiments.

SS 190 Environmental Psychology 3:0:3
The study of the way in which people use and are affected by their physical environments. Includes research in natural environments as well as built urban areas. Research on personal space, privacy, territoriality, crowding and design-behavior relationships. Students are involved in field research to assess the fit of environments to human needs, using interview techniques, behavioral observation and unobtrusive measures. Prerequisite: SS 189 or equivalent.

SS 191 Social Psychology 3:0:3
Study of behavior as function of social stimulation. Nature of sociopsychological inquiry, 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 the function of human and animal sensory and perceptual systems. Theoretical approaches to the problem of sensory thresholds: classical psychophysical theory, neural 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, carry out and analyze experiments dealing with such complex behavior as learning verbal responses, concept formation, communication nets; perform original experiment (designed with help of instructor). Laboratory reports required. Lectures on both substance and method 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. Dis-

cussions of neurophysiological and pharmacological basis of drug action and behavioral effects of different drugs. Economic, historical, political, sociological, anthropological aspects of drug use and abuse. 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 theory, biological, etiological models. Relation 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 that result from stress and the relationship between stress and disease. Techniques of reducing stress and anxiety such as Jacobsen's relaxation technique, meditation, yoga and biofeedback are examined. The laboratory gives the student the opportunity to measure the body's behavioral and physiological responses to stress and anxiety and to practice in the relaxation techniques including yoga and biofeedback training.

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
Course of human development from birth to old age with special emphasis on effects of age on thinking, learning, social behavior. Current research related to implications for teaching and educational program. Prerequisite: SS 189.

SS 199 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. Analysis of administration problems by case studies and simulated situations. Prerequisite: SS 189.

SS 203 Psychology of Learning* 3:0:3
Process of 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
Introduction to relationships between physiology, anatomy, behavior. Physiological, anatomical, biochemical bases for such functions as memory, learning, motivation, sleep, arousal, stress. Prerequisite: SS 189.

SS 205 Comparative Psychology* 3:0:3
Introduction to comparative study 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
Study of human cognitive capabilities and information processing. Topics include the structure of memory and the internal representation of knowledge, concept formation, symbol manipulation, mental operations and schema, consciousness and strategies for problem-solving. Special emphasis on cognitive development and on the role of language in thinking. Prerequisite: SS 189.

SS 211 Cultural Backgrounds of African Nations* 3:0:3
Introduction to precolonial history and cultures of Africa. Impact of colonialism, changing forms of political, economic and social organization. Emergence of nationalism, Pan-Africanism, 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 outline of 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 concentration and 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. History of Indian relations with Spanish, French, Dutch, English in relation to mission activity, exploration, trade, war. Westward movement of settlers and struggle for land. Changing patterns of Indian societies. Contemporary Indian life and sociopolitical orientations—rural and urban. Prerequisite: SS 185 or SS 186.

ECONOMICS

SS 251 Microeconomics 3:0:3
Introduction to supply and demand analysis. The allocation of resources and distribution of income. Various market structures: perfect competition, imperfect competition, oligopoly and monopoly.

SS 252 Macroeconomics 3:0:3
Introduction to 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
Issues such as unemployment and inflation, urban fiscal crisis, 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
Inflation, unemployment, growth and recession. Special attention to interest rates, money, the stock market, wages, productivity, profit rates and the balance of payments. Role of military expenditures. Legacy of the Vietnam War. Evaluation of the Federal Reserve and government regulation of the economy: spending, taxation, deficits and monetary policy. Wage-price controls, unions and the future of economic planning. Prerequisite: SS 252 or permission of the instructor.

SS 257 History of Economic Thought* 3:0:3
Development of economic thought concentrating on various schools of thought that anticipated and prefigured modern economic analysis. Prerequisite: SS 252 or SS 254 or equivalent.

SS 258 Comparative Economic Systems* 3:0:3
Introduction to the concepts of history of economic systems: capitalism, socialism, the market and planning. Analysis of in-

come distribution, resource allocation and modes of economic decision-making under alternative socioeconomic 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**
Consideration of theories of development for both advanced and underdeveloped economies, different historical paths to development, problems of technological change, capital accumulation, economic planning. Prerequisite: SS 252 or SS 254 or equivalent.

SS 262 Collective Bargaining **3:0:3**
Study of institution of 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, strike and its alternatives, comparisons with other bargaining settings (e.g. international negotiations).

SS 263 Labor Economics **3:0:3**
Theoretical and empirical analysis of operation of labor markets in job-oriented culture. Labor force composition and trends, nature of labor markets, significance of wages and income security, trade unionism and collective bargaining, automation. Related issues, poverty, urban environments. Prerequisite: SS 251 or permission of instructor.

SS 264 Urban Economics* **3:0:3**
Contemporary American city and changing functions. Interrelation of population with housing, jobs, transportation. Problems of public finance and services, land use, urban decay and renewal. Analytic tools to examine economic aspects and evaluate policy alternatives. Prerequisite: SS 251 or instructor's permission.

SS 265 Money and Banking* **3:0:3**
Nature of money, gold and paper standards, commercial banks and Federal Reserve system, financial institutions, balance of payments, exchange rates, international monetary order. Money, prices, inflation, business fluctuations. Domestic and international monetary policy. Prerequisite: SS 251 or SS 252 or SS 254.

SS 266 Libertarian Economics* **3:0:3**
Libertarian, free-market analysis of economy and government policy. Contrasts nature and consequences of government operation and intervention into economy with workings of the market. Alternative free market solutions examined for problems now met by political intervention.

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 Women in Current Perspective **3:0:3**
Psychology, anthropology, sociology of women and women's movement. Emphasis on biological basis of sex role differentiation, sex role acquisition in cross-cultural perspective, societal allocation of roles. Women's movement—history and potential for change in current attitudes, lifestyles, the political and economic system.

SS 357† Technology Transfer to Developing Countries **3:0:3**
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, economic factors in technology selection and utilization. Technology and political influence. Case studies of recently industrializing nations.
Also listed under IE 357 and MG 757

SS 358† Human Resources Development in Developing Countries **3:0:3**
Spectrum of technology-related manpower needs in less developed countries. Education of engineers, technicians and skilled mechanics. Using foreign personnel, foreign schools, "brain-drain" problems. Economic consequences. Comparisons of educational systems of Western, Eastern and developing countries. Design of curricula to suit national needs. Role of technical assistance programs. Forecasting of human resource needs.
Also listed under IE 358 and MG 758

SPECIAL TOPICS

The following special topics courses will be offered from time to time by the staff of the department or visiting scholars. The specific titles and prerequisites will be announced prior to registration. May be repeated for credit.

SS 361 Special Topics in Social Sciences* **each 3:0:3**
362 Special Topics in History*
363 Special Topics in History of Science and Technology*
364 Special Topics in Economics*
365 Special Topics in Psychology*

SS 500-501 Social Sciences Theory and Method I, II* **each 3:0:3**
Historically oriented considerations of problems in developing integrated approach to social processes. Major formulations from ancient times through 17th century. Emergence of various social science disciplines in 18th and 19th centuries. Issues in contemporary theory and method. Similarities and contrasts between physical and social science. SS 501 prerequisite: SS 500.

SS 502-503 Social Science Theory and Method III, IV* **each 3:0:3**
Seminar dealing with formulations of hypotheses and designing of research with methods for data collection and analysis specific to various social science disciplines. Practical experience in use of archival and other primary source materials, in formulation and analysis of questionnaires, and in techniques of interviewing and observation. Evaluation of various methods in relation to types of problems raised. Relation between theoretical framework and study design. SS 502 prerequisites: SS 500-501. SS 503 prerequisite: SS 502.

GRADUATE COURSES

HISTORY OF SCIENCE AND TECHNOLOGY

SS 600† History of Science and Technology: Antiquity to the Scientific Revolution **2½:0:3**
History of biological and physical sciences from antiquity to Renaissance. Intensive introduction to issues, aims and tools of historian of science working in this period.

SS 601† Introduction to History of Science and Technology: Scientific Revolution to Darwin 2½:0:3
History of biological and physical sciences from scientific revolution to period of Darwin. Intensive introduction to issues, aims and tools of historian of science working in this period.

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 permission of instructor.

SS 615† Guided Reading in History of Ideas 2½:0:3
Independent study of leading interpretive works and sources in intellectual history of Western civilization. Regular tutorial sessions and periodic student-faculty colloquia. Course may be taken twice for credit with different topical emphasis and permission of instructor. Comprehensive written examination.

SS 616† Guided Reading in History of Science 2½:0:3
Independent study 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 emphasis and permission of instructor. Comprehensive written examination.

SS 620† History of Biology* 2½:0:3
Upper-level course with discussion of principal issues to which biologists have addressed themselves, solutions which they have offered, and relationships between these solutions and both technical capacities 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
Upper-level course investigating origin of knowledge that eventually led to criticism of Newtonian synthesis and attempt to find suitable, more general replacement.

SS 622† Theory and History* 2½:0:3
Advanced study of techniques and philosophy 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 detailed studies of the evolution of techniques and tools used in man's attempts to master environment. Introduction to reciprocal relationships between technology and other facets of society's economic and social structures, political policies: general cultural manifestations. Particular investigation of technological bases of historical change 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. Treatment of early psychology as speculative discipline, essentially part of philosophy, following with differentiation of psychology into various fields. Prerequisites: SS 189-190 or equivalent or SS 135-136 or equivalent.

SS 640-641† Environmental Studies Seminar* 3:0:3
This seminar provides the opportunity to investigate environmental issues in-depth by focusing on a specific topic each year. The aim of the seminar 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. Each student is responsible for a seminar paper. Guest participants on special topics. Prerequisite: SS 182 or other appropriate environment studies or permission of the instructor.

SS 672 Technological Forecasting 2½:0:3
Introduction to problems of technological forecasting. Morphological analysis, extrapolation of trends, heuristic and intuitive forecasts. Consideration of rational directing of technological change. Students prepare forecasts on topics of own 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 and MG 757

SS 676† Human Resource Development in Developing Countries 2½:0:3
Spectrum of technology-related manpower needs in less developed countries. Education of engineers, technicians and skilled mechanics. Using foreign personnel, foreign schools, "brain-drain" problems. Economic consequences. Comparisons of educational systems of Western, Eastern and developing countries. Design of curricula to suit national needs. Role of technical assistance programs. Forecasting of human resource needs.
Also listed under IE 758 and MG 758

ECONOMICS

SS 700† Industrial Organization of American Economy* 2½:0:3
Measuring monopoly and competition in American economy. Effects of industrial structure on business performance—profit rates, output, etc., and business behavior—collusive practices, price discrimination, 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 permission.

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 permission of the instructor.

SS 713† Econometric Models and Methods* 2½:0:3
Econometric models with and without stochastic formulation, principal component analysis, representation of economic phenomena, supply and demand, elementary Keynesian model, consumption function. Linear hypothesis and multiple regres-

sions, linear models with errors in variables, time series analysis, autoregressive and distributed lag models. Simultaneous equation models. Spectral technique applications in economics. Prerequisites: SS 251 or SS 252, and MA 092 and MA 232, or equivalent.
Also listed under MG 674 and OR 674

SS 730 Mathematical Economics* 2½:0:3
Contributions of mathematical analysis to traditional economic problems. Review of basic mathematical tools. Capital theory, economic growth, static equilibrium, individual behavior, welfare economics. Subjects of special interest to students. Each topic approached in specific manner. Assumptions underlying (axiomatic to) models sought in empirical evidence. Given these assumptions, necessary consequences deduced with some rigor.
Also listed under OR 730

PSYCHOLOGY

SS 908† Experimental Psychology I* 2:3:3
An examination of the basic methodology of experimental psychology. Topics include research design, evaluation and treatment of experimental data. Psychophysics and scaling techniques, signal detection, simple and complex learning in both humans and animals. Prerequisite: SS 189, equivalent or permission of instructor.

SS 909† Experimental Psychology II* 2:3:3
The purpose of this course is to acquaint students with research methods, paradigms and procedures for laboratory and field research with human subjects. The substantive matter of the research covered will include social and environmental psychology. Students will be expected to perform research in laboratory and field settings using both experimental and quasi-experimental research designs. The emphasis of the course will be on developing research skills which can generalize to a wide variety of situations. Prerequisite: SS 908†, equivalent or permission of instructor.

SS 910† Theories of Learning* 2½:0:3
Review of different theories of learning and associated experiments: application of theories to areas of programmed learning, behavior therapy, attitude function, social interaction. Each student 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
Analysis of verbal behavior, including 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. Each student required to do 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, kinesthetic senses, their relation to nonsensory controlling stimuli auch as states of the organism, learning, social psychological variables. Techniques of obtaining psychophysical data on each sensory system and relation 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
Discussion of the physiological and anatomical bases of behavior. Topics such as memory, motivation, emotion, sleep, reward mechanisms, psychosurgery and higher cortical function are covered. Prerequisite: SS 189.
Also listed under BE 895

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 permission.
Also listed under BE 676

SS 915 Behavioral and Societal Aspects of Transportation 2½:0:3
Behavioral analysis of transportation decision-meking and travel characteristics. User needs in design of transportation systems including effects of such factors as crowding, social isolation, crime, comfort and convenience. Social impact of transport systems on communities. Prerequisite: undergraduate introductory psychology, or MG 601 or equivalent.
Also listed under MG 856 and TR 756

SS 920 Proseminar in Psychology 2½:0:3
Intensive review of major areas in psychology required of all majors. Topics include history and systems, sensation and perception, learning, developmental and abnormal.

SS 924 Social Impact Assessment 2½:0:3
This course will be concerned with the way in which physical changes within urban or rural settings affect social systems and group and individual behavior. Issues to be discussed and considered include problems in measuring quality of life and socie! response to technology, and the use of alternative futures paradigms. Students will be expected to do an in-depth analysis of a problem in social impact and report findings to the class.

SS 926 Environment Psychology 2½:0:3
Readings and discussion on critical issues in person-environment relations, including privacy, crowding and environmental design. Course work will include a term paper and a major research project, emphasizing the application of psychological research methods to practical design problems or specific environmental issues.

SS 928 Advanced Topics in Environmental Psychology 2½:0:3
The subject matter of this course will vary from year to year depending on the needs and interests of both students and instructors. Potential subjects include: Social Impacts of Transportation Systems, Stress and the Environment, Adversive Environmental Factors, Laboratory in Animal Learning and the Effects of Pollution, The City—From a Psychological, Ecological and Historical Perspective, Applied Behavioral Analysis.

SS 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.

SS 997 Thesis for Degree of Master of Science in the History of Science* each 3 units
Independent research project demonstrating scientific competence performed under guidanca of adviser.

FACULTY

I. Leonard Leeb, Associate Professor of History and Head of Social Sciences
B.A., University of Pennsylvania; Ph.D., Columbia University
History of the Netherlands, colonialism and imperialism, history of political thought

Marvin E. Gettleman, Professor of History
B.A., CCNY; M.A., Ph.D., The Johns Hopkins University
History of the United States, American constitutional history, nationalism, modern radicalism

Helmut Gruber, Professor of History
B.S., CCNY; M.A., Ph.D., Columbia University
History of socialism and communism; intellectual, social and cultural history of 19th and 20th centuries; contemporary history

Frederick C. Kreiling, Professor of History of Science
A.B., Hofstra College; A.M., Ph.D., New York University
History of science, environmental studies, music history

Murray N. Rothbard, Professor of Economics
A.B., M.A., Ph.D., Columbia University
Political and economic history, Austrian economics

Kurt Selzinger, Professor of Psychology
B.A., New York University; A.M., Ph.D., Columbia University
Behavior theory and learning, abnormal psychology, language behavior

Felix F. Strauss, Professor of History and Administrative Officer
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., CCNY; Ph.D., New York University
Labor economics, industrial relations, economic policy

Pamela E. Kramer, Associate Professor of Psychology
B.A., Bryn Mawr College; M.Ed., M.S., Tufts University; Ph.D., Yeshiva University
Psychology of women, developmental psychology, psycholinguistics

Louis Menashe, Associate Professor of History
B.A., CCNY; M.A., Ph.D., New York University
Russian social history, revolutionary thought and politics, contemporary history

David Mermelstein, Associate Professor of Economics
B.A., Amherst College; Ph.D., Columbia University
Radical economics, current macroeconomic problems, comparative economic systems, urban fiscal problems

Thomas B. Settle, Associate Professor of History of Science
B.A., M.A., Ph.D., Cornell University
History of science, Galilean studies, history of biology

Romualdas Sviedrys, Associate Professor of History of Technology
B.A., Cornell University; Licenciada, Universidad Nacional (Colombia, S.A.); Ph.D., The Johns Hopkins University
Technology forecasting and technology assessment, history of technology and science since 1750, technology and science in America

F. David Mulcahy, *Assistant Professor of Anthropology*
B.A., M.A., Ph.D., University of Massachusetts
Marginal communities, human ecology, cultural symbolism

Richard E. Wener, Research Assistant Professor of Psychology
B.A., University of Wisconsin; M.S., Ph.D., University of Illinois, Chicago Circle
Environmental psychology, crowding, clinical psychology

ADJUNCT FACULTY

Edward A. DeCarbo, Dean of Students and Lecturer in Anthropology
B.S., F.S., Georgetown University; M.A., University of Chicago; M.A., Ph.D., Indiana University
Cultural anthropology, expressive culture, African studies

Steven J. Freimark, Assistant Professor
B.S., M.S., Polytechnic Institute of Brooklyn; M.A., Queens College; Ph.D., SUNY (Stony Brook)
Physiological psychology, stress and behavioral therapy

STATISTICS

Through the mathematics department, Polytechnic offers graduate study in the field of statistics leading to the M.S. and Ph.D. degrees. A full range of courses are offered in the areas of applied and mathematical statistics, supported by a range of elective courses in probability, operations research and topics in mathematics. Students may also take elective courses from other departments, selected under the supervision of their graduate adviser.

The curriculum for each of the degree programs, along with descriptions of all non-thesis courses, is presented in the mathematics department section of this catalog.

COURSES

ST 995 Project for Degree of Master of Science in 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 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 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. Minimum of 24 dissertation units required for degree. Prerequisite: degree status and qualifying examination. Reregistration fee, any part: 3-unit charge.

SYSTEM ENGINEERING

System engineering is based on the body of theoretical knowledge that underlies the engineering of modern complex systems. System engineering is the application of this body of knowledge to the design of systems, usually involving the integration of several disciplines to achieve the desired design objective. The theoretical resources of these fields include selections from among the newer branches of applied mathematics, methods of modeling and simulation, methods for the analysis of signals and systems, the theories of communication and control, the techniques of optimization and of decision-making, and many of the facets of computer science.

Faced with a diverse and complex scientific environment, the system engineer may receive assignments crossing traditional lines of engineering applications. System engineering is presently applied in areas such as transportation, urban services, bioengineering, resource management, power and energy, and environmental and pollution control.

The course work 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 Engineering 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'S DEGREE

The entrance requirement for the master of science in system engineering is a bachelor's degree in engineering or science from an accredited institution, with a superior undergraduate record, including undergraduate courses in differential equations, probability, linear systems, feedback control and computer programming. Students with deficiencies in these areas may be admitted if they take appropriate introductory courses to remove these deficiencies.

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.		6-12
3. Approved electives		21-15
		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.

For graduation, a minimum average of B must be obtained in the required courses (the three selected from the above list, plus those in the two one-year sequences). In addition, an overall average of B or better is required for all 36 units offered toward the degree.

The *Electrical Engineering Graduate Student Manual* should be consulted for more detailed rules and procedures, including student status, recommended electives and one-year sequences, current areas of research and disqualification for low grades.

REQUIREMENTS FOR THE ENGINEER DEGREE

This post-master's professional degree is intended for engineers who desire to advance their professional development and training beyond the master's degree, by taking additional graduate courses and carrying out a substantial design project.

A candidate for the engineer in system engineering degree must have a program of study approved by an advisory committee. This program of study must contain a minimum of 72 units beyond the B.S. degree, and the candidate must have satisfied the requirements for a master's degree in system engineering.

In all other respects, the procedures and rules concerning this degree are identical to those for the engineer degree described in the electrical engineering section of this catalog.

REQUIREMENTS FOR THE DOCTOR'S 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 departmental *Graduate Student Manual.* These include course requirements, guidance committee formation, area examination, foreign language requirement, 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 doctoral adviser.

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 candidacy.

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 project is 6-12 units by prior agreement with adviser; continuous project registration required. Prerequisite: degree candidacy.

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 feature 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. Registration beyond 12th unit requires passing of area examination. Prerequisites: degree candidacy and passing of qualifying examination.

PARTICIPATING FACULTY

Frank Kozin, Professor of System Engineering and Director of System Engineering Program

Joseph J. Bongiorno, Jr., Professor of Electrical Engineering

Rudolf F. Drenick, Professor of System 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 J. Lupo, Professor of Electrical Engineering

William R. McShane, Professor of Transportation and System Engineering

Athanasios Papoulis, Professor of Electrical Engineering

Philip E. Sarachik, Professor of Electrical Engineering

Leonard G. Shaw, Professor of Electrical Engineering

Martin L. Shooman, Professor of Electrical Engineering and Computer Science

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

Dante C. Youla, Professor of Electrical Engineering

Richard A. Haddad, Associate Professor of Electrical Engineering

Gerald Weiss, Associate Professor of Electrical Engineering

Christodoulos Chamzas, Assistant Professor of Electrical Engineering

TRANSPORTATION MANAGEMENT

The field of transportation today encompasses not only the application of engineering approaches to transportation problems, but also the management of the sundry private and public operators, planning agencies, consulting services and government departments that comprise the industry.

For those students whose goals lie in the management of technology rather than the direct engineering of it in the transportation sector, this unique program provides graduate training specifically designed for their needs. The curriculum provides a mixture of basic management skills, basic knowledge of the transportation industry and a core of specially designed courses in management and policy applications in the transportation field. The students emerge with a critical combination of skills preparing them for a managerial or policy-level position in any sector of the transportation industry.

The program emphasizes the overall management of transportation systems rather than concentrating on a single segment such as private trucking firms and goods distribution. It views the transportation manager as one who may find the field of application in an airline, a publicly or privately operated transit system, a metropolitan planning organization, a federal, state, or local government unit, a public authority or any one of the myriad organizations involved in the industry. The program is intended to produce a graduate who has a thorough knowledge of the characteristics of transportation systems, the systems by which they are planned, built and operated and the ability to apply basic managerial principles to the optimizing of these systems.

The program is jointly administered by the Department of Transportation Planning and Engineering of the Division of Engineering and the Division of Management. It is a 45-unit program leading to the master of science, an undesignated degree. Polytechnic has petitioned the New York State Department of Education for registration of the degree as a master of science in transportation management and will award the designated degree as soon as approval is received.

While there is at present no doctoral degree in transportation management, completion of this program fulfills from one-half to two-thirds of the course requirements for the Ph.D. in transportation planning and engineering. Interested students should arrange an interview with a member of the faculty for further information and specific guidance.

ADMISSIONS

To be eligible for admission in this transportation management program, the applicant must hold a baccalaureate degree or its equivalent from an accredited institution in one of the following areas: engineering, physical science, liberal arts, business or public administration or social sciences. Students are expected to have an adequate background in mathematics, including probability and statistics. Students lacking such background may be admitted, subject to taking courses making up the deficiency. Such courses are *in addition* to other normal degree requirements.

Students are expected to have basic skills in English that are adequate for the preparation and presentation of reports and papers. Such skills will be evaluated in appropriate courses together with technical material. All foreign students admitted to the program will be required to take a written examination in English before their first registration. Based on the evaluation of that examination, they may be required to take one and in rare cases, two additional courses in English as a second language for which no graduate credit will be given.

GRADE REQUIREMENTS

To earn a degree, students enrolled in the program are required to maintain:

1. An overall average of B in courses submitted for the degree.
2. An overall average of B in those courses *required* for the degree.
3. An overall average of B in guided studies (readings, project, thesis) submitted for the degree.

Grading is on the basis of A, B, C or F. A student whose overall average falls below a B may be placed on *graduate probation.* Such students must have written approval of the chairman of the program committee *and* the dean of graduate studies to register for subsequent semesters. Incomplete grades and withdrawals are granted in accordance with Institute policy.

DEGREE REQUIREMENTS

The master of science program in transportation management requires 45 units of work beyond the baccalaureate, as follows:

Required of all students for the master of science:

		Units
MG 600	Management Process	3
MG 601	Organizational Behavior	3
MG 700	Managerial Accounting	3
TR 601	Travel Demand Forecasting	3
TR 750	Transportation Economics	3
TR 751/MG 853	Transportation Finance	3
TR 660	Urban Public Transportation	3
TR 757/MG 857	Transportation Management	3
		24

Electives in the amount of 18 units may be selected from the listing below, with the approval of the student's adviser. Normally, the student will be required to select at least two courses from each of two areas of specialization. The student must select a minimum of two TR courses and two MG courses. All courses are 3 units.

A. Policy Development

MG 740	Process of Policy Formation
MG 744	Social Forecasting
MG 746	Public Sector Management
MG 800	Policy Analysis and Planning
TR 758/MG 858	Transportation Policy and Decision-Making
MG 840	Financial Aspects of Public Policy

B. Organizational Development

MG 622	Personnel Psychology
MG 623	Organizational Change, Training and Development
MG 624	Organizational Development

C. Project Management

MG 810	Project Planning and Control
MG 811	Cost Accounting in a Project Environment
MG 820	Project Management
MG 825	Construction Administration
MG 826	Construction Estimates and Costs
MG 827	Specifications and Contracts

D. Transportation and Urban Planning

TR 600	Transportation Studies and Characteristics
TR 602	Urban Transportation Planning
TR 603	Computer Packages in Transportation and Traffic Planning
TR 630	Principles of Urban and Regional Planning
TR 631	Methods of Urban and Regional Analysis in Planning
TR 640	Environmental Analysis of Transportation Projects

E. Transportation Economics

TR 752/MG 855	Analysis of Transportation Markets
TR 755/MG 852	Legal and Regulatory Aspects of Transportation
TR 756/MG 856/ SS 915	Behavioral and Sociological Aspects of Transportation
TR 661	Intercity Passenger and Freight Transportation

F. Transportation Facility Design and Operation

TR 600	Transportation Studies and Characteristics
TR 670	Planning and Design of Terminals
TR 671	Airport Planning and Design
TR 701	Traffic Control, Operations and Management
TR 715	Urban Goods Movement
TR 866	Transportation System Safety

All students are required to take a 3-unit project in transportation management:

TM 962	Independent Project or Paper in Transportation Management	3 units

In lieu of the required project and two electives, some students may elect to complete a formal thesis of 9 units:

TM 997	Thesis in Transportation Management	3 units each

In lieu of up to two elective courses, students may choose to complete up to two reading courses:

TM 901-902	Readings in Transportation Management I, II	3 units each

While registered in the program, *full-time* students are required to continuously register for a noncredit discussion and presentation seminar:

TM 951	Seminar in Transportation Management	nc

ADVISORY COMMITTEE

To assist in the development of the program, an advisory committee, consisting of noted professionals in transportation management and policy positions, has been formed. They meet about once each semester with program faculty to discuss curriculum development, placement of graduates and related matters.

COURSES

The following courses have been specifically developed for the transportation management program:

TR 751/MG 853 Transportation Finance **2½:0:3**
Material is approached from a public finance perspective, including a review of those economic theories and analytical techniques that are of particular relevance to transportation. Special attention is given to such areas as (a) the equity vs. efficiency question in transport finance (b) general vs. earmarked revenue methods (c) the valid (and invalid) uses of cost-benefit and cost-effectiveness studies and (d) peak load (marginal cost) pricing.

TR 752/MG 855 Analysis of Transportation Markets 2½:0:3
Application of the precepts of marketing to public and private transportation operations. Basic market structure of major modes is reviewed to demonstrate how gaining and using market data can increase efficiency and profitability of operations. Attention is given to (a) how factors that affect modal choice are determined and (b) how this information can be integrated into a "marketing plan" that includes service, pricing and promotional aspects.

TR 755/MG 852 Legal and Regulatory Aspects of Transportation 2½:0:3
An in-depth treatment of the origins, causes and effects of regulation on transportation and society in the U.S. Economic and conditional bases for transportation regulation. The legal basis, structure and function of federal, state and local regulating bodies and their interaction with transportation industries. Current controversies concerning the deregulation of sectors of the transportation industry.

TR 756/MG 856 Behavioral and Sociological Aspects of Transportation 2½:0:3
Behavioral analysis of transportation decision-making and travel characteristics. Sociological factors involved in travel decisions—crime, social isolation, comfort and convenience. **Also listed under SS 195**

TR 757/MG 858 Transportation Management 2½:0:3
Management problems in the private and public transportation sectors; discussion of various types and forms of transportation organizations—planning organizations, modal operators, consulting firms, etc.—and treatment of organizational problems and issues from the managerial perspective. Private vs. public transportation operators and agencies. Public and semi-public operating authorities: legal basis, fiscal structure, purpose, interaction with private operators. Prerequisites: MG 601 and TR 660, or equivalent, or adviser's approval.

TR 758/MG 858 Transportation Policy and Decision-Making 2½:0:3
A high-level treatment of policy formulation and decision-making in the transportation industry on several levels: federal policy, state and local policy, individual operating policies. Course uses an intensive case-study approach in a seminar or discussion format. Emphasis is on mass transit operations.

GUIDED STUDIES

Guided studies are individually supervised student efforts under the guidance of a faculty member or faculty committee. Before registering for one of these offerings, the student should have an accepted topic formulated in conjunction with the faculty member who will supervise.

TM 962 Independent Project or Paper in Transportation Management 3 units
A one-semester guided effort resulting in a written report submitted at the semester's end. Project may entail the study of a particular problem or issue in transportation management, or a case-study of a type of or particular transportation organization. A bound report is not required. Prerequisite: adviser's approval.

TM 901-902 Readings in Transportation Management I, II each 3 units
A guided studies effort on a topic or subject related to transportation management but not covered in detail in the regular courses. Research is primarily conducted through the literature and other secondary sources. The student is required to submit a written report at the end of the semester. Prerequisite: adviser's approval.

TR 951 Seminar in Transportation Management nc
A regular forum in which students present and discuss the results of their project and other independent research. Distinguished speakers are also invited to present talks and discussions on topics of current interest.

TM 997 Thesis in Transportation Management each 3 units
A significant piece of independent research under the guidance of a faculty committee. Total thesis is 9 units and results in a bound document that must be orally defended. Prerequisite: adviser's approval.

All other courses which are part of the transportation management program are described under the transportation planning and engineering or management sections of this catalog.

PARTICIPATING FACULTY

Louis J. Pignataro, Professor and Head of Transportation Planning and Engineering and Director of Transportation Training and Research Center

A. George Schillinger, Associate Professor of Management

Edmund J. Cantilli, Professor of Transportation Planning

Norbert Hauser, Professor of Industrial Engineering, Operations Research and Management

William R. McShane, Professor of Planning and System Engineering and Associate Director of Transportation Training and Research Center

Anthony J. Wiener, Professor of Management

Seymour Kaplan, Associate Professor of Industrial Engineering, Operations Research and Management

Harold G. Kaufman, Research Associate Professor of Management

John C. Falcocchio, Associate Professor of Transportation and Engineering

Philip A. Habib, Associate Professor of Transportation Engineering

Roger P. Roess, Associate Professor of Transportation Engineering and Member of Transportation Management Program Committee

William H. Crowell, Assistant Professor of Transportation Economics and Chairman of Transportation Management Program Committee

David A. Schrier, Assistant Professor and Director of Organizational Behavior Program Management

Dipayan Bhattacharya, Academic Associate, Management

ADJUNCT FACULTY

Joseph Kaming, Adjunct Professor of Transportation Planning and Engineering

William A. Allison, Adjunct Professor of Transportation Planning and Engineering

TRANSPORTATION PLANNING AND ENGINEERING

The Department of Transportation Planning and Engineering offers programs leading to the degrees of master of science in transportation planning and engineering, engineer in transportation engineering and doctor of philosophy in transportation planning and engineering.

The students of transportation live in a boundless workshop in which they are able to experience first hand many of the problems involved in the movement of peoples and goods, both within congested urban areas and between them. The facilities, regulations and controls which are discussed in the context of lectures and problems, are on display in abundance in the activities of each passing day. Education in transportation is unique in the degree of feedback and personal involvement which the student experiences. This is a great asset in that virtually every student is familiar with the transportation medium.

Transportation planning and engineering is quite unlike many of the traditional engineering fields. In transportation, the professional works in a field which is intimately involved with human behavior and reactions. It is possible to compute the braking distance for e given physical situation, but each driver has a different reaction time. The transportation professional must discern and predict how people will travel, or desire to travel, at any given time. This involves the study and understanding of the basic factors that motivate people to travel and that motivate people to travel to particular places on particular modes of transportation. The prediction of transportation demand is complex, and because of the uncertainties of the human element, it is less precise than other engineering crafts, such as the resolution of stresses on a structure, in which all physical loads and conditions can often be precisely stated. The human element expresses itself in myriad ways. The transportation engineer cannot provide positive control of transportation systems. The placement of a stop sign at an intersection does not guarantee that every vehicle approaching it stops. An air traffic controller can guide a pilot, but there are no fail-safe devices that can physically prevent a pilot from flying a plane improperly.

Transportation planning and engineering is then best described as the application of traditional planning and engineering approaches to the solution of problems involving a strong human element. While all of the methods and techniques employed must be modified to account for this human element, the approach to problem investigation and solution is very much an engineering one. Transportation is a vital, living field for students to apply their efforts and is well suited to those having undergraduate degrees in engineering and/or science, as well as to many with backgrounds in the arts and social sciences. It is a broad field requiring an inter-disciplinary approach for effective problem solving.

The primary goal of the academic program is to train transportation planners and engineers who are able to plan and functionally design facilities and operational controls that are capable of satisfying the public demand for transportation services. This must be done with full awareness of the human element and in such a way as to optimize the use of public funds, while protecting the environment and energy resources, and causing minimal social disruption. This is a challenging goal for the program, but it is the same challenge that must be met by every professional working in the field.

The program stresses the multi-modal approach to transportation and maintains strong curricula in highway and traffic engineering, public transportation engineering, transportation planning, transportation safety and urban and regional planning. The student is exposed to an atmosphere that provides a meaningful integration of practical and theoretical approaches. A combination of classroom presentations and practical problem solutions strengthens the overall education.

DEPARTMENT REQUIREMENTS

To be eligible for admission as a graduate student, an applicant 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 an sdequate background in mathematics, including probability and statistics. Students lacking a background in probability and statistics will be admitted but must take MA 551, Applied Statistics, in addition to other degree require-

ments. Credit toward a graduate degree will not be given for this course. Where additional background in mathematics is lacking, admission may be subject to the completion of specified undergraduate courses to make up the deficiency.

Students are expected to have basic skills in English that are adequate for the preparation of reports and papers. Such skills will be evaluated in appropriate courses together with technical material. All foreign students admitted to the department will be required to take an examination in English before their first registration. Based on the evaluation of that examination, they may be required to take one and in rare cases two additional courses in English as a second language for which no graduate credit will be given.

Registration status—Students are admitted to the department in either degree, nondegree or special status.

Grade requirements—To earn a graduate degree, Institute regulations require that the student maintain an average of B or better for all course work submitted for the degree, and a B or better average in individual guided studies efforts submitted for the degree (readings, project, thesis, dissertation). Averages are separately computed for course work and guided studies.

In addition to Institute grade requirements, the department requires an overall average of B or better in *required* courses taken toward a degree.

DEGREE REQUIREMENTS FOR THE MASTER'S DEGREE IN TRANSPORTATION PLANNING AND ENGINEERING

The M.S. degree in transportation planning and engineering requires 36 units of graduate work beyond the baccalaureate, half of which are required courses, half of which are elective. Full-time students, particularly those studying under research fellowships, *may* be required to do a project for which they would receive three units as part of their electives.

The following courses are *required* of all students:

		Units
TR 600	Transportation Studies and Characteristics	3
TR 601	Travel Demand Forecasting	3
TR 630	Urban and Regional Planning Principles	3
TR 629	Transportation Workshop	3
TR 701	Traffic Operations, Control and Management	3
TR 750	Transportation Economics	3
		18

Students are expected to consult their advisers in selecting electives. Elective courses should be selected to provide the student with a cohesive body of knowledge in one or more areas of interest. The selection of electives is subject to the approval of the student's assigned adviser.

The residency requirement for the M.S. degree is 27 units; i.e., a minimum of 27 units of work must be taken at Polytechnic. The student may transfer up to 9 units of acceptable course work from other institutions subject to the department's approval. Students may apply for transfer credit through the dean of graduate studies after they have completed 12 units of appropriate graduate courses at Polytechnic. To be eligible for transfer credit, the course in question must be relevant to the transportation program, and the student must have received a B or better in the course. Courses graded on a pass-fail basis will not be considered for transfer credit unless a detailed course evaluation from the instructor is provided. All transfer credit requests must be accompanied by an official transcript from the transferring institution.

In lieu of 6 transfer credits, the student may request validation of up to 6 units of graduate credit. To qualify for validation, the student must demonstrate an acquired knowledge or ability in an area covered by one of the courses offered by the department. The student is then examined in the area (by written and/or oral examination), and validation credit is awarded or denied on the basis of the examination by the dean of graduate studies. Students must pay a fee for each such examination. In no case may the *total* of transfer and validation credits exceed nine units.

REQUIREMENTS FOR THE ENGINEER DEGREE IN TRANSPORTATION ENGINEERING

The engineer degree in transportation engineering is intended to be a terminal degree for those students wishing advanced practical education beyond the M.S. level. Candidates for the engineer degree are required to have an M.S. in transportation planning and engineering or its equivalent and an undergraduate degree in engineering. The degree requires an additional 30 units of course work and a 6-unit engineering project beyond the M.S. degree. 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.

All courses required for the M.S. degree, or their equivalents, must be completed to earn the engineer degree. In most cases, this would have been done as part of the candidate's M.S. study. In rare cases where this is not the case, any such courses not yet completed must be taken as part of the engineer degree program of study.

Residency requirements for the engineer degree are 27 units of study at Polytechnic. No more than 9 units of transfer and validation credit may be awarded toward this degree, with a maximum of 6 validation units.

DOCTOR OF PHILOSOPHY DEGREE IN TRANSPORTATION PLANNING AND ENGINEERING

The Ph.D. in transportation planning and engineering requires 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 planning and engineering, including all of the courses required for the M.S. degree.

2. Two 15-unit minors in related areas, one of which may be a specific area of focus within the transportation field.

3. A 30-unit dissertation, which must be an original piece of research that meaningfully advances the state-of-the-art in 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 course work in support of their dissertation development and to ensure passage of the Ph.D. qualifying examination, described below. Applicants to the Ph.D. program are urged to make an appointment with a faculty adviser for individual consultation and recommendations.

Before being permitted to register for dissertation units, the candidate must pass a comprehensive Ph.D. qualifying examination. The examination is given once a year, usually in June, and consists of several written portions and an oral part. Copies of previous examinations are available on request from the department office to aid the student in preparation for this examination.

Students normally take the qualifying examination after their first year of full-time course work (or its part-time equivalent) is completed. All students who wish to take the examination are permitted to do so once they have been advised. Subsequent attempts are at the discretion of the department and in no case are more than three attempts permitted.

Ph.D. candidates must also qualify in one foreign language, which entails translation of a part of a technical book or article with the aid of a dictionary.

The residency requirement for the Ph.D. is 30 units, which must include the dissertation. Thus, a candidate is only required to complete the dissertation at Polytechnic to earn the degree here. Any and all course work taken at other institutions that is appropriate for either the major or minors may be transferred provided they are of graduate level and a grade of B or better was 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 include members of the faculty from many programs, as appropriate, including the following: mechanical and aerospace engineering, civil engineering, electrical engineering, management, mathematics, operations research, social sciences, transportation planning and engineering.

It should be emphasized that Ph.D. programs are individually tailored to the needs of the student and to their research interests. A continuing review of such programs is maintained throughout the student's course of study, and modifications are made as needed. A close relationship between the student and faculty adviser is recommended for all students at this level.

PROGRAM FOR INTERNATIONAL STUDIES IN REGIONAL AND TRANSPORTATION DEVELOPMENT

This program is intended to provide the international student with a curriculum specifically tailored to individual needs. The program requires 54 units (3 semesters, full-time) of study and results in the award of the master of science in transportation planning and engineering and the diploma in international studies in regional and transport development.

Admission and other requirements for this program are similar to the standard M.S. degree program, except that students are advised to submit applications for admission by:

- December 1—for admission in summer or fall of the following year
- October 1—for admission in the spring of the following year

This will assure that visa arrangements and other matters can be handled without difficulty or delay.

The residency requirement for the program is 45 units (that is, a minimum of 45 units of work must be taken at Polytechnic). Transfer and validation regulations are the same as for all degree programs.

The program is intended to serve international students sponsored by their governments, foreign universities or other organizations as well as those who are supporting themselves. The 54 units of work include 21 units of specifically required courses, 24 units of elective courses and a 9-unit thesis. The thesis will most often involve problem-oriented work on a subject agreed on by the student's sponsor and the department. Topics are generally transportation subjects related to the problems of developing economics, offering the international student the opportunity to do significant work on a topic of critical importance to that student's home country. The program concentrates on four areas of study: project management and economics, energy, planning, design and operations.

Required of all students:

		Units
TR 600	Transportation Studies and Characteristics	3
TR 601	Travel Demand Forecasting	3
TR 630	Principles of Urban and Regional Planning	3
TR 704	Traffic Capacity and Design	3
TR 833	Economic Analysis of Transportation Projects in Developing Countries	3
TR 880	Case Studies in Regional and Transportation Development	3
MG 700	Managerial Accounting	3

Electives are selected with the approval of the student's adviser from among the following listings (all courses 3 units each):

A. Project Management and Economics

MG 600	Management Process
MG 740	Process of Policy Formulation
MG 820	Project Management
TR 834	Financing Transportation Projects in Developing Countries
TR 882	Construction of Transportation Projects in Developing Countries

B. Transportation Planning

TR 631	Methods of Urban and Regional Analysis in Planning
TR 715	Urban Goods Movement

C. Facility Design and Operation

TR 665	Design of Rail Facilities
TR 670	Planning and Design of Terminals
TR 671	Airport Planning and Design
TR 881	Design and Construction of Roads in Developing Countries

D. Energy

TR 830	Energy in the Transportation Sector
ES 927	Energy Policy Issues
ES 928	Energy Resource Distribution and Conversion
ES 929	Energy Alternatives for Developing Countries

The student is also *required* to complete a 9-unit thesis (TR 997) and must register continuously for TR 951, 952, Transportation Seminar, a non-credit discussion forum, while enrolled in the program.

Those students wishing to enter this special program should note "International Studies in Transportation" on their admission applications. Such applications will be handled separately from those for normal degree programs.

CERTIFICATE PROGRAMS

The department offers graduate certificates to students completing from 12 to 15 units of course work in a concentrated sub-area of transportation planning and engineering. Certificate programs are geared to the students who do not wish to commit themselves to a full advanced degree program. These may be students with B.S. degrees who wish to specialize in one aspect of transportation, or those already holding advanced degrees who wish to develop an additional specialty and receive some formal certification for it. Students who enroll in certificate programs may apply for transfer to degree programs without loss of credit, assuming the courses taken are appropriate to the degree.

Students enrolling in certificate programs will normally apply as non-matriculating students. An appropriate B.S. or B.A. degree is required. The Department of Transportation Planning and Engineering offers the following certificates:

Traffic Engineering Certificate (12 units)

Required:

TR 701	Traffic Control, Operations and Management
TR 703	Traffic Studies
TR 704	Traffic Capacity and Design

Plus 1 of:

TR 710	Design of Traffic Facilities
TR 715	Urban Goods Movement
TR 865	Highway Traffic Safety

Transportation Planning Certificate (15 units)

Required:

TR 600	Transportation Studies and Characteristics
TR 601	Travel Demand Forecasting
TR 602	Urban Transportation Planning
TR 701	Traffic Control, Operations and Management

Plus 1 of:

TR 603	Computer Packages in Transportation and Traffic Planning
TR 630	Principles of Urban and Regional Planning
TR 845	Techniques in Transportation Analysis

Transportation Facility Design and Operation (15 units)

Required:

TR 660	Urban Public Transportation
TR 670	Planning and Design of Terminals
TR 671	Airport Planning and Design
TR 710	Design of Traffic Facilities

Plus 1 of:

TR 665	Design of Rail Facilities
TR 704	Traffic Capacity and Design

Urban and Regional Planning (12 units)

Required:

TR 630	Principles of Urban and Regional Planning
TR 631	Methods of Urban and Regional Analysis in Planning
TR 632	Urban and Regional Science in Transportation
TR 640	Environmental Analysis of Transportation Projects

Transportation Safety and Environment (12 units)
Required:

TR 640	Environmental Analysis of Transportation Projects
TR 846	Transportation System Safety
or	
TR 866	Transportation Safety
TR 865	Highway Traffic Safety

Plus 1 of:

TR 641	Environmental Law and Technology
TR 703	Traffic Studies
TR 830	Energy in the Transportation Sector

Public Transportation (12 units)
Required:

TR 660	Urban Public Transportation

Plus 3 of:

TR 661	Intercity Passenger and Freight Transportation
TR 662	Public Transportation in Small Towns and Rural Areas
TR 665	Design of Rail Facilities
TR 670	Planning and Design of Terminals
TR 671	Airport Planning and Design
TR 864	Transportation Safety
TR 866	Transportation System Safety

Transportation Economics and Management (15 units)
Required:

MG 600	Management Process
MG 601	Organizational Behavior
TR 751	Transportation Finance

Plus 2 of:

TR 750	Transportation Economics
TR 752	Analysis of Transportation Markets
TR 755	Legal and Regulatory Aspects of Transportation
TR 756	Behavioral Aspects of Transportation

Energy Policy and Engineering (12 units)
Required:

ES 927	Energy Policy Issues
ES 928	Energy Resource Distribution and Conversion
TR 830	Energy in the Transportation Sector

Plus 1 of:

TR 660	Urban Public Transportation
TR 715	Urban Goods Movement
TR 750	Transportation Economics

Units earned toward certificate programs are transferable to degree programs if they are applicable. No course, however, may be credited toward more than one certificate program.

RESEARCH AND STUDENT AID

The Department of Transportation Planning and Engineering is extremely active in research on a wide variety of transportation related topics. All research activities are housed in the Transportation Training and Research Center (TTRC), a separate research unit of Polytechnic, integrally associated with the department. Many of the research contracts and grants handled by TTRC provide for the involvement of students and research fellows. These fellowships will normally provide for full tuition plus a monthly stipend. Research fellows normally have a commitment of 20 hours per week of effort for the period of their appointments. Students wishing more information on research fellowships should write to: Professor Roger P. Roess, Administrative Officer, Department of Transportation Planning and Engineering, Polytechnic Institute of New York, 333 Jay Street, Brooklyn, New York 11201.

Depending upon the source of funding, some fellowships may be restricted to U.S. citizens. Fellowships are awarded on the basis of merit, not need, and require a strong sense of commitment on the part of the student to the completion of the research with which they are associated.

In addition to full fellowships, the Polytechnic offers a limited number of tuition-remission awards in the amount of ½ of the tuition. Students receiving such assistance are responsible for the remaining tuition and their living expenses. They are normally required to commit 5 hours per week to departmental activities. One-half tuition scholarships are applied for in the same way as research fellowships, as described above.

ADVISING

In any graduate program, the relationship between the student and adviser is an important one. It is the academic adviser who will assist the student in selecting courses, and give guidance in all academic matters. The adviser also maintains a check on the student's progress, and makes recommendations where problems arise.

Shortly after acceptance into the transportation program, each student is asked to select an area of special interest. This is in no way binding, nor does it commit the student to a particular course of study, but it does help us in the assignment of the most appropriate academic adviser in each case.

The students should meet with their adviser prior to each registration, and at any other time when they desire advice or consultation. The academic adviser must formally approve the student's course selections prior to registration. The academic adviser also handles requests for waiver of certain degree requirements, such as required courses. Such waivers must be approved in writing by the academic adviser and the instructor of the required course, and must be entered into the student's departmental file. When such waivers are granted, the student may be required to take another specific course in its place, or may be permitted to select an additional elective.

When a student registers for any guided study activity (readings, project, thesis, dissertation), he or she is also assigned an adviser for each such activity. This

may or may not be the same as the academic adviser, depending upon the subject being studied. In order to register for a guided studies activity, the students must have submitted a written proposal of their topic to an appropriate adviser and have the adviser's written approval. Doctoral students, in addition, are not permitted to register for dissertation until they have passed the Ph.D. Qualifying Examination.

Students studying under a research fellowship appointment will be assigned a research adviser, who is normally the principal investigator of the project which funds their fellowship. In some cases, the same faculty member will often act as the academic adviser. While the adviser's function is to consult with and give advice to the student, it is *the student's responsibility to ensure that the requirements are fulfilled and submit all proper forms and applications when necessary.*

FACILITIES

In addition to the regular Polytechnic facilities, including the Spicer Library and the IBM 360/65 computer and support equipment, the following department facilities are available.

Departmental Library—The department maintains a small library collection which includes research reports and other technical documents not normally retained by the main library, as well as duplicates of key periodicals also held in the Spicer Library. In addition, the departmental library is a depository for transportation-related publications of the National Technical Information Service. The library is available to students as a reference and limited lending facility.

Computer Center—The department and its students have available a computer center well suited to their academic, research and administrative needs. The computer facility consists of an IBM 360/65 with 1,000,000 bytes of core memory, seven 3330-type tape drives holding upwards of 700,000,000 bytes of information, four magnetic tape drives, two card readers and two 100-line-per-minute printers. Persons using the center's batch-processing capability may use languages such as Fortran IV, PL/1, WATFIV, PLAGO, ICES, SIMSCRIPT, GDSS, CSMP, SPSS and many others. In addition, the department has active a complete battery of transportation planning and traffic engineering computer packages, including the FHWA and UMTA (UTPS) programs. The department also has available its own APPLE computer for research and academic applications. Also available are two videotape cameras and monitors for automated data collection.

Student Study Hall—The department maintains its own student study facility with locked file drawers, which is available to all full-time students and many part-time students. It provides a place for students to work either together or in groups, and a facility where books and other possessions may be safely kept.

UNDERGRADUATE COURSES

The department offers a limited number of undergraduate courses as electives for students in the various undergraduate programs at Polytechnic. These may not be taken for graduate credit by students of the Department of Transportation Planning and Engineering.

TR 360 Traffic Planning and Operations 3:0:3
An introductory course in the development and use of traffic engineering techniques to aid in the planning, functional design and control of highway and street systems. Emphasis on practical applications. Prerequisite: junior status.

TR 361 Transportation Models 3:0:3
Introductory course in modeling for transportation planning and engineering. Emphasis on planning process and public transit. Modeling of travel demand, route selection and system evaluation. Emphasis on model-building and applications. Group project required. Prerequisite: junior status.

TR 362 Public Transportation Technology and Operations 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 rail, rail rapid transit, demand actuated transit, etc. Operational and planning aspects: scheduling, fares, labor relations, etc. Prerequisite: junior status.

GRADUATE COURSES

Graduate courses are grouped into major specialty areas of transportation planning and engineering. These groupings are intended to aid students in their course selection, which is subject to the approval of the academic adviser.

TRANSPORTATION PLANNING

TR 600 Transportation Studies and Characteristics 2½:0:3
An introductory course in travel demand characteristics, transportation systems characteristics and data collection for transportation studies. Data acquisition techniques for major transportation planning studies as well as for small-scale projects are discussed.

TR 601 Travel Demand Forecasting 2½:0:3
Theory and applications of travel forecasting methods to predict the amount and nature of travel on transportation systems. Emphasis on UMTA transportation planning system models. Prerequisite: **MA 551** or equivalent.
Also listed under CE 804

TR 602 Urban Transportation Planning 2½:0:3
The course is structured to provide a comprehensive treatment of transportation system planning from the regional to the local level. Problem identification; issues and needs related to the planning, design and operations of transportation systems. Evaluation of transportation system performance and impacts. Prerequisite: TR 601 or equivalent.

TR 603 Computer Packages in Transportation and Traffic Planning 2½:0:3
The course introduces the atudent to a range of computer programs available for use in transportation and traffic planning.

Major emphasis is given to understanding the capabilities of the FHWA and UMTA (UTPS) computer packages, which are widely used. Students are introduced to these tools through computer-based problem solving as well as manual solutions, where practical. Prerequisites: TR 601 and TR 701 or equivalent.

TR 629 Transportation Workshop 0:5:3
Comprehensive projects utilizing basic fundamentals from courses taken or concurrently taken in the M.S. program. Projects assigned on an individual or team basis depending on the scope. Principles and methods of technical report writing. Prerequisites: TR 601 and TR 701 or equivalent.

URBAN AND REGIONAL PLANNING

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

TR 631 Methods of Urban and Regional Analysis in Planning 2½:0:3
A course in formal methods of analysis of the major components of comprehensive planning. Population, economic activity and land use, and their interrelationships. The theoretical exposition is supplemented by illustrative practical applications.

TR 632 Urban and Regional Science in Transportation 2½:0:3
An examination of the structure of urban and regional systems and the interrelationships between their components, including transportation and their evolution. The course builds on and utilizes the analytical tools developed in TR 631. Prerequisites: MA 551 and TR 631 or equivalent.

TR 840 Environmental Analysis of Transportation Projects 2½:0:3
Methods and practices for forecasting, identifying, measuring, analyzing and preventing or tempering the impacts of effects of transportation and other facilities, including air, noise, water and other ecological impacts, as well as community, psychological and other social impacts.

TR 841 Environmental Law and Technology 2½:0:3
Investigation of current crises involving the environment and its relationship to transportation technology. Subject matter has been specially developed to cover case law, legislative history, and economic and political issues concerning technology and the environment. Subjects of study include land-use planning, conservation aesthetics, regulatory control, transportation and related pollution of all forms. Student projects shall be required. Prerequisite: adviser's approval.
Jointly offered with the Brooklyn Law School.

PUBLIC TRANSPORTATION PLANNING, OPERATIONS AND TECHNOLOGY

TR 660 Urban Public Transportation 2½:0:3
Characteristics of urban transportation systems. Composition of the transit industry and its structure. Planning, design, operations and management of public transportation modes.

TR 661 Intercity Passenger and Freight Transportation 2½:0:3
Review of past and present operations, financial position and transportation role of each of the intercity passenger and freight modes in the United States with foreign comparisons. History of each mode is presented, including the economic, technological and political factors that caused these modes to prosper (and decline). The role of government regulatory and fiscal agencies. Economic efficiency of government actions, the methods of "shared cost" estimation, and related rate setting, and intra- and intermodal competitive forces are analyzed.

TR 662 Transportation in Small Towns and Rural Areas 2½:0:3
The need for rural transit services, characteristics of service users, methods for estimating demand, range of services that can be provided, institutional framework of rural transit, vehicle and vehicle maintenance. Prerequisite: TR 601 or equivalent.

TR 665 Design of Rail Facilities 2½:0:3
The course deals with the design of systems for moving passengers and freight on rails. It involves roadbed, track, alignment, yards, station, signals communications and protection devices. The course also devotes several lectures to design of light-rail transit facilities.

TR 670 Planning and Design of Terminals 2½:0:3
An introductory course of passenger and freight terminals with emphasis on the system description of these facilities. Land, marine and air terminals are discussed. Methods are discussed for determining the level of service for pedestrian flows, service times for passengers boarding and alighting, transit vehicles and simulation methods for transit terminals.
Also listed under CE 840

TR 671 Airport Planning and Design 2½:0:3
Techniques for forecasting air passenger traffic, aircraft operations at commercial and general aviation facilities. Principles and practices for the planning and design of terminal facilities, ground transportation systems, parking facilities, runways and navigational aids. Airport site selection, configuration and economics.
Also listed under CE 871

HIGHWAY AND TRAFFIC ENGINEERING

TR 701 Traffic Control, Operations and Management 2½:0:3
The traffic stream is comprised of automobiles, commercial vehicles, buses, pedestrians and other elements. The operation and control of this stream is treated on two levels: (1) overall articulation—Transportation Systems Management (TSM), and (2) the specifics of each component user and facility. Intersections, arterials, networks, freeways and traffic corridors are considered. Signal timing and coordination, over-saturated control, detectorization and computer applications are taught.

TR 703 Traffic Studies 2½:0:3
Techniques for collection of traffic data and information: speed, travel time, volume, origin-destination, parking, accidents, etc. Analysis and interpretation of results. Corrective actions and program formulation based on study results. Prerequisites: MA 551 and TR 701 or equivalent.
Also listed under CE 805

TR 704 Traffic Capacity and Design 2½:0:3
The use of highway capacity analysis techniques in design, planning and operational analysis is treated. Highway Capacity Manual methods as well as foreign techniques and recent research developments are discussed and illustrated. Functional design of freeways, arterials, streets and rural highways is covered.
Also listed under CE 806

TR 710 Design of Traffic Facilities 2½:0:3
Presents 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
A description of urban goods movement, primarily by truck, and its effect on urban mobility. Includes 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 tests. 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 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

TRANSPORTATION ECONOMICS AND MANAGEMENT

TR 750 Transportation Economics 2½:0:3
A brief review of the principles and concepts of engineering economic analysis and a thorough application of these principles to decision-making in the transportation sector; methods for estimation of capital, operating and direct-user costs in transportation; benefit concepts, and estimation of benefits, indirect effects; transportation finance and taxation: concepts of public finance and equity in taxation.
Also listed under CE 812

TR 751 Transportation Finance 2½:0:3
Material is approached from a public finance perspective, including a review of those economic theories and analytical techniques that are of particular relevance to transportation. Special attention is given to such areas as (a) the equity vs. efficiency queation in transport finance (b) general vs. earmarked revenue methods (c) the valid (and invalid) used of cost-benefit and cost-effectiveness studies and (d) peak load (marginal cost) pricing.
Also listed under MG 853

TR 752 Analysis of Transportation Markets 2½:0:3
Application of the precepts of marketing to public and private transportation operations. Basic market structure of major modes is reviewed to demonstrate how gaining and using market data can increase efficiency and profitability operations. Attention is given to (a) how factors that affect modal choice are determined and (b) how this information can be integrated into a "marketing plan" that includes service, pricing and promotional aspects. Case studies.
Also listed under MG 855

TR 755 Legal and Regulatory Aspects of Transportation 2½:0:3
An in-depth treatment of the origins, causes and effects of regulation on transportation and society in the U.S. Economic and constitutional bases for transportation regulation. The legal basis, structure and function of federal, state and local regulatory bodies and their interaction with transportation industries. Current controversies concerning the deregulation of sectors of the transportation industry.
Also listed under MG 852

TR 756 Behavioral and Sociological Aspects of Transportation 2½:0:3
Behavioral analysis of transportation decision-making and travel characteristics. Sociological factors involved in travel decisions—crime, social isolation, comfort and convenience.
Also listed under MG 856 and SS 815

TR 757 Transportation Management 2½:0:3
Management problems in the transportation sector, discussion of various types and forms of transportation organizations — planning organizations, operators, consulting firms, etc.—and treatment of organizational problems unique to each. Private vs. public transportation operators and agencies. Public authorities: legal basis, structure, purpose. Prerequisites: MG 601 and TR 660, or equivalent or adviser's approval.
Also listed under MG 857

TR 758 Transportation Policy and Decision-making 2½:0:3
A high-level treatment of policy formulation and decision-making in the transportation industry on several levels: federal, state and local policy, individual operating policies. Course uses an intensive case-study approach in a seminar or discussion-format. Emphasis is on mass transit operations. Prerequisite: adviser's approval.
Also listed under MG 858

REGIONAL AND TRANSPORTATION DEVELOPMENT IN DEVELOPING COUNTRIES

TR 833 Economic Analysis of Transportation Projects in Developing Countries 2½:0:3
Principles of economic engineering. Methods of empirical analysis for transportation projects in developing countries. Role of major transportation projects in economic development. Quantitative techniques for transportation decision-making in developing economies.

TR 834 Financing Transportation Projects in Developing Countries 2½:0:3
Domestic financing mechanisms for funding of transportation projects in developing economies. Available international sources of economic assistance. Impacts of monetary arrangements and effects of exchange-rate fluctuations on projects cost. Role of users' charges to finance transportation projects. Project cost analysis and role of government actions in wage and price setting. Private sector role in project financing.

TR 880 Case Studies in Regional Transport Development 1¼:1¼:3
Comprehensive projects utilizing basic fundamentals from courses taken or concurrently taken in the program. Such case studies are developed based on past and/or ongoing projects undertaken in developing countries. Assignments are on an individual or team basis depending on the scope. Prerequisites: TR 600, TR 601 and TR 704 or equivalent.

TR 881 Design and Construction of Roads in Developing Countries 2½:0:3
Introduction to functional and preliminary design principles for freeways and arterials. Low-volume road technology. Design, construction and maintenance of roads in rural areas of LDCs. Criteria for upgrading earth roads to gravel roads, and unpaved roads to paved roads. Geometric design for unpaved roads. Cri-

teria for selecting one vs. two lane roads. Low-cost water crossings. Labor intensive techniques for construction and maintenance. Inventory of material resources.

TR 882 Construction of Transportation Projects in Developing Countries 2½:0:3
Management problems unique to construction of transportation projects in developing countries, including licensing, bonding, insurance, employee relations, etc. The planning, scheduling and progress control of projects with emphasis on critical path methods and PERT. Application of accounting data for decisions on pricing, bidding analysis and feedback reporting for cost control. Principles of contract law and legal problems in preparing and administering construction contracts.

TRANSPORTATION SAFETY AND OTHER SPECIAL TOPICS

TR 830 Energy in the Transportation Sector 2½:0:3
Transportation consumes about 25 percent of all energy. It is necessary to consider the variety of sources, transportation modes and travel needs. Total energy, not just propulsion energy is addressed. Three prime areas are the motor vehicle, programs and policies, and public transportation. Technology, costs and interactions are noted. Developing engines, motors, alternative fuels and the electric vehicle are reviewed. Transport of energy itself is studied.

TR 845 Techniques in Transportation Analysis 2½:0:3
Analytic techniques are introduced on three levels: (1) basic concepts, (2) case studies and (3) review of literature. Material covered includes: survey design and interpretation, use of simulators in transportation, construction and use of deterministic models for insight, statistical models, introduction to queuing and linear programming, introduction to Delphi Technique and cost-utility. Course emphasizes the modeling concept and its application. Prerequisite: MA 551 or equivalent.

TR 860-861 Selected Topics in Transportation I, II each 2½:0:3
These courses are utilized for the periodic presentation of topical material of current interest. Some recent topics presented as Selected Topics courses are: decision-making in transportation, computer packages in transportation, transportation systems safety and others. Some of these have been added to the regular curriculum because of their popularity as Selected Topics offerings. Prerequisite: adviser's approval.

TR 884 Transportation Safety 2½:0:3
Comparative review of history and current practices in safety of all transportation modes: land, sea and air. Development of government participation and regulation. Analysis of related approaches in differing modes for reducing accidents and attenuating accident effects; lessons to be learned with applications from one mode to another. Safety promotion and educational activities. The economics of safety. Prerequisite: **TR 600** or equivalent.

TR 885 Highway Traffic Safety 2½:0:3
Methods used in the achievement of lower levels of highway traffic accident occurrence and accident severity, with concentration on proved, practical approaches based on sound engineering principles. Application of principles to real-life situations. Prerequisite: **TR 701** or equivalent.

TR 886 Transportation System Safety 2½:0:3
An introductory course in transportation system safety and its applicability to the transportation industry. Description of managerial and analytic techniques to be used in conjunction with system safety analyses. Safety programs, management, planning and organization. Intermodal interface safety consideration. Safety measurement criteria. Measurement of performance. Evaluation of safety programs.

GUIDED STUDIES

TR 901-902 Readings in Transportation 2½:0:3
Study of special problems in transportation under the direct supervision of one or more members of the faculty. Prerequisite: adviser's approval.

TR 940 Joint Project or Internship in Transportation Management each 3 units
An independent project or internship in transportation management for students enrolled in the joint M.S. degree program. Prerequisites: degree status and adviser's approval.
Also listed under MG 940

TR 951-952 Seminar in Transportation I, II nc
Presentations by guest speakers on relevant topics in transportation. Presentations and discussion of on-going research by course participants and faculty. Required of all full-time degree students in the program. Prerequisite: adviser's approval.

TR 962 Master's Project or Internship in Transportation each 3 units
An independent project, or internship with a relevant transportation agency, leading to a report demonstrating the student's professional competence. Students are examined orally and must submit an acceptable written report (unbound). Prerequisites: degree status and 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 properly motivated students. Prerequisites: degree status and adviser's 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 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. Dissertation must be worthy of publication in a recognized scientific or engineering journal. The student is required to take an oral examination on the subject of the dissertation and on related topics. Prerequisites: degree status, passage of Ph.D. qualifying examination and adviser's approval.

FACULTY

Louis J. Pignataro, Professor, Head of Transportation Planning and Engineering and Director of Transportation Training and Research Center
B.C.E., Polytechnic Institute of Brooklyn; M.S., Columbia University; Dr.Tech.S., Technical University of Graz (Austria)
Traffic engineering, transportation economics, public transportation, transportation and energy

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
Transportation safety, environmental impacts of transportation, urban planning, pedestrian and bicycle planning

William R. McShane, Professor of Transportation and System Engineering and Associate Director of Transportation Training and Research Center
B.E.E., Manhattan College; M.S., Ph.D., Polytechnic Institute of Brooklyn
Transportation models, traffic control and operations, transportation systems management, transportation noise, computer applications, transportation and energy

John C. Falcocchio, Associate Professor of Transportation Engineering
B.S.C.E., M.S., Ph.D., Polytechnic Institute of Brooklyn
Transportation planning, public transportation, transportation for disadvantaged groups

Philip A. Habib, Associate Professor of Transportation Engineering
B.E., CCNY; M.S., Ph.D., Polytechnic Institute of Brooklyn
Goods movement, highway design, highway planning, transportation planning

Roger P. Roess, Associate Professor of Transportation Engineering and Administrative Officer
B.S., M.S., Ph.D., Polytechnic Institute of Brooklyn
Traffic capacity and design, public transportation, transportation economics, traffic engineering

William H. Crowell, Assistant Professor of Transportation Economics
B.S., Boston College; M.A., Ph.D., New York University
Transportation economics and finance, planning, transportation and energy

ADJUNCT FACULTY

Joseph S. Kaming, Adjunct Professor
B.S., Massachusetts Institute of Technology; M.S., Rensselaer Polytechnic Institute; LL.B., Columbia University
Transportation law, transportation regulation, law and technology

Walter H. Kraft, Adjunct Professor
B.S., M.S., Newark College of Engineering; Dr.Eng.Sc., New Jersey Institute of Technology
Transportation terminals, design of facilities

William S. Allison, Adjunct Professor
A.B., Williams College; M.B.A., Harvard University
Transportation policy and decision-making

Martin F. Huss, Lecturer
B.S.C.E., University of Maryland; M.S., Ph.D., Polytechnic Institute of New York
Design of rail systems, public transportation, urban planning

Harry Mortkowitz, Lecturer
B.S., Florida Institute of Technology
Air transportation, airport planning and design

Paul J. Menaker, Lecturer
B.S., M.S.T.P., Ph.D., Polytechnic Institute of New York
Computer packages, transportation system planning

THE CORPORATION

Chairman

Joseph J. Jacobs, *Chairman of the Board, Jacobs Engineering Group, Inc.*

Vice Chairmen

William F. May, *Retired Chairman and Chief Executive Officer, American Can Company*

Clarence F. Sillieck, *Vice President, C. J. Osborn Chemicals, Inc.*

Sidney G. Albert, *President, Albert Pipe Supply Company*

Donald M. Alstadt, *President, Lord Corporation*

David Baclini, *President, David Baclini, Inc.*

Mark H. Berger, Esq., *Mark H. Berger, P.C.*

Jeremiah B. Bloom, Esq., *Bloom Epstein, Wayne, Reiss and Milner*

Joseph D. Brown, *Retired President, Poloron Products, Inc.*

Robert P. Brown, *Retired*

Harry W. Buchanan, *President, Virginia Chemicals, Inc.*

George Bugliarello, *President, Polytechnic Institute of New York*

Vincent A. Calarco, *President, Uniroyal Chemical Company*

William J. Catacosinos, *Chairman and Chief Executive, Applied Digital Data Systems, Inc.*

Donald M. Cox, *Senior Vice President, Exxon Corporation*

David Dibner, *Chairman of the Board, Burndy Corporation*

Winfield Fromm, *Vice President, Instruments and Systems Operations, Eaton Corporation*

Joseph G. Gavin, Jr., *President, Grumman Corporation*

Paul Hallingby, Jr., *Bear, Stearns & Company*

Norman Hascoe, *President, Semi-Alloys Inc.*

Fred Heinzelman, Jr., *President, Fred Heinzelman & Sons*

Frank G. Hickey, *Chairman, President and Chief Executive Officer, General Instrument Corporation*

Harmon F. Hoffmann, *President, Ryder Truck Rentals, Ryder Systems, Inc.*

Arthur J. Keenan, *Vice President, Business Markets, New York Telephone Company*

Koji Kobayashi, *Chairman of the Board and Chief Executive Officer, Nippon Electric Company, Ltd.*

Richard Laster, *Executive Vice President, General Foods Corporation*

Gerald D. Laubach, *President, Pfizer Inc.*

William E. Leistner, *Partner, Phoenix Chemical Company*

Stephen L. Levy, *Senior Vice President, Motorola, Inc.*

Eugene H. Luntey, *President, Brooklyn Union Gas Company*

David L. Mitchell, *Managing Director, Shearson Loeb Rhoades, Inc.*

Stanley M. Nisenson, *Senior Staff Engineer, New York Telephone Company*

Donald D. Pascal, *Chairman, Executive Committee, National Starch & Chemical Corporation*

Leonard F.C. Reichle, *Executive Vice President, Ebasco Services, Inc.*

Louis N. Rowley, Jr., *Consulting Editor, Power & Electrical World, McGraw-Hill Publications*

Robert Sanator, *Senior Vice President, Fairchild Republic Company*

Harrison V. Smith, *Chairman, Trust and Investment Committee, Morgan Guaranty Trust Company*

Paul Soros, *President, Soros Associates International, Inc.*

Charles Strang, *President, Outboard Marine Corporation*

Jerry M. Sudarsky, *President, J M S Associates*

Harry C. Wechsler, *President, Beatrice Chemical, Division of Beatrice Foods Company*

David Westermann, Esq.

George Wilcox, *Director, Westinghouse Electric Corporation*

Trustees Emeriti

Benjamin Adler, *Consulting Engineer*

Preston R. Bassett, *Retired President, Sperry Gyroscope Company*

George F. Habach, *Management Consultant*

Marvin Lee, *Retired President, Lifetime Consultant, Burndy Corporation*

Robert E. Lewis, *Retired Chairman Executive Committee, Perkin Elmer Corporation*

Herman F. Mark, *Dean Emeritus, Polytechnic Institute of New York*

Ernst Weber, *President Emeritus, Polytechnic Institute of New York*

THE ADMINISTRATION

George Bugliarello, Dr.Ing., Sc.D., President
Eleanor Adams, B.A., Executive Assistant to the President
Gloria Kaplan, Executive Secretary
Ernst Weber, Dr.Phil., D.Techn., Sc.D.Eng., President Emeritus

ACADEMIC ADMINISTRATION

Albert Gold, Ph.D., Provost
Robert J. Maciag, M.S., Deputy Provost
Helen Warren, Special Assistant, Office of Provost
James J. Conti, D.Ch.E., Vice President for Educational Development and Director of the Long Island Campus
Stanley Preiser, Ph.D., Dean of the Westchester Center
Bernard J. Bulkin, Ph.D., Dean of Arts and Sciences
Alice Blanchard, Executive Assistant to the Dean of Arts and Sciences
Sidney S. Shamis, M.S., Acting Dean of Engineering
James M. McCarthy, J.D., Executive Assistant to Dean of Engineering
Norbert Hauser, Eng.Sc.D., Dean of Management
Anthony B. Giordano, D.E.E., Dean of Graduate Studies
Kenneth Danielsen, Director of Computer Activities
Robert J. Cresci, Ph.D., Director, Aerodynamics Laboratory
Paul R. DeCicco, M.C.E., Director, Center for Urban Environmental Studies
Herbert Morawetz, Ph.D., Director, Polymer Research Institute
Arthur A. Oliner, Ph.D., Director, Microwave Research Institute
Louis J. Pignataro, Dr.Tech.Sc., Director, Transportation Training and Research Center

Student Life

Edward A. DeCarbo, Jr., Ph.D., Dean of Student Life
Myma Singer, Executive Assistant to Dean
Robert H. Isaacs, M.Ed., Associate Dean of Student Life
Harvey R. Delaney, Jr., B.S., Coordinator of Student Activities and Director of the Student Center
Suzanne Singer, International Student Adviser

Admissions and Financial Aid

Elizabeth Sharp Ross, B.A., Director of Admissions/Financial Aid
Cynthia Bailey, M.S., Director of Financial Aid
G. Peter Cooney, M.A., Assistant Director of Admissions
Carol A. Fazio, M.S., Assistant Director of Admissions, Long Island Center
Christine Stefano, B.A., Assistant Director for Transfer Admissions
Abraham I. Goodman, M.A., Admissions Consultant, Long Island Center
Brian A. Amelkin, B.A., Financial Aid Counselor
M. Hillary O'Rourke, M.A., International Student Admissions Counselor

Career Services/Cooperative Education

Ernest B. Racz, Ed.D., Director of Career Services and Cooperative Education
Irene Dorzback, M.A., Assistant Director of Career Services and Cooperative Education
Arthur L. Rucks, M.A., Coordinator, Part-time job development
Sandra P. Santana, B.A., Coordinator, Cooperative Education

Registrar

Janyce G. Wolf, M.S., Registrar
Marcia Moallem, B.A., Assistant Registrar
Gary R. Kunz, Office Manager

Libraries

Leonard Cohan, M.S. in L.S., Director of Libraries and Associate Professor of Social Sciences
Zena Jacobs, M.L.S., Head, Reference Department
James Jarman, M.L.S., Head, Order Department
Vera Marek, M.L.S., Head, Catalog Department
Liliana Middleton, M.L.S., Head, Circulation Department
Lorraine Schein, M.S. in L.S., Head, Long Island Center Library
Hana Stranska, M.L.S., Reference Librarian
Heather Walters, B.S., Head, Serials/Documents Department

ADMINISTRATION AND FINANCE

Seymour Scher, Ph.D., Vice President for Administration and Finance
John Rorer, M.P.A., Assistant Vice President for Administration and Finance
Thomas Ford, M.A.; M.I.L.R., Comptroller
Robert E. Hawks, M.A., M.P.A., Budget Director
Frances Temchin, M.A., Personnel Officer
Lyle Loper, B.B.A., Systems Manager

Administrative Services

Catharine Sharp, Director of Administrative Services
Richard Urevich, Supervisor, Buildings and Grounds
Charles Wildermuth, Supervisor, Print and Mail Services
Elaine Cummings, Word Processing

Development

Joseph R. Burkart, B.A., Vice President for Development
Raymond C. Soldavin, B.A., Director of Development
Barbara L. Bender, Director of Special Projects
Richard Gerber, B.A., Director of Annual Fund
Arthur L. Rossoff, M.E.E., Assistant to the President, Associate Director of Development

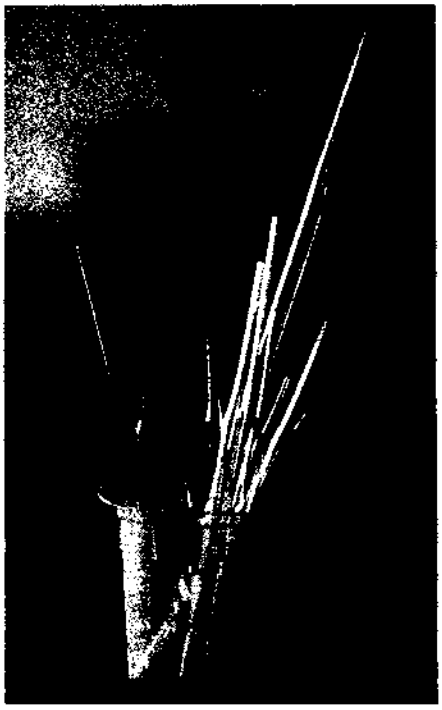
Public Relations

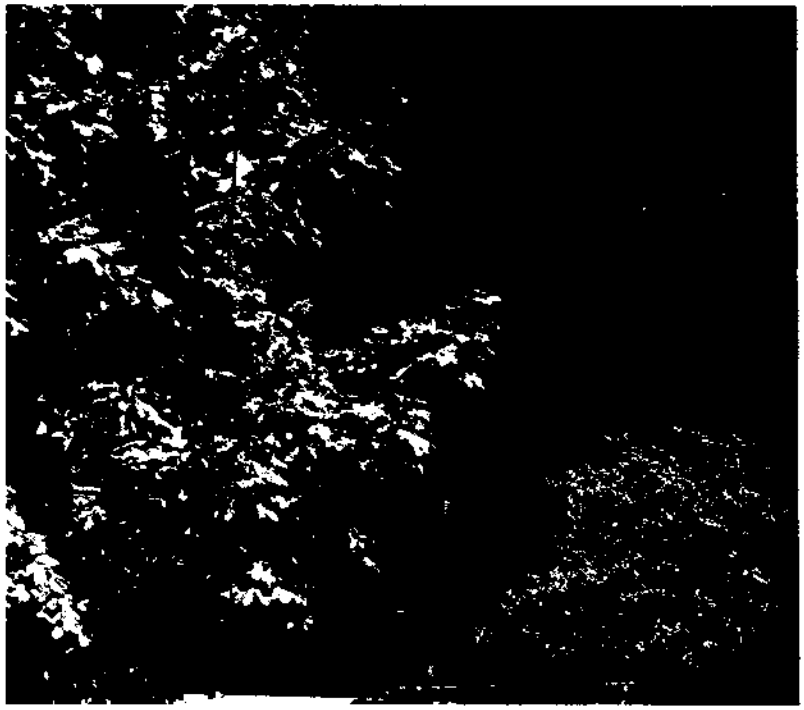
William P. McDonald, M.S.Ed., Director of Public Relations
Peter Kaufman, M.A., News Writer
Loretta Lawrence Keane, B.A., Director of Publications
Carol Mennella, Program Coordinator

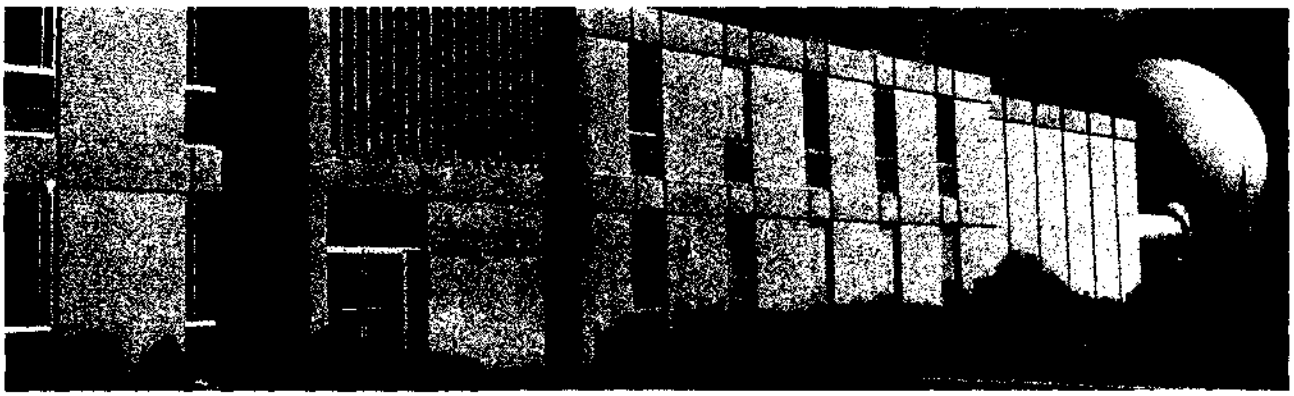
The Alumni Association

Robert E. Schuck, M.A., Executive Director
Officers for 1980-81
Sidney A. Savitt '45, President
Henry Bachman '51, Vice President
Dorothy Pinkert '52, Vice President
Harold L. Brownman '44, Vice President
Franklin Blecher '49, Secretary
Charles F. Wagner '65, Treasurer

GENERAL INDEX







NOTES

NOTES

NOTES

NOTES