

Polytechnic UNIVERSITY

CATALOG
1992 - 1994

ADMINISTRATIVE OFFICES

Polytechnic University has three campus centers:

- The Brooklyn Center with administrative offices in the Jacobs Building, is located at 6 Metrotech Center, Brooklyn, NY.
- The Long Island Center is on Route 110 in Farmingdale, NY.
- The Westchester Center is at 36 Saw Mill River Road, Hawthorne, NY.

ADMISSIONS

Undergraduate Admissions:

Brooklyn Center - Rm. 158, Jacobs Bldg. (718) 260-3100

Long Island Center - Rm. 118, Administration Building (516) 755-4200

Graduate Admissions:

All Centers (718) 260-3200

- Interviews are scheduled by appointment, Monday through Friday, 9AM-5PM. Call the admissions office for appointment and information.

STUDENT LIFE

For counseling, guidance, problem resolution, housing, co-curricular activities, new student programs, health insurance, academic and disciplinary policy administration, and related matters:

Brooklyn:

Monday-Thursday, 9AM-5PM
Friday, 9AM-2PM
(718) 260-3800

Farmingdale:

Monday-Friday, 9AM-5PM
(516) 755-4325

FINANCIAL AID

For advice on tuition and all matters relating to financial aid and scholarships:

Brooklyn Center - Room 158, Jacobs Building, Monday through Friday, 9AM-5PM, Telephone (718) 260-3300.

Long Island Center, Admissions and Financial Aid Office, Room 118, Monday through Friday, 9AM-5PM, Telephone (516) 755-4345.

REGISTRAR

For registration and other record-related information:

Monday and Thursday, 9AM-6PM (during semester); 9AM-5PM when classes are not in session.

Tuesday and Wednesday, 9AM-5PM, and Friday, 9AM-3PM, Room JB359, Telephone (718) 260-3900.

Long Island Center, Room 121, (516) 755-4450.

COOPERATIVE EDUCATION

For consultation on this earning and learning program, Monday through Friday, 9 AM to 5 PM, 3rd floor, Nichols Building; Telephone (718) 260-3650. Long Island Center Grumman Hall (516) 755-4270.

CAREER SERVICES

For assistance in finding part-time, full-time and summer positions and for advice on careers, Monday through Friday, 9AM-5PM, 3rd floor, Nichols Building, (718) 260-3650.

Long Island Center, (516) 755-4270.

BURSAR

For consultation regarding accounts and payment of bills, Brooklyn Center hours are Monday and Thursday, 9AM-6PM; Tuesday and Wednesday, 9AM-5PM, Friday, 9AM-2PM, Room JB256, 2nd floor, (718) 260-3700.

Long Island Center hours are Monday through Friday, 10:30AM - 2:30PM, (516) 755-4225. Hours at both campuses are extended during registration periods.

LONG ISLAND CENTER

For information concerning programs offered on Long Island. Monday through Friday, 9AM-5PM, (516) 755-4200.

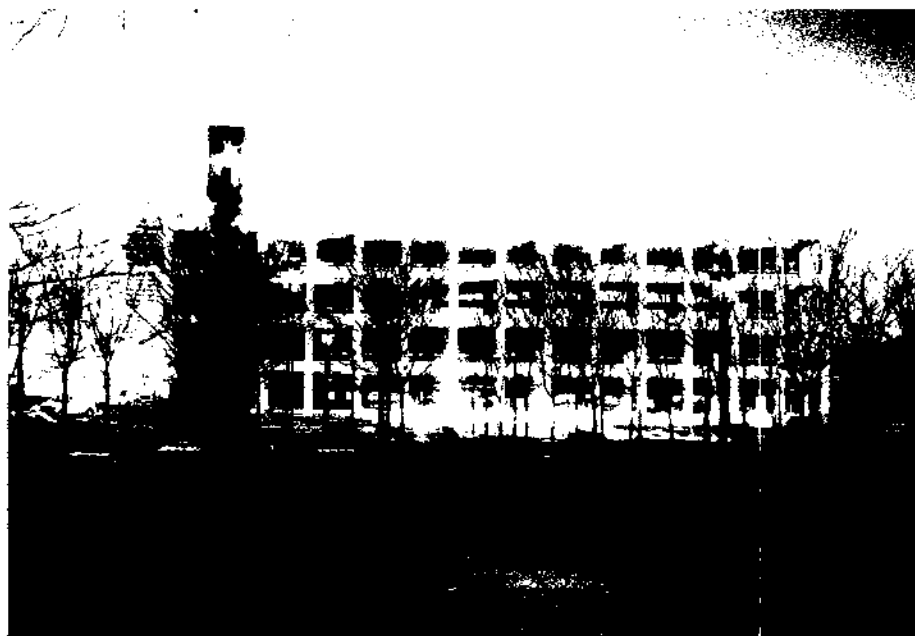
WESTCHESTER CENTER

For information concerning graduate programs offered in Westchester. Monday through Friday, 9:00AM - 5:30PM, (914) 347-6940. All office services are provided through the main administrative office.

Cover photo shows the [001] convergent diffraction pattern from NbAl_3 , a compound whose very high melting point of F3000 and low density make it a candidate for possible future use in airplane manufacture. Photo courtesy of Professor Said Nourbakhsh of Metallurgy and Materials Science.



Westchester Campus



New York City
Campus

Long Island Campus



Polytechnic UNIVERSITY

CATALOG 1992 - 1994

Brooklyn: Six Metrotech Center, Brooklyn, N.Y. 11201 718/260-3600

Long Island: Route 110, Farmingdale, N.Y. 11735 516/755-4400

Westchester: 36 Saw Mill River Road, Hawthorne, N.Y. 10532 914/347-6940

Polytechnic University is an internationally renowned institution dedicated to the advancement and application of the science and engineering of technology. It is the leading technological university in the New York City metropolitan region. Its mission is to provide undergraduate and graduate education in engineering, the sciences, mathematics, management, and the liberal arts, and to conduct state-of-the-art basic and experimental research to advance technology, management of technology, and the relationships between social institutions and technology. Through excellent teaching and research programs, Polytechnic's goal is to play a positive role in the improvement of society in general, particularly as it relates to the development and application of technology.

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PART I:

GENERAL AND INSTITUTIONAL INFORMATION

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

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



ACADEMIC CALENDAR

1992 - 1993

FALL 1992

Wed., Thurs., Fri., Mon., Tues., Aug. 26, 27, 28, 31, Sept. 1,
Registration

Thursday, September 3
Classes Begin

Monday, September 7
No Classes (Labor Day)

Monday, September 28
No Classes (Rosh Hashana)

Tuesday, October 6
No Classes after 4:00PM

Wednesday, October 7
No Classes (Yom Kippur)

Thursday, Friday, Nov., 26, 27
No Classes (Thanksgiving Recess)

Tuesday, December 8
Only evening classes (Make-up)

Thursday, December 10
Monday classes meet (Make-up)

Thursday, December 10
Classes End

Friday, December 11
Reading day

Monday, December 14 - Tuesday, December 22
Final Exams

Friday, December 25, 1992 -
Friday, January 1, 1993
Recess

Monday, Jan. 4, 1993 - Friday, Jan. 15, 1993
Intercession/Mini Session

SPRING 1993

Monday, January 18
Holiday (Martin Luther King Jr. Day)

Tuesday, January 19 - Friday,
January 22
Registration

Tuesday, January 26, 1993
Classes Begin

Tuesday, April 5 - Friday, April 9
Spring Recess

Monday, May 3
Classes End

Tuesday, May 4
Reading and Make-up day

Wednesday, May 5 - Thursday,
May 13
Final Exams

Friday, May 14 - Thursday
May 27, 1993
Intercession

SUMMER 1993

Wednesday, Thursday, May 27, 28
Registration

Monday, May 31
Holiday (Memorial Day)

Wednesday, June 2
Classes Begin

Monday, July 5
No Classes

Friday, July 9
Monday classes meet (Make-up)

Tuesday, August 24
Classes End

NOTE:

**SUBSEQUENT CALENDARS WILL
BE PUBLISHED IN SEMESTER
REGISTRATION BULLETINS**



DEGREES OFFERED AT POLYTECHNIC

Polytechnic offers a wide range of degree programs leading to the award of a Bachelor of Science, Master of Science, Engineer, or Doctor of Philosophy. Polytechnic offers degree programs on three campuses located in Brooklyn, Farmingdale, and White Plains. Not all programs are available on all campuses. The table below lists all degree programs, and the campuses on which they are available. For detailed information on any particular degree program, consult the appropriate program section(s) of this manual.

Program Title	HEGIS Code	BS	MS	ENG	PhD**
Aerospace Engineering	0902	BF	—	—	—
Aeronautics & Astronautics	0902	—	—	—	F
Applied Mechanics	0291	—	B	B	B
Applied Statistics	1702	—	BFW ^{1,2}	—	B
Bioengineering	0905	—	B ³	—	B
Chemical Engineering	0906	BF ²	B	B	B
Chemical Physics	1902	—	B	B	B
Chemistry	1905	B	BW	—	B
Civil Engineering	0908	BF	BFW	BF	B
Computer Engineering	0999	BF	—	—	—
Computer Science	0701	BF	BFW	—	B
Dental Materials Science (Joint w/NYU)	1224	—	B	—	—
Electrical Engineering	0909	BF	BFW	BFW	B
Electrophysics	0919	—	BF	—	F
Environment-Behavior Studies	2201	—	B	—	—
Environmental Engineering	0922	—	B	—	B
Environmental Health Science	0922	—	B	—	—
History of Science	2205	—	B	—	—
Humanities	4903	B	—	—	—
Industrial and Applied Mathematics	1703	—	B	—	—
Industrial Chemistry	0906	—	B	—	—
Industrial Engineering	0913	B	BW ²	B	—
Industrial Eng & Operations Research	0913	—	—	—	B
Information Management	0702	BF	—	—	—
Information Systems Engineering	0990	—	W	—	—
Journalism & Technical Writing	0602	B	—	—	—
Materials Science	0915	—	BW	—	B
Management	0506	—	BFW ²	—	—
Management of Technology	0599	—	W	—	—
Manufacturing Engineering	0913	—	BW	—	—
Materials Science & Engineering	0915	B	—	B	—
Mathematics	1701	B	B	—	B
Mechanical Engineering	0910	BF	B	B	B
Operations Management	0506	—	BFW ²	—	—
Operations Research	0913	B	B	—	—
Organizational Behavior	0515	—	BFW ²	—	—
Physics	1902	B	B	—	B
Polymer Science and Engineering	0906	—	B	—	B
Social Sciences	2201	B	—	—	—
Specialized Journalism	0602	—	B	—	—
System Engineering	0901	—	BFW	BFW	—
Telecommunications & Computing Management	0599	—	W	—	—
Transportation Engineering	0908	—	—	B	—
Transportation Management	0510	—	B	—	—
Transportation Planning and Engineering	0908	—	B	B	B

1. Registration pending.

2. Some attendance at Brooklyn may be required to complete the degree program.

3. Program being phased out.

* Higher Education General Inventory System.

** Although most programs at the Ph.D. level are registered in Brooklyn, many of the required and elective courses for Ph.D. programs are also offered at the Long Island (Farmingdale) Center.

B = Brooklyn Center; F = Farmingdale (Long Island) Center; W = Westchester Center



STATISTICS ON POLYTECHNIC

ENROLLMENT (1991 FALL)

	<u>Brooklyn</u>		<u>Long Island</u>		<u>Westchester</u>	
	<u>FT</u>	<u>PT</u>	<u>FT</u>	<u>PT</u>	<u>FT</u>	<u>PT</u>
Undergraduate	951	183	338	69	--	--
Master of Science	185	624	15	318	7	435
Engineer	4	7	0	3	0	6
Doctor of Philosophy	92	183	3	20	0	23

STUDENT PROFILE (1991 FALL)

	<u>Caucasian</u>	<u>Asian</u>	<u>Black</u>	<u>Hispanic</u>	<u>Foreign</u>	<u>American Indian</u>
Undergraduate	42.8 %	35.0 %	8.7 %	8.5 %	4.9 %	0.1 %
Graduate	54.9 %	17.6 %	4.3 %	3.2 %	19.9 %	0.0 %

	<u>Male</u>	<u>Female</u>
Undergraduate	87.5 %	12.5 %
Graduate	85.0 %	15.0 %



TUITION AND FEES

Up-to-date and detailed information on tuition and fees as well as announcements of cost changes can be obtained from the Schedule of Classes available before the start of each semester. The Schedule is an official supplement to this catalog. Tuition and fees are paid by the term and not all at once for the entire academic year.

TUITION COSTS

The following costs are in effect at the time of publication, beginning with the Fall 1992 term.

Undergraduate students

Full-time (12-20 credits*)	
Each semester	\$7,250.00
Part-time (0.5 - 11.5 credits)	
Each credit/credit hour	\$450.00
Zero credit remedial courses	\$1350.00

Graduate students

Full-time (12-20 units*)	
Each semester	\$7,250.00
Part-time (0.5 - 11.5 units)	
Each unit	\$500.00

*All credits/units in excess of 20 must be paid for individually at the per credit/unit rate.

Tuition rates are set by the Board of Trustees. Due primarily to economic conditions and inflationary costs, the University reserves the right to change tuition charges and fees when it is deemed necessary. The University is mindful of the economic hardships of attending a first rate private school such as Polytechnic; accordingly, the University will continue to make every effort to keep cost increases to the lowest possible level consistent with maintaining educational quality.

Tuition covers instruction costs, use of libraries and the facilities of the Office of Student Life.

OTHER CHARGES AND FEES

Facilities Fee (Required of all students each term of registration)

Full-time	\$100.00
Part-time	\$60.00

Student Activity Fee (required only of undergraduates, payable each term)

\$40.00

New Student/Orientation Fee (payable once by new first time, full-time registrants)

\$100.00

Application Fee

Undergraduate	\$40.00
Graduate	\$45.00

Acceptance Deposit*

\$250.00

Cooperative Education Program Fee

\$65.00

Credit by Examination Fee (undergraduate courses)

per credit \$70.00

Diploma Fee

\$50.00

Doctoral Dissertation

Microfilm Fee \$75.00

Laboratory/Seminar Fees

**

Late Registration Fee

\$75.00

Program Adjustment Fee

\$5.00

Transcript Fee

\$5.00

Validation Credit (graduate courses)

per unit \$70.00

Other fees include the Returned Check Fee, Late Payment Penalty Fee and, for transfer students, possible charges for supplies or kits, and details on these charges can be found in the Schedule of Classes.

All fees are non-refundable.

*to be applied toward first term's tuition

**Laboratory and course fees are charged for some classes, mostly labs. Lists of these charges by course are given in the Schedule of Classes.

HOUSING

Housing charges vary according to arrangements at Brooklyn and Farmingdale. For details, consult the Office of the Dean of Students.

PAYMENT OF TUITION AND FEES

Each semester, tuition and fee payments are due in full from all students at the time of registration.* Payment in full refers to various methods, used alone or in combination, including cash, check, money order or credit card (Visa and MasterCard only) financial aid, grants and loans, or tuition arrangements with outside independent agencies. Evidence of financial aid must be presented at registration.

The Office of the Bursar collects all payments, and checks should be made payable to "Polytechnic University."

*except for early registration when payment is due by the date specified in the Schedule of Classes, usually about one month prior to the start of classes.

PAYMENT

Consult the financial aid section of this catalog for more information on the following plans.

Tuition payment arrangements are available from several agencies that provide independent tuition deferment arrangements. Specific information on the plans offered by these agencies can be obtained at the Polytechnic Financial Aid Office.

Also, special education loan programs enable families, or students themselves, to repay over extended periods in monthly installments and are available at many banks for both graduate and undergraduate students.

Another financing option is that families may qualify for a New York State Higher Education Assistance Loan. Applications are available at local banks. These loans normally take from six to eight weeks to arrange and process.

Graduate students who submit written proof of their eligibility for tuition reimbursement from their employer are eligible for a special deferred payment plan. Under this plan full payment will be due approximately one month after the end of the term. Complete details are in the Schedule and available from the Bursar.

The Financial Aid office is available to assist students and their families in pursuing additional payment plan arrangements.

REFUND OF TUITION/REDUCTION OF LIABILITY

This section pertains to all students, regardless of the method of payment or the manner of covering tuition costs. Once registered, students must officially drop or withdraw from classes in order to be eligible for any applicable tuition refund or to avoid responsibility for payment of charges already assessed. This applies regardless of whether or not classes have been attended.

Refund Schedule

The refund schedule applies only during the first four weeks of the semester. 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.

Withdrawal forms are available in the Office of the Registrar.

Whenever a student drops or withdraws from a course or from all courses, tuition charges are adjusted according to the schedule outlined below, provided that:

- (1) the withdrawal notice is filed within the refund period,
- (2) it is submitted in writing to the Office of the Registrar, and
- (3) the withdrawal lowers the student's program to less than 12 credits

Withdrawal during	% Refund
Prior to first day of classes	100%
First Week* of semester	90%
Second Week of semester	75%
Third Week of semester	50%
Fourth Week of semester	25%
After the fourth week of semester	0%

*In this context, week refers to seven calendar days, excluding holidays. For example, if the term begins on a Thursday and there are no holidays, then the last day of that week would be the following Wednesday.

Students entitled to refunds from program adjustments or withdrawals will have their accounts credited. Students may request that the amount be refunded by check rather than credited to their accounts by writing to the Office of the Bursar. Refunds are not processed during registration. Normal turnaround time for a refund is two weeks.

Appeals for an exception to the refund schedule must be submitted in writing to the Registrar, along with all documentation which supports the request.

Awareness of University refund policy and withdrawal procedures is expected and lack of this knowledge, by itself, is not sufficient reason for making an appeal.

Impact of Refund on Financial Aid

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

R = Amount to be returned to Title IV programs

I = Institutional Refund

T = Title IV aid for the payment period (minus work-study earnings)

A = Total aid for payment period (minus work-study earnings)

$$R = I \cdot (T/A)$$

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

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

REGISTRATION

Registration is the process of obtaining academic advisement and approval of courses from a faculty advisor, recording courses with the Registrar, and paying tuition and fees to the Bursar according to published deadlines. For complete details about registration dates and procedures, and course schedules, see the Schedule of Classes published prior to each registration period and available from the Registrar.

To receive academic credit, registration is required each semester for every course, including thesis, projects and guided studies, where applicable. Attendance in class without registration is not permitted.

ADVISEMENT FOR REGISTRATION

Polytechnic University endorses close faculty-student relationships. The faculty advising system is the basis for selection of courses and registration. Each academic department identifies faculty who will serve as student advisors. Before registration, students must meet with their advisor and receive written approval for their anticipated program of study. A list of advisors and their office number may be obtained from each respective departmental office (or the Dean of Students) and is available from the Registrar prior to each registration.

Approval to register for a course does not necessarily constitute approval to use that course as a substitution for another course in order to satisfy a specific degree requirement. If the course is not usually used for that purpose, such approval should be explicitly requested from the advisor and must be formally granted on the form used for this purpose, the Request for Adjustment of Degree Requirements, and filed with the Office of the Registrar. For example, approval to register for a guided readings course is not necessarily approval to substitute that course for another, similar course prescribed in the curriculum.

REGISTERING FOR CLASSES

Polytechnic offers three registration periods for each semester and two for the Summer and mini-session terms. In addition, new freshmen entering the Fall semester are offered a special advance registration during the Summer preceding their admission.

Early registration: All continuing degree-seeking students (graduate and undergraduate) have the opportunity to early register for the next semester during the latter part of each ongoing semester. Graduate students, particularly those who work, are encouraged to take advantage of early registration by mail. Payment of tuition and fees, or arrangement for payment, is due to the Bursar no later than the deadline date announced in the Schedule of Classes.

Regular Registration: This usually takes place during the week preceding the start of classes. Information and a registration appointment is mailed to each continuing student who did not early register prior to the regular registration periods for Fall and Spring. New students and special students receive information from the Admissions Office. Payment of tuition and fees is due on the day of registration.

Late Registration: Students are expected and encouraged to complete registration by the end of the fifth class day of each semester as indicated in the academic calendar. The late period, during the first few days of classes, provides a last opportunity to register for the semester. Students who do not complete registration by the end of the late registration period will not be registered for that semester, except by special permission of the Registrar and the course instructor(s). Although permitted, late registration is not desirable as classes may be filled and early meetings of classes missed. A late fee is assessed all continuing and readmitted students. Payment of tuition and fees is due on the day of late registration.

PROGRAM ADJUSTMENTS (ADD/DROP)

Additions or deletions to a student program or course schedule may be made during the first five class days of the Fall and Spring semesters or summer sessions. Written approval from the faculty advisor, on the Program Adjustment form, is required for each course added or dropped.

Nominal fees are charged for adding or dropping courses or changing sections, except where the change is necessitated by course cancellation, section adjustments, or other administrative changes made for University convenience.

Students may not add or change courses within the freshmen mathematics or physics programs without the permission of the respective directors of these programs. Authorized changes within these two programs will be allowed through the fourth week of the semester.

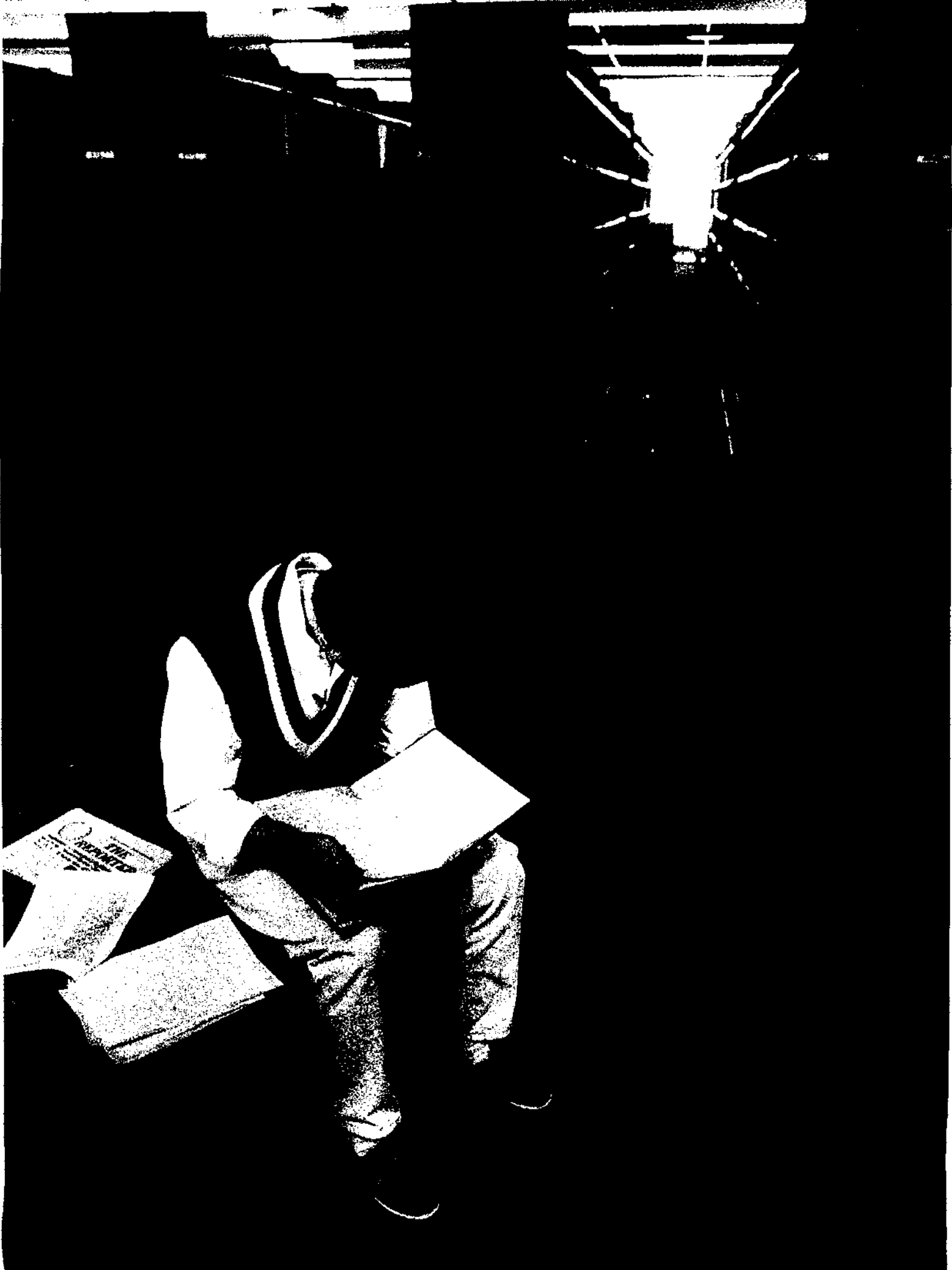
STUDENT IDENTIFICATION

All students are required to carry and maintain at all times photo-identification cards issued by the Office of the Registrar. The photo-ID's must be presented at each registration for validation by the Bursar. ID's must be presented and/or surrendered to any official of the University upon request.

A student ID number is used by the University to identify a student's records (grades, accounts, etc.) from the time of admission through the completion of his/her degree. Student numbers are usually social security numbers, but not always. Students who do not have a U.S. Social Security number at the time of application to the University, as in the case of international students, are assigned a number by the Admissions Office. Assigned numbers may be replaced when a Social Security number is obtained by bringing the original Social Security card to the Office of the Registrar, at which time this number will then become the student's ID number.

REFUNDS

See the section Tuition and Fees for information on refund policies.



POLYTECHNIC UNIVERSITY

PROFILE

Polytechnic is a coeducational, independent private university accredited by the Middle States Association. Undergraduate programs in aerospace, civil, computer, chemical, electrical, industrial, mechanical, and metallurgical engineering are accredited by the Accreditation Board for Engineering and Technology (ABET). The undergraduate program in computer science is accredited by the Computer Science Accreditation Board (CSAB), and the undergraduate chemistry program is approved by the American Chemical Society.

The student body includes over 1600 undergraduates and 2000 graduate students. The graduate enrollment in engineering is among the largest in the nation. In 1990, Polytechnic ranked fifth in the nation in the number of graduate engineering degrees awarded. The majority of its students live in the New York metropolitan area, but many students come from throughout the country and the world to study at Polytechnic as well. About 13% of the student population are women, about 11% are Black and Hispanic, and about 30% are Asian. Polytechnic is among the leading private universities in the nation in awarding engineering degrees to women and under-represented minorities.

Undergraduate programs at Polytechnic prepare students in Engineering and Science equally for immediate entry into the professional practice of their specialties or for continued graduate study at Polytechnic or other leading graduate institutions. Polytechnic ranks eighth in the nation in the percentage of its graduates who go on to receive a Ph.D. in engineering or empirical science, and has an excellent placement record for those students entering the job market.

Beginning in their first semester, Polytechnic students are taught by a world-class faculty. Polytechnic believes that the primary mission of its faculty is undergraduate and graduate education. Even its most prestigious researchers teach regularly, exposing students to leading professionals who are engaged in advancing the state-of-the-art in their specialties.

Polytechnic graduates enjoy an outstanding reputation with both public and private employers, and many have achieved remarkable success. Approximately 1 of every 30 Polytechnic graduates is a company president or high executive. About 100 CEO's on Long Island alone are Polytechnic graduates. Four Polytechnic alumni are currently the Presidents of prestigious universities in the U.S. and abroad. There are more than 165 Polytechnic alumni who have been named fellows of the Institute of Electrical and Electronics Engineers, and numerous others who are fellows of other professional organizations.

HISTORY

Polytechnic is the second oldest private institution of science and engineering in the U.S. It was founded in 1854 as the Brooklyn Collegiate and Polytechnic Institute. 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 conferred in 1871. In 1889, the institution adopted the name "Polytechnic Institute of Brooklyn" and in 1901 offered its first Master of Science degree. An evening graduate program was instituted in 1920, and Polytechnic's first Ph.D. was granted in 1935.

In 1961, Polytechnic opened its Long Island Center at Farmingdale as a graduate and research center. In 1974, it began offering undergraduate programs at Farmingdale. In 1975, the Westchester Graduate Center at White Plains was

opened, and in 1987 moved to its current location in Hawthorne.

In 1973, the New York University School of Engineering and Science merged into the Polytechnic Institute of Brooklyn to form the Polytechnic Institute of New York. The merged institution was granted university status by the NYS Board of Regents and was officially renamed Polytechnic University in 1985. To this day, the University is often referred to by its historic acronym, "Brooklyn Poly."

ACADEMIC PROGRAMS

Polytechnic offers Bachelor of Science degrees in 17 disciplines covering engineering, the physical sciences, mathematics, information management, and the liberal arts. Master of Science degrees are offered in 35 disciplinary specialties. The Engineer degree is offered in 10 specialties, and the Ph.D. is offered in 20 disciplines.

Bachelor of Science programs prepare students for entry level employment in the various professional disciplines, as well as for study at an advanced level. Master of Science programs are oriented towards professional development in the subject area, and can be arranged to provide the core coursework for Ph.D. study. The Engineer degree is intended to be a terminal program for practicing professionals. It is available only in engineering disciplines, and requires the completion of a design project. The Ph.D. is the terminal research degree for those seeking careers in industrial or academic research. It requires an independent research dissertation which advances the state-of-the-art in the discipline of study. Details of academic degree requirements and detailed program descriptions are given in other sections of this catalog.

ACADEMIC DEPARTMENTS

This catalog is arranged by academic program area. All programs are administered by academic departments as indicated in the program descriptions. A listing of academic departments at Polytechnic is shown below.

- Aerospace Engineering
- Chemistry
- Chemical Engineering
- Civil and Environmental Engineering
- Computer Science
- Electrical Engineering
- Humanities and Communications
- Management
- Mathematics
- Mechanical and Industrial Engineering
- Metallurgy and Materials Science
- Physics
- Social Sciences

School of Electrical Engineering and Computer Science

The School of Electrical Engineering and Computer Science was formed in 1990 to house the university's two largest academic departments, and to provide greater visibility and administrative support to these activities.

RESEARCH PROGRAMS AND CENTERS

Polytechnic University maintains major programs in experimental and theoretical research, making significant contributions to the advancement of the state-of-the-art in many areas of technology. Polytechnic faculty have been and continue to be among the world's leaders in such diverse areas as electromagnetics and wave propagation, telecommunications, polymer chemistry and engineering, condensed matter and plasma physics, chemical and electronic imaging, materials science and engineering, transportation and traffic engineering,

geotechnical engineering, software engineering, and others.

In 1990, Polytechnic University conducted over \$12 million of sponsored research under contracts and grants, of which 75% were funded by the federal and state governments and 25% by private industry. Over 90 faculty members were involved in these efforts, which also provided support for over 90 research fellows.

Research at Polytechnic is conducted either through academic department structures, or through one of six major interdisciplinary research centers, each of which is briefly described below:

CENTER FOR ADVANCED TECHNOLOGY IN TELECOMMUNICATIONS (CATT)

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

Technology innovation is the sustaining force behind the development of new industries, new jobs, and productivity improvements. To encourage the growth of technology based industries, New York State is implementing a comprehensive strategy which relies on an active partnership among business, labor, government, and educational institutions. A key component of this strategy is a closer collaboration between the State's industrial community and its major universities to promote technology transfer.

A number of research areas are actively pursued within the Center, including:

- Dynamic Routing
- High-Speed Networks
- Image Communications
- Local Area Networks
- Massive Distributive Databases
- Network Management and Control
- Optical Communications
- Optical Information Systems Materials
- Opto-Electronic Device Structures
- Routing Algorithms
- Superconducting Thin Films
- Superconductor Devices

- UHF Radio Propagation
- Wireless Information Systems

Polytechnic's role as a leader in telecommunications research and education is enhanced by the multi-million dollar high-technology center called Metrotech. CATT is an integral component of this complex which will facilitate industry-academic cooperation in research and development. Organizations such as the Securities Industry Automation Corporation (SIAC), the Chase Manhattan Bank, and Brooklyn Union Gas have established operations at Metrotech, and have established strong working relationships with CATT.

The Center also develops innovative educational programs to help users and providers of telecommunications services to manage and innovate technological change and regulatory upheavals. To this end, the Center has developed curricula combining special courses in telecommunications practice with electrical engineering, computer science, and management offerings. Details of graduate programs in Telecommunications and Computing Management, and in Information Systems Engineering, appear in the program descriptions of this catalog.

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

CENTER FOR APPLIED LARGE-SCALE COMPUTING (CALC)

The Center for Applied Large-Scale Computing engages in research and development involving applications of large-scale computer systems. In particular, the Center focuses on research concerned with very large, heterogeneous, distributed data base systems. This research includes: efficient methods for data storage, data transformation, data compression, information retrieval technologies, user interfaces, computationally intensive applications, protocols for high-speeds networks (with at least gigabit per second capabilities), the design of high-speed networks, image compression and transmission, and related areas. The telecommunications aspects of these investigations are carried out in cooperation with Polytechnic's

Center for Advanced Technology in Telecommunications.

A secondary mission of the Center is to offer courses and participate in degree programs related to its primary mission. Thus, the Center will coordinate with the academic departments in offering special seminars related to large-scale computer applications.

INSTITUTE OF IMAGING SCIENCES (IIS)

The Institute of Imaging Sciences was founded in 1981 on the initiative of Dr. Gregory Halpern. It brings together the basic sciences involved in various aspects of visual information by conducting research on a wide variety of imaging subjects.

Twelve members of the faculty from the departments of Electrical Engineering, Computer Science, Physics, and Chemistry are currently involved in the activities of the Institute. They sponsor doctoral candidates in image processing, image compression and reconstruction, machine vision and pattern recognition, acoustic-electron- and electron-tunneling microscopes, photo-polymers, and microlithography. Imaging research at the Institute is being sponsored by various government agencies and increasingly by industrial firms. The Institute is supported in this by Agfa-Gevaert, Ciba-Geigy, DuPont, Eastman Kodak, the 3M Company, Mitsubishi Kasei, Northrup, Olin Hunt, IBM, Polychrome, Siemens, and Xerox.

The Institute functions furthermore as a nucleus for the emerging imaging community of New York. It organizes short courses and is holding regular Imaging Colloquia which have become an established feature of Polytechnic, and draw a lively audience from the whole tri-state area. The present director of the Institute is Dr. Arnost Reiser, formerly head of the Photochemistry laboratory of Kodak in England.

POLYMER RESEARCH INSTITUTE (PRI)

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

Graduate students studying polymer science and engineering can presently complete M.S. and Ph.D. programs in Chemistry, Chemical Engineering, or Polymer Science and Engineering, a joint departmental program.

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

The multidisciplinary program includes about 25 faculty members from several academic departments, and the Herman F. Mark Professor of Polymer Science, Dr. Otto Vogl. In addition, some research faculty formerly in industry directly participate in the Institute. Research is done on both synthetic and biologically related polymers. Funding has come from varied agencies such as the National Science Foundation, the Department of Energy, the National Institutes of Health, and other government agencies. A significant component of the research program is funded by U.S. and international industrial companies. The research covers virtually all aspects of polymers, including functionalization, blends, optical activity, conductive systems, photoreactive systems, membranes, rheological properties, composites, flammability, and processes.

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

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

WEBER RESEARCH INSTITUTE (WRI)

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

director and later served as President of the University.

In the early days of MRI, the research programs consisted primarily of projects involving electromagnetics and microwave engineering. Over time the breadth of research programs has grown to cover a range of areas including: electromagnetic propagation and material interaction, antennas, pulse power, power conditioning, acoustics, gaseous electronics, plasma physics, solid state materials, quantum electronics, electric power engineering.

WRI is a University-wide research institute with faculty, students and research staff from many departments including Electrical Engineering, Chemistry, Physics, Aerospace Engineering and Mechanical Engineering. The research activities of the Institute have fostered specialized M.S. and Ph.D. degree programs in Electrophysics and provide support for students in many other graduate programs.

The Institute has state-of-the-art experimental facilities and has just recently established a major laser facility for experimental studies of materials, chemical processes, and short pulse electromagnetic phenomena in the pico-second and femto-second ranges. The experimental facilities of WRI are complemented by the latest work stations and access to supercomputers for computational work in support of its research programs.

Regular seminars on current research topics are presented by faculty, visitors and guests of the Institute. These are open to students and interested individuals from other universities, research establishments and companies. WRI also organizes and hosts international symposia/conferences.

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

TRANSPORTATION TRAINING AND RESEARCH CENTER (TTRC)

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

Acting through TTRC, the Polytechnic is a participating member of the Regional Transportation Consortium, which consists of 12 universities in Federal Region II having a special interest and desire for mutual interaction in transportation research, training, and technology transfer. Agencies may contract with Polytechnic directly, or through the Consortium. Polytechnic is also a member of the Council of University Transportation Centers (CUTC).

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

Current and recent projects within the Center include research on the operation and level of service on freeway ramps (National Cooperative Highway Research Program), tools to alleviate urban congestion (Port Authority of New York and New Jersey, through RTC), development of revised models for permitted left turns at signalized intersections (Federal Highway Administration), and ice-pavement bonding (Strategic Highway Research Program). Other projects have included development of a NETSIM training program for the Federal Highway Administration and joint development of the HCM/Cinema computer package with KLD Associates.

Additional TTRC research projects have been the development of text for the 1985 edition of the *Highway Capacity Manual*, and the related personal computer software development; development of freeway capacity analysis

procedures for the 1985 HCM; planning and design guidelines for high-speed ferry systems; trip generation estimation; and policy studies on van-pooling, express buses, and local bus routing. Training efforts have included highway capacity, transit management, and micro-computer applications.

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

In addition to these interdisciplinary research centers, individual academic departments housing significant research programs include the Department of Metallurgy and Materials Science, the Department of Chemical Engineering, the Department of Chemistry, the Department of Civil and Environmental Engineering, and the Department of Physics.

FACULTY

The heart of the Polytechnic is its distinguished teaching and research faculty. Numbering some 170, the Polytechnic faculty is committed to providing the best possible educational environment in the classroom, in the laboratory, through individual guided studies and projects, through advising, and through the strong one-on-one relationship most faculty members develop with their students.

The faculty originates, organizes, and approves all curricula taught at the University, and also establishes the academic standards for student performance. Polytechnic undergraduates interact with faculty from their first day of classes. Class sizes are relatively small, and all faculty maintain regular office hours for consultation with individual students. As many of the faculty are actively involved in on-campus research, they are easily accessible outside of the classroom. All formal academic advising after the first semester is done by the faculty.

The Polytechnic faculty is one of the most distinguished in the world. Polytechnic faculty were among the founders of the National Academy of Engineering,

the Institute for Electrical and Electronics Engineers, the American Institute of Chemical Engineers, and the American Society of Engineering Education. The faculty includes four current members of the National Academy of Engineering, and numerous fellows of the various professional disciplinary organizations. Polytechnic faculty have authored numerous undergraduate and graduate textbooks used throughout the U.S. and abroad, and edit leading professional journals. Faculty are frequently honored with prestigious awards, including the following recent achievements:

- **Ernst Weber**, *President Emeritus*, National Medal of Science, National Academy of Engineering.
- **Athanasios Papoulis**, *University Professor*, Humbolt Award, IEEE Education Medal.
- **Nathan Marcuvitz**, *Professor Emeritus of Electrical Engineering*, IEEE Microwave Career Award, IEEE Herz Medal.
- **Erich Kunhardt**, *Professor of Electrical Engineering and Physics*, Halliburton Excellence in Research Award.
- **Herbert Morawetz**, *Professor Emeritus of Chemistry*, American Chemical Society Award in Polymer Chemistry.
- **Leopold Felsen**, *University Professor*, Herz Medal of IEEE, Humbolt Award, National Academy of Engineering.
- **Dante Youla**, *University Professor*, IEEE Field Award in System Science and Engineering, National Academy of Engineering.
- **Eli Pearce**, *University Professor*, Society of Plastics Engineers International Award in Education, Paul J. Flory Award in Polymer Education.
- **Otto Vogl**, *Herman Mark Professor of Polymer Science*, American Institute of Chemists Pioneer Award, Japan Prize in Polymer Chemistry.
- **Herman Mark**, *Professor Emeritus of Chemistry*, National Medal of Science.
- **Donald Othmer**, *Professor Emeritus of Chemistry*, Perkin Medal in Applied Chemistry.

ALUMNI

The Polytechnic Alumni Association is dedicated to the advancement of the University. It fosters fellowship and sponsors activities for the alumni and students, including continuing education programs, professional career placement, and new student recruiting. For students, the Association helps sponsor the annual Freshman Orientation and presents career symposia featuring prominent alumni speakers.

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

The Alumni Association has established a student committee to work closely with the Association's Board of Directors to promote collaboration between alumni and current students, to develop programs whereby student alumni mutual interests can be more fully realized, and to acquaint students with the benefits to be derived by becoming active alumni after their graduation.

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

Alumni residing outside the New York City region have formed various Poly Groups, providing opportunities for formal and informal alumni gatherings, and providing an opportunity to represent Polytechnic to the community. Large groups now exist in several areas of the nation, and in several foreign countries.

CAMPUS CENTERS

The campus centers and accompanying facilities are described in greater detail in the sections which follow, along with the types of programs offered at each.

The Brooklyn Center at Metrotech Six Metrotech Center Brooklyn, New York 11201 (718) 260-3600

The Brooklyn Center is the focus of an exciting new environment with the arrival of Metrotech, a joint University-industry development now nearing completion. After over 12 years of planning, Metrotech is now a reality. Four major industrial companies share a common campus with Polytechnic University, with the University as its core. This new urban campus is surrounded by five new corporate and university buildings:

- **Dibner Library/Center for Advanced Technology in Telecommunications** Polytechnic's new academic building houses a new state-of-the-art library, two of its prestigious research centers (CATT and CALC), and the Departments of Electrical Engineering and Computer Science. The new building, which opened in January of 1992, provides 128,000 square feet of new academic space, and anchors the north end of the new campus.
- **Securities Industry Automation Corporation (SIAC)**, which operates the computer information networks of the New York and American Stock Exchanges and their transaction clearing operations, has moved its headquarters to Metrotech. The new 533,000 square-foot office and data processing complex opened in September of 1990, and anchors the south end of the new campus.
- **Brooklyn Union Gas Company** has also moved its headquarters to Metrotech. The new 845,000 square-foot office facility is now complete and occupied. *Bear Stearns*, a major brokerage house, became a major co-tenant of this building in June, 1992.
- **Chase Manhattan Bank** is building two major office facilities totalling approximately 1.5 million square feet of office/data processing space. Occupancy of these buildings began in the Spring of 1992.

These new buildings, as well as Polytechnic's existing academic build-

ings, surround a three acre joint campus area. A closed pedestrian environment was created on the campus by closing all streets formerly running through the Metrotech area. As of spring 1992, all of the buildings noted above and the joint campus area were completed, bringing to fruition a dramatic concept in university-industry cooperation introduced by Polytechnic University over a decade ago.

In addition to a radically new environment and a new building, Polytechnic has already begun to develop interactions with its Metrotech neighbors. These corporations, all major employers, are heavily involved in communications technology, and Polytechnic is already working on joint research and educational programs in this critical area.

The Brooklyn Center at Metrotech is located at a major junction of public transportation routes, and is easily accessible by auto from the Brooklyn or Manhattan Bridges or the Brooklyn-Queens Expressway. All of the new commercial buildings of Metrotech have parking facilities, and Polytechnic continues to maintain a small parking facility of its own. The Brooklyn Center is easily accessible from all parts of New York City, Long Island, New Jersey, and Connecticut.

The Brooklyn Center consists of five significant buildings:

- **Rogers Hall**, named after Dr. Harry Stanley Rogers, Polytechnic's fifth president, is the main academic building. It houses faculty and administrative offices, classrooms, research and teaching laboratories and student areas. The Office of the Associate Provost for Academic Affairs and Dean of Engineering is located in Rogers Hall.
- **The Jacobs Building** is named after Dr. Joseph Jacobs, the former and current Chairman of the Polytechnic Board of Trustees, and a major benefactor to the University. It houses primarily administrative and faculty offices. Offices of the President and all Senior Vice Presidents (Academic Affairs, Academic Operations, Finance and Administration, and Development) are located in the Jacobs Building. Most student service offices are also located here, including the Office of Admissions, Registrar, Bursar, Financial Aid,

and Research and Graduate Studies. Business-related functions of the Polytechnic are also housed in Jacobs.

- **The Dibner Library/Center for Advanced Technology in Telecommunications** is Polytechnic's first new academic building in Brooklyn, and has been described previously.
- **William H. Nichols Hall**, located just opposite the Dibner Library/CATT Building, houses faculty offices, laboratories, and classrooms. The Department of Physics, ROTC, and the Office of Career Services are located in Nichols Hall. Over the next five years, it is expected that Polytechnic will vacate this building, gradually moving these functions into vacated areas of Rogers Hall, or into another facility.
- **The Student Center** is directly across the campus from Rogers Hall, and houses student-related functions. It has student lounges, student organization offices, a game room, and is the focal point for student co-curricular activities. The building has been designated a historic landmark, and is currently undergoing extensive renovation. During the renovation period, many functions have been temporarily relocated into Rogers Hall.

The Brooklyn Center represents a major renaissance in which Polytechnic is the center of one of the most unusual and successful joint university-industry-public ventures in the nation. For Polytechnic students, it means a new urban campus, markedly improved surroundings, a dramatic new library, new homes for Electrical Engineering, Computer Engineering, and Computer Science programs, and the opportunity to interact with major information industries.

**The Long Island Center
at Farmingdale, Route 110
Farmingdale, New York 11735
(516) 755-4300**

The Long Island Center is located on Route 110, one mile east of the Nassau - Suffolk county border. It is next door to Republic Airport and is located in a rapidly growing corridor of industrial

and business activity which stretches both north and south along Route 110. It is located on 25 acres of land near scores of Long Island high-technology industries.

Most engineering undergraduate programs and many graduate engineering and management programs are available at the Long Island Center, which currently serves approximately 575 undergraduates and 550 graduate students. The world renowned Weber Research Institute for electrophysics research is located at the Long Island Center, as are the University's unique aerospace laboratories.

- **The Main Administration Building** houses administrative and faculty offices, classrooms, a cafeteria, the Long Island Center Library, a student lounge, conference and meeting rooms, and research and teaching laboratories.
- **The Preston R. Bassett Building** houses the Weber Research Center, its offices and laboratories, faculty offices, and teaching and research laboratories.
- **Grumman Hall**, the student center, houses a lounge, game room, bookstore, student organization offices, the Career Services Office, and the Student Life office.
- **East Residence Hall** consists of apartment-style suites, each containing four single bedrooms and a common room with cooking facilities. The facility accommodates 50 students.
- **West Residence Hall** was opened in January 1991, and contains double-occupancy rooms and a large lounge. No cooking facilities are available in West Hall, and all students residing here are required to be on a meal plan. The facility accommodates 40 students.
- **The Gymnasium** is utilized for intercollegiate, intramural, and recreational sports. It consists of a multipurpose gym floor, a weight room, and a wrestling room. The Gymnasium is also the site for special student and outside activities.

**The Westchester Center at Hawthorne
36 Saw Mill River Rd.
Hawthorne, New York 10532
(914) 347-6940**

The Westchester Center offers only graduate programs, serving scientists, engineers, and managers employed in the high-technology companies of the Lower Hudson Valley, as well as southern Connecticut and northern New Jersey. The Center fulfills their educational needs through provision of part-time graduate degree programs and specialized continuing education programs.

To serve this unique population, most classes at the Westchester Center are held in the late afternoon, evenings, and/or on Saturdays. Programs are offered in Electrical Engineering, Computer Science, Metallurgy and Materials Science, Chemistry, Management, Manufacturing Engineering, Telecommunications and Computing Management, and Information Systems Engineering, the latter two in executive format, meeting on alternate Fridays and Saturdays throughout the semester.

This modern facility contains classrooms, administrative offices, the Richard Laser Library, a computer terminal laboratory, and a microcomputer laboratory.

POLYTECHNIC LIBRARIES

The goal of Polytechnic Libraries is to satisfy the recorded information and document needs of the students, faculty, and administration supporting the undergraduate, graduate, and research programs. Highly skilled librarians and information specialists offer the following services:

- Circulation of a book collection of over 100,000 volumes and a large course reserve collection.
- Reference assistance to locate the book, article, or information at Polytechnic or other locations which meets users' needs.
- An active interlibrary loan program capable of locating and retrieving books through a powerful international computer system (OCLC, with about 3,000 libraries). Mem-

bership in cooperatives such as the Academic Libraries of Brooklyn, the New York Metropolitan Reference and Research Library Agency, and the Long Island Library Resources Council provides additional interlibrary loan access, and on-site access and circulation privileges at many area libraries.

- Database searching capability, available at cost, to do detailed author, title, or subject searches in virtually any area of interest from over 250 computerized databases, some of which provide full abstracts of relevant papers and articles.
- CD-ROM search capability in five categories of databases: journal citations, free text, full text image, monograph citations/abstracts, and reference works. This system is being constantly expanded, and will be a major component of the new Dibner Library, described in a subsequent section.
- InfoDash, a service which retrieves journal articles from the Polytechnic Libraries or any of the major New York metropolitan area libraries.
- Other services include library orientations for all students, requested classroom instruction on specific aspects of library use, maintenance of over 1200 journals, an excellent collection of encyclopedias, almanacs, indices and abstracts, biographical dictionaries, and other reference material.

The Bern Dibner Library opened in January of 1992. It replaced the Spicer Library as the Brooklyn Center Library, and is the center of state-of-the-art electronic search and retrieval facilities serving all three Polytechnic campus centers.

The new library occupies two floors of Polytechnic's new building at Metro-tech, and doubles the amount of space available for book and journal collections, and greatly expands the amount of study and reading space available for students, faculty, and staff. Expanded facilities for reading microfiche and microfilm, as well as video facilities are provided. Individual study carrels provide study space for individuals, while a set of study rooms can be reserved for group study.

This new \$15,000,000 library and information center accesses information

electronically from resources throughout the nation and the world. It is a prototype for advanced electronic information centers to follow, and enables users in homes, offices, classrooms, and laboratories as well as libraries to locate and retrieve information, books, journal articles, or other documents.

The Long Island Center Library is electronically connected to the Brooklyn Center, and offers the same services as provided in Brooklyn. The on-site collection is smaller, but all books and journals at any Polytechnic location can generally be acquired within 24 hours.

The Richard Laster Library serves the Westchester Center, and is available during the normal operating hours of the Center. It is also electronically connected to the Brooklyn Center, and all services are available. The library maintains a small on-site collection serving those graduate programs given at the Westchester Center.

POLYTECHNIC COMPUTING FACILITIES

Computing facilities at Polytechnic are continually undergoing expansion in terms of the number and power of computers, and the range of software services provided. Polytechnic's student-to-device ratio now stands at 8:1, and is continually declining. All three campuses are electronically linked, and all mainframe facilities can be accessed from any Polytechnic campus center, as well as by dial-up from an external location.

The Polytechnic Data Processing Department provides a wide range of equipment and services which are available to the entire University community: students, faculty, researchers, and administrative personnel.

Available equipment includes:

- Supercomputer (Convex C120)
- Mainframes (IBM 4348-R14, IBM 4341-P12)
- Minicomputers (AT&T 3B2/1000, 3B2/500, 3B2/400, IBM AS/400 B30, IBM 9370 Model 60, Tandem EXT25)

- Personal computers (IBM PS/2 Models 80, 70, 55-SX, 30-286, AT&T 6386)
- Workstations (SUN SPACstation, SUN-3, SUN-4, HP/Apollo, IBM RS/6000, IBM RT/PC)
- Graphic terminals (AT&T 630, AT&T 730X, IBM 5080, IBM 3279)
- Printers and plotters (HP LaserJet III, LaserJet 2000, IBM 3287, IBM 6186)
- Networking:
 - Ethernet (TCP/IP network linking computers at all three campuses)
 - Access to global networks (Internet, NYSENet, BITNET, Usenet)
 - State-of-the-art digital telephone switch (with high-speed data transmission)
 - High speed modems for dial-up access to computers and networks
 - Laboratories (terminals to access mainframes and minicomputers; personal computer labs)

Available services include:

- User Services Department to provide assistance and guidance in the use of computing facilities.
- Seminars, classes, and publications to familiarize users with available resources and allow new users to become computer proficient.
- Discounts on purchases of IBM PS/2 and Apple Macintosh computers.

Available software includes:

- Mainframe, Minicomputers, and Workstations:
 - Languages (C, FORTRAN, Pascal, C++, PL/1, LISP, Prolog, APL, plus mathematical and scientific libraries)
 - Graphics and special purpose (CATIA, CADAM, CAEDS, CBDS, ACSL, GDDM, MAPICS, RPMIS, X - Windows)
 - Document processing (TeX, LaTeX, troff)
 - Database (SQL/DS, Ingres CS)
 - Operating systems (UNIX, VM/CMS, MVS, Guardian)
 - Statistical Packages (SPSSX)

• Personal Computers:

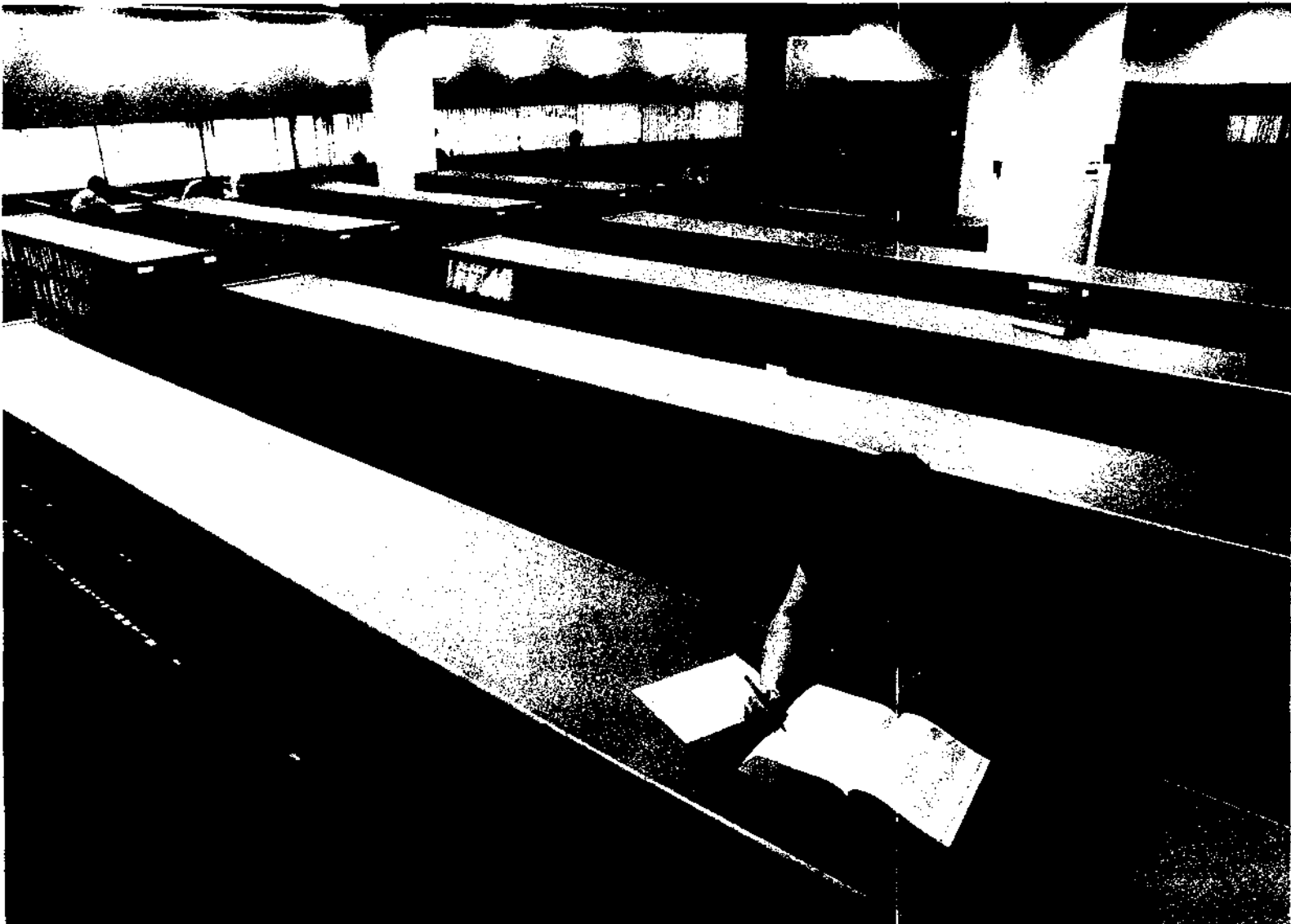
- Languages (Turbo Pascal, Turbo C, PC Scheme)
- Spreadsheets (Lotus 1-2-3, Excel, Quattro)
- Word processing (WordPerfect 5.1)
- Desktop publishing (PageMaker)
- Graphics and special purpose (IBM CAD, MATLAB)
- Operating systems (DOS, Windows, IBM AIX)

Each Polytechnic campus center has general-use terminal and microcomputer laboratories available. In addition, many departments including computer science, electrical engineering, civil engineering, mechanical and industrial engineering, chemical engineering, physics, and others maintain dedicated special-use computer facilities for their students and faculty. Several of Polytechnic's research centers including CATT and WRI also maintain dedicated computer facilities for research purposes.

All Polytechnic computer facilities are managed and supported by the Data Processing Center and its staff. The Center supports a wide range of languages and operating systems, word

processing and spreadsheet systems, and specialized software for graphics and other purposes, as noted above. The Center provides a full-time systems programming staff which is available to assist students and faculty, and staffs University computing laboratories with full-time and part-time consultants. The Association for Computing Machinery (ACM) is a student organization which provides extensive user support services, including debugging assistance, distribution of software documentation, and seminars on facility use.

Dial-up lines are available to students, faculty, and staff at all times, 24 hours per day, 7 days per week.



ACADEMIC PROGRAMS, POLICIES AND DEGREE REQUIREMENTS

PROGRAM AREAS

Polytechnic is a university uniquely focused on the world of technology and its interactions with society. To fulfill this mission, Polytechnic offers degree programs in four general academic areas:

- Engineering
- The Sciences and Mathematics
- Management
- Liberal Arts

ENGINEERING

Engineering is perhaps best described as the creation of devices and implements which can control or manipulate nature to produce a desired effect. It is the application of science to the building of the infrastructure, devices, tools, and other implements of society in a way which should improve the quality of life and environment for all.

The modern engineer must have a firm background in the sciences which he or she will apply, as well as in mathematics, the language with which scientists describe nature and through which engineers manipulate it. The engineer must also have a background in the liberal arts, as no one can hope to improve society without understanding its character, needs, and desires. The modern engineer must also develop excellent communications skills, both to deal with fellow professionals as well as with decision-makers and the public.

Engineering programs at the Polytechnic build on a firm foundation of mathematics and science to develop the engineering analysis and design skills required of a practicing professional. Undergraduate programs prepare students equally for entry into the profession and for continued education at the graduate level.

Above all, an engineering education from Polytechnic prepares the graduate for a lifetime of education and growing

knowledge. The ability to continue learning is perhaps the most lasting gift of education, particularly in the rapidly-developing field of technology. By giving its students a comprehensive education in the principles of science and engineering, and by developing the creative skills required for engineering design and analysis, Polytechnic provides its graduates with the ability to continue to learn and grow as their careers progress.

Just as current Polytechnic faculty and alumni are advancing the state-of-the-art in such varied fields as telecommunications, microwaves, space electronics, imaging sciences, quantum electronics, pulse power, materials, aerospace, geotechnology, software engineering, earthquake performance of structures and numerous others, the Polytechnic engineer is equipped to carry this tradition forward to the next generation of technological breakthroughs.

THE SCIENCES AND MATHEMATICS

Science and mathematics are the underpinnings of modern technology. As scientists and mathematicians discover and describe new secrets of the natural world around us, engineers look to apply them to the development of technology. Without the physical sciences and mathematics, engineers would have no tools to invent the technology of tomorrow.

Undergraduate science and mathematics programs at Polytechnic give the student a unique opportunity to study basic theory, while at the same time interacting with design disciplines. The structure of undergraduate programs in these areas allows students to select concentrations of elective courses in technology areas, and students are encouraged to do so.

Students are exposed to modern laboratories, and interact with faculty who are world-class researchers. As many junior and senior classes are quite small, students in these areas get to

develop one-on-one relationships with faculty, and have the opportunity to work with them in their appropriate research areas.

The future of technology critically depends on our ability to develop a better and more accurate understanding of nature and its opportunities and constraints. For technology to advance, scientists must continue to unlock the secrets of the universe, and mathematicians must continue to develop the analytic and logical processes whereby we can extend and apply that which we discern. Polytechnic programs prepare scientists and mathematicians for this vital role, enabling them to lead us to a better future.

MANAGEMENT

Management programs at Polytechnic focus on the management of technology. The management of top-flight technology is no longer a luxury in today's fast-paced industrial environment. Management of technology requires unique skills, and a firm understanding of where technology is going, and, just as importantly, how it is developed and supported.

Management of technology has two aspects. For the manager of a technology business or industry, the need to know how to support and nurture the development of a new technology or product is critical. Decision-making must recognize the need for research and product development and place this need into the traditional fiscal and operating requirements of an organization.

On another level, every commercial enterprise must now deal with complex technologies, including information systems, telecommunications, computers, automation, and the like. Managing these aspects of organizations also requires specialized skills and knowledge.

Management programs at Polytechnic combine the traditional skills and knowledge in basic management sciences with the very special needs of both busi-

nesses involved in the development, production, and sales of technology and those critical technology components of every commercial and public enterprise.

LIBERAL ARTS

It is through the study of the liberal arts that we learn to understand human society, its development, its needs, its desires, and the means through which it makes these known. No one can adequately address technology, or its creation and development, without an adequate understanding of the human and societal needs which it seeks to serve. On the other hand, no humanist can adequately understand society and its development without a knowledge and understanding of how it interacts with and is affected by technology.

While studying traditional programs in social sciences and humanities, liberal arts majors at Polytechnic also take a curriculum specifically addressing the interactions between society and technology. At Polytechnic, there are unique curricula in history of science, technical journalism, and specialized journalism. In addition, Polytechnic offers courses on the philosophy of technology, and on such critical matters as professional and engineering ethics as they relate to technology and its societal impacts.

SELECTION OF A MAJOR (UNDERGRADUATE STUDENTS)

Undergraduate students admitted to Polytechnic are permitted to declare their major immediately, should they so desire. Incoming freshman, however, do not have to declare a major until the end of the first semester of study, and may initially enter as "undeclared" majors. For many freshman who wish to consider several program options, it is useful to delay the choice of a major.

Typical programs for first-semester freshmen are detailed in the programmatic sections of this catalog. For those students entering as "undeclared" majors, the following typical program is recommended:

		Credits
CS 200	Programming in PASCAL	3 ¹
MA 101	Calculus I	4 ²
CM 101	Gen. Chemistry I	2½
CM 111	Gen. Chemistry Lab I	½
HU 101	Writing and the Humanities I	3 ³
SS 104	Contemporary Themes in World History	3 ⁴
SL 101	Freshman Seminar	0
CP 101	Cooperative Education (optional)	1 ⁵
PE 10x	Physical Education (optional)	0

Notes: (1) All students take computer programming during their first year of studies. Depending upon the major discipline, either Fortran or Pascal is selected. Pascal is recommended for undesignated students, as Fortran is a less complex language which can be more easily learned through individual study. Polytechnic will offer between-semester mini-sessions for students who after taking Pascal enter a major featuring Fortran. (2) MA 100 may be substituted on the basis of placement examinations. (3) HU 103, HU 008, or HU 009 may be substituted on the basis of placement examinations. See "degree requirements for bachelor of science degrees" for details. (4) IS 141 may be selected by the student as an alternative. See general degree requirements for bachelor of science degrees for details. (5) Only taken by students interested in the cooperative education option, described elsewhere in this catalog.

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

The above typical program may be modified with the approval of an academic advisor. Modifications may be made to accommodate advanced standing or advanced placement credits, the results of Polytechnic's placement examinations, or the desire of students to lighten or accelerate their progress.

DEGREE REQUIREMENTS

REQUIREMENTS FOR THE BACHELOR OF SCIENCE DEGREE

Students may work towards the bachelor of science degree either in four years of full-time study or over a longer period of time. The program descriptions of this catalog outline typical four-year programs for students entering as freshman in September. For students entering in January, programs need to be worked out individually with a faculty advisor.

The bachelor of science degree requires completion of from 126 to 136 credits, as indicated in the program descriptions herein. Most courses are given during the day, and students may attend on a full-time or part-time basis. Some undergraduate course offerings are available in the evening, but it is not possible to complete a full bachelor's degree program by taking only evening courses.

To earn a Polytechnic undergraduate degree, students must take a minimum of 34 credits of approved upper-class subjects at the Polytechnic.

In all fields of study, this catalog prescribes a specific curriculum which the student must complete. To qualify for the degree, the student must complete the program as outlined in the respective program section of the catalog. The sections which follow specify minimum university-wide criteria which apply to all undergraduate degree programs as a minimum. More restrictive requirements may be imposed by individual departments, as detailed in the program sections of this catalog.

Grade-Point Average to Graduate

To receive a bachelor of science degree, the student must maintain a grade-point average of 2.0 in all courses taken at the Polytechnic. In some programs, additional criteria on grade-point average may be applied to specified courses or subsets of courses in accordance with the program requirements set forth in this catalog by the various departments.

Humanities and Communications

All students must complete courses HU 101 "Writing and the Humanities I," and HU 200 "Writing and the Humanities II." All entering students must take an English Composition Placement Test upon entering Polytechnic. On the basis of this test, students may be placed in HU 101, or a similar course, HU 103, which covers equivalent content for students whose home language is not English. If the test results indicate that remedial work is necessary, students may be placed in HU 008 (for students whose home language is not English) or HU 009 (for students whose home language is English), for which no credit is given. Upon completion of remedial courses, students are required to complete HU 101 or HU 103 and HU 200. IS 140 "Language and Communication," may be taken as an alternative to HU 200. If taken, it must be followed with IS 141 "The Self and Society."

Social Sciences

All students are required to complete SS 104, "Contemporary Themes in World History". Students who select IS 140 instead of HU 200 will take IS 141 instead of SS 104. In general, students assigned to either HU 008 or HU 009 must successfully complete that course before permission will be granted to register for SS 104.

Humanities and Social Science Requirements for Engineering and Computer Science Majors

All undergraduates enrolled in an engineering program or computer science must take a minimum of 24 credits in the humanities and social sciences. Students enrolled in the computer science program take 30 credits, and electrical engineering students take 28 credits. Of these, a minimum of one semester, or 16 credits, must be taken in accordance with the requirements of the Accreditation Board for Engineering and Technology (ABET). These credits MAY NOT include courses dedicated to developing communications skills, such as public speaking, technical writing, English as a second language, college composition, etc. The credits must be taken in content areas of the humanities and social sciences, such as foreign languages, literature, history, psychology, philosophy, anthropology, sociology, economics, music, and the fine arts. Further,

these content courses must reflect study at both an introductory and advanced level.

To accomplish this, the Polytechnic faculty has established the following specific criteria for humanities and social science credits taken by engineering and computer science students. Three (3) introductory content credits are provided by HU 101 and HU 200 (1.5 each) and three (3) by SS 104 (3 credits). All students in engineering disciplines and computer science will take a total of 18 credits of content courses, except for electrical engineering students, who will take 17 credits. The remaining credits (beyond the 6 provided in required courses) must be taken such that at least two courses are on an advanced level. This is accomplished by electing courses in sequence, taking either a three-course sequence with two courses at an advanced level, or by taking two-course sequences with one course of each at an advanced level. Any remaining humanities or social science credits may be freely selected. Current sequences available for selection in accordance with this criteria are listed in the *appendix* to this section of the catalog. Each semester, a listing of courses offered on each campus in each concentration is published to assist students and advisors in course selections.

Freshman Seminar (SL 101)

All incoming freshmen with fewer than 6 credits are required to take SL 101, "Freshman Seminar." This seminar includes weekly discussions and presentations on time management, study and test-taking skills, available support services at Polytechnic, and many other subjects of importance to beginning students. A short paper on the selection of a major is required of all students in this non-credit bearing course.

In the last week of this seminar, students will formally select or confirm their major area of study. Students who have already declared a major may confirm their selection or opt to change majors. Undeclared students will select their major at this time.

Other Requirements for the Bachelor of Science

All other requirements for Bachelor of Science degrees vary by program. Consult the appropriate program section of this catalog for further details.

Graduation Check List

Undergraduates who are nearing completion of their degrees receive a graduation check list which shows the completed courses and their assignment to required areas of study, and lists the courses which remain to be completed for the degree. After approval by the academic department, the graduation check lists are mailed to students by the Registrar, usually during the summer of the year preceding the prospective graduation. Full-time students receive their graduation check lists after completion of 85 credits, and part-time students after completion of 105 credits. A revised check list may be issued to any student not completing his or her degree within a reasonable period after receipt of the initial list.

Course Substitutions and Other Modifications to Curricula

Because of curriculum and course changes, it is occasionally necessary to substitute courses to meet degree requirements. Such substitutions must be documented on an "Adjustment of Degree Requirement" form -- also known as a "blue sheet." The form is available in the Registrar's Office. Each substitution must be documented on a form, and must be approved by the student's departmental faculty advisor and by the Associate Provost for Academic Affairs. If a graduation check list has already been issued, the change should also be formally entered on the check list and approved by the advisor and Associate Provost.

Senior Honor Students

Each spring, departments select students with high grade-point averages who will complete their B.S. requirements during the following year. Those students are listed as Honor Students in that year's commencement program and are given special permission to make substitutions in their selection of senior courses. Most often, this takes the form of substituting more advanced graduate courses in place of the usual requirements. To be eligible for this designation, transfer students must complete at least one-half of the credits needed to satisfy degree requirements at Polytechnic.

Degrees with Honors

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

Degree *cum laude* 3.40 - 3.59

Degree *magna cum laude* 3.60 - 3.69

Degree *summa cum laude* ≥ 3.70

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

Dual Majors

A student who meets the graduation requirements in two disciplines may receive a bachelor's degree indicative of that accomplishment, providing that the student:

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

Interested students should consult departmental advisors, as not all disciplines are available as dual majors.

Dual Undergraduate Degrees

A student may apply to receive two bachelor's degrees from Polytechnic, with a separate diploma awarded for each. Special requirements for each degree are determined by the senior undergraduate advisor or head for each department, in accordance with the following rules:

1. The set of courses includes all of the required courses for each degree; some elective credits for one curriculum may be fulfilled with required credits from the other, provided that sufficient senior/graduate-level electives are completed to provide depth in each discipline.
2. The total credit requirements must exceed those required by one of the

degrees by at least one full year of credit. Courses dealing with the same material, although possibly satisfying degree requirements of the two departments, can be counted for credit once only. (For example, if each curriculum has 136 credits, then the minimum for two degrees is $136 + 136/4 = 170$ credits. If one has 136 and the other 128, then the minimum is $136 + 128/4 = 168$ credits. If each has 128 credits, the minimum is $128 + 128/4 = 160$ credits.) If the majors are closely related (such as AE/ME, PH/EE, or CS/EE), approximately five years may suffice. If they are less closely related (such as SS/CM, HU/AE, ME/EE), additional time may be needed to satisfy the depth in discipline criteria.

3. Students working towards two degrees must:

- Register in a "home" department which will be responsible for the student's first degree, and notify that department of the intent to pursue a second degree;
- Apply for and receive admission to the second department in the same manner as a student wishing to change departments;
- Obtain approval from both of the senior undergraduate academic advisors when registering for, or withdrawing from, a course during the period from admission to the dual program and graduation from one of the programs;
- Maintain good academic standing in the University, and in each department; and
- Complete all courses specified in the Graduation Check List provided by each department, with satisfactory grades. One degree may be received simultaneously with or subsequent to the other degree. Graduation honors for each degree are separately determined.

To graduate in minimum time, students should choose their degree programs as early as possible. The courses of the two degree programs can then be interwoven to provide good educational sequences and to satisfy all prerequisites.

Please note that many students, rather than earn two undergraduate degrees, prefer to earn a single baccalaureate degree followed by a master's degree in another, but related, discipline.

Interested students should check with departmental advisors, as not all disciplines are available as dual degrees.

REQUIREMENTS FOR THE MASTER OF SCIENCE

Admission to Master of Science degree programs requires a bachelor's degree from an institution acceptable to the Polytechnic in an appropriate preparatory discipline. Candidates for Master of Science degrees must complete not less than 36 units of advanced study and/or research beyond the bachelor's degree in the program selected. Specific course requirements for each Master of Science program are detailed in the programmatic descriptions of this catalog.

Effective Fall 1983, to obtain *any* graduate degree or certificate, students must maintain 3.0 grade-point average or better in *all* graduate courses taken at the Polytechnic, including those not used to fulfill specific program requirements, and a B or better average in all guided studies efforts (including readings, project, thesis, and dissertation).

Students may offer no more than 12 units of project, special student units and/or thesis towards fulfillment of Master of Science degree requirements. Registration in project and/or thesis must be continuously maintained until the work is completed and a grade recorded.

A maximum of nine (9) units may be accepted as transfer and/or validation credits, the latter not to exceed six (6) units. All requirements for the Master of Science degree must be completed within a period of no more than five years after beginning graduate studies at Polytechnic. Any extension of this period requires the approval of the Dean of Research and Graduate Studies. A minimum of 27 units of work must be taken at the Polytechnic.

Individual programs may specify required courses, minimum grade-point averages in specific courses or course groups, and/or require a comprehensive examination, presentation of a seminar, or completion of a project or thesis.

REQUIREMENTS FOR THE ENGINEER'S DEGREE

Admission to an Engineer's program requires an undergraduate degree in an engineering discipline from an institution acceptable to the Polytechnic, and a minimum of 36 graduate units earned beyond the bachelor's degree or a master's degree in a relevant specialty. Candidates for the Engineer's Degree must complete a minimum of 36 units *beyond the master's degree*. This work must include a project of up to 12 units, or demonstration of equivalent knowledge and experience. At least 27 units of work must be completed at the Polytechnic. Registration in project must be continuous until grades are recorded.

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

To graduate, the student must maintain a 3.0 grade-point average for all graduate courses taken at Polytechnic, and a B or better average in all individually guided studies (readings, project).

REQUIREMENTS FOR THE DOCTOR OF PHILOSOPHY

Requirements for the Ph.D. 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 at an advanced level.

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

All candidates for the doctorate must complete a minimum of 90 units of graduate work beyond the bachelor's degree, including a minimum of 24 units of dissertation research.

Students may not register for dissertation research until they have passed the

doctoral qualifying examination given by their major department. These examinations are generally scheduled once or twice each year, and students should consult the academic department for specific information. Once the student has started the dissertation, registration for dissertation must be continuous until the dissertation has been completed and accepted, unless a leave of absence is formally granted.

Most departments have specific course requirements which must be fulfilled. A minimum of 30 units, including dissertation, must be taken at Polytechnic. Each student must maintain a 3.0 cumulative grade-point average for all graduate courses taken at Polytechnic, and a B or better average for the dissertation. Foreign language requirements, if any, are determined by the individual departments.

Full-time doctoral students are required to complete all work for the doctorate within six (6) years of initiation of graduate work at Polytechnic. Part-time students must complete within twelve (12) years. Any extension of these periods requires the approval of the Dean of Research and Graduate Studies.

GRADUATE CERTIFICATE PROGRAMS

Polytechnic offers a number of graduate certificate programs in a number of specialized subject areas for students who may not wish to enroll in a full degree program. These programs are described in the appropriate programmatic section of the catalog.

To earn a certificate, a minimum of 12 units must be taken at Polytechnic. A cumulative grade-point average of 3.0 in all graduate courses taken at Polytechnic is required for receipt of a certificate. No courses applied to one certificate program can be applied to another. Requirements for certificates must be completed within three years.

Applicants must be formally admitted to a certificate program. A student in such a program who subsequently decides to pursue a graduate degree must file a separate application for admission to the regular graduate program. Formal application to transfer appropriate courses taken for the certificate program to a degree program must also be made.

The following graduate certificate programs are available, and are described in the program sections of this catalog:

Program	HEGIS Code*
Management and Business Admin.	0506
Applied Statistics	1702
Computer Applications	1701
Computer Mathematics	1703
Construction Management	0599
Econometrics and Forecasting	2204
Economics	2204
Economics Systems	2204
Engineering Statistics	1702
Finance	0504
Human Resources	0515
Industrial Engineering	0913
Mathematical Programming	0704
Mathematical Statistics	1702
Operations Management	0506
Operations Research	0507
Organizational Behavior	0515
Polymeric Materials	0906
Production and Inventory Control	0913
Public Policy	2102
Public Transportation	0908
Quality Control and Reliability	0913
Technology Management	0599
Traffic Engineering	0908
Transportation Facility Design:	
Operations	0908
Transportation Management and	
Economics	0908
Transportation Planning	0908

* Higher Education General Inventory System - a taxonomy of programs and subject areas.

APPLICATION FOR DEGREE

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

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

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

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

THESES AND DISSERTATIONS

Undergraduate Theses

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

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

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

Undergraduate theses are generally optional, except in the B.S. (Materials Science and Engineering) program, in which undergraduate students are required to complete a thesis. All theses and results obtained become the property of the Polytechnic University.

Graduate Research (Projects, Theses, Dissertations)

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 the advancement of 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 commensurate acquaintance with current practices, the literature, and the work of leaders in the field of study.

Master of Science students may elect to complete an M.S. Project or M.S. Thesis, and may be required to do so in certain programs. Consult the programmatic descriptions of this catalog for details. The thesis is generally a more extended piece of work, usually entailing 9 to 12 units, while the project usually entails 3 to 6 units of effort. At this level, research shall exhibit a thorough understanding of advanced scientific thought or ability to apply advanced principles constructively to engineering planning and design.

Engineer degree candidates must complete an Engineering Design Project, unless they can demonstrate equivalent experience. A design project, usually entailing 6 units, must apply state-of-the-art knowledge to the solution of an engineering problem through design.

All Doctor of Philosophy students must complete a Ph.D. Dissertation. Research at this level must demonstrate critical and constructive thought, as well as the ability to use the techniques necessary in the exploration and development of new areas of knowledge in science or engineering. A successful dissertation must demonstrably advance the state-of-the-art in the subject area of research. Unit requirements for dissertation vary by department, but consist of a minimum of 24 to 30 units of registration, depending upon the program.

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

Registration for Theses and Dissertations

After a project, thesis, or dissertation advisor and/or guidance committee has been appointed, the candidate should register for a number of units which realistically reflects the amount of time and effort the candidate expects to devote to this research. Registration must be

continuous each fall and spring until an adequate research effort has been completed and the required oral examination has been passed. Registration may not be interrupted until a grade is entered on the permanent record except with the permission of the Dean of Research and Graduate Studies. If, at the end of any semester, the work covered by any unit of registration is deemed unsatisfactory by the advisor, re-registration for the same unit may be required, obligating the student for full tuition and laboratory fees involved. Registration for the last unit is required until a final grade is submitted to the Office of the Registrar.

For the Ph.D., if the minimum number of dissertation units have already been taken and the dissertation is finished except for the final defense, then the student will be allowed to register for the dissertation for 1/2 unit in order to keep the tuition charges to a minimum. Registrations for 1/2 unit may only be done once.

Manuscript Presentation

The research is to be presented to the appointed guidance committee by the candidate in final manuscript form for official acceptance on or before the Monday seven weeks before commencement. Draft copies of research manuscripts towards 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. Registration for 1/2 unit may only be done once.

Research Submission

The format of the bound document resulting from research is prescribed in a brochure entitled "Regulations on Format, Duplication, and Publication of Project Reports, Thesis, and Dissertations," which is available from the Office of Research and Graduate Studies and in the various departmental offices. Some of the regulations are summarized below.

Master's or Engineer's 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 addi-

tion, each doctoral candidate is required to submit two copies of an abstract of not more than 350 words suitable for publication in "Dissertation Abstracts."

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

Publication

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

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

ACADEMIC POLICIES

DEFINITION OF CREDITS AND UNITS

Undergraduate semester credits are based upon the number of 55-minute periods scheduled each week during one semester. Normally, one credit signifies a minimum of either one 55-minute period of classwork, or three hours of undergraduate laboratory, over a period of 14 weeks. In a few cases, more time per credit is given. The final examination period is an integral part of the semester.

Graduate studies are expressed in terms of units. One 55-minute period of graduate classwork for a single semester carries 1-1/5 graduate units. A standard graduate course meeting for 2-1/2 55-

minute periods per week would be equivalent to 3 units. This is the most common format for graduate courses. Graduate laboratories involve approximately twice this amount of time per graduate unit. Courses meeting more or less than 2-1/2 periods each week are assigned units in the appropriate proportion.

CREDITS FOR COURSES TAKEN ELSEWHERE (TRANSFER CREDITS)

Residency

To earn a Polytechnic University degree, students must complete a minimum number of credits at the Polytechnic University. The minimum number of credits which must be completed at Polytechnic University to satisfy residency requirements is:

- *Bachelor of Science* 34 credits in approved Junior and Senior subjects
- *Master of Science* 27 units
- *Engineer* 27 units beyond the M.S.
- *Ph.D.* 30 units including dissertation
- *Graduate Certificate* 12 units

Undergraduate Students

Students who have completed some undergraduate courses at other colleges or universities are encouraged to consider transferring into Polytechnic programs. Polytechnic will award transfer credit for appropriate courses satisfactorily completed elsewhere. Students transferring to the Polytechnic from other universities must have transcripts of their courses examined by the Office of Admissions and an advisor from the student's major department to determine the acceptability of individual substitutions and general acceptance of credits from their former institution(s). Much of this can be accomplished during the application process if the student's records are complete. All evaluations of transfer credits must be completed by the end of the student's first semester of registration at the Polytechnic.

Transfer credit is never given for any course in which a grade less than "C" has been earned. In addition, any student completing a course at Polytechnic for which transfer credit has already been given automatically forfeits the transfer credit for that course.

The contents and standards of courses vary from school to school. Thus, a transfer student may find, after semes-

ter's work at Polytechnic, that he will be better prepared for advanced courses if he re-enrolls in a course at Polytechnic for which he has been given transfer credit. A student may be required to do this in consultation with his advisor. In some instances, course requirements may be waived for students who demonstrate sufficient knowledge of a specific course content through either written or oral examination given by the appropriate academic department. In such cases, no credit is awarded, but the student will be permitted to submit a more advanced course to satisfy degree requirements.

Grades of courses for which transfer credit is given are not included in the computation of the student's cumulative or current semester grade-point average.

Polytechnic will also grant students credit for appropriate Advanced Placement courses taken in high school, given acceptable performance on AP examinations. Credit may also be granted for college preview courses taken at Polytechnic or other universities while a high-school student, if these courses are relevant to the student's degree program and acceptable grades have been achieved. Grades for such courses are also not included in the computation of the cumulative or current semester grade-point averages.

Graduate Students

A limited number of units, consistent with residency requirements, for graduate courses completed with honor grades (A or B) from accredited institutions may be allowed towards meeting the requirements for M.S., Eng., Ph.D., or graduate certificate programs. Courses must be acceptable at the transferring institution for similar degree programs, and must usually have been taken after receipt of a bachelor's degree. Evaluation of graduate transfer units is done by the student's major academic department.

Graduate courses taken at Polytechnic while a student is pursuing an undergraduate degree may be subsequently applied towards a graduate degree provided that they were not submitted in fulfillment of an undergraduate degree and a grade of B or higher was earned. Such courses are not subject to the 9-unit maximum transfer limitation for the M.S. degree and the grades are not figured into the cumulative grade-point average.

Transfer Credits While in Residence

Students enrolled at Polytechnic are expected to take coursework at Polytechnic University. Exceptions can be made in cases where Polytechnic does not offer courses of importance to the attainment of the student's academic goals.

To obtain credit/units for courses taken elsewhere while enrolled at Polytechnic, written permission must be obtained from the major academic advisor and the department head of the course for which transfer credit is requested. This must be done before registering for the course at another institution. Forms for such permission are available in the Office of the Registrar. The following requirements apply:

- The other institution must be accredited.
- Grades earned must be C or better for undergraduate courses and B or better for graduate courses.
- Pass/Fail courses are not acceptable under any conditions.
- Only credits/units will be granted; grades are not included in the computation of cumulative or current semester grade-point averages.

CREDIT BY EXAMINATION (UNDERGRADUATE STUDENTS)

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

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

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

degree or for a degree with honors or towards the grade-point average.

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

VALIDATION CREDITS (UNDERGRADUATE AND GRADUATE STUDENTS)

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

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

The sum of validation units, special student units, and transfer units, is limited to a maximum of nine units for the Master of Science degree.

CLASS STANDING FOR UNDERGRADUATES

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

<i>Freshman</i>	<i>1 - 27 credits</i>
<i>Sophomore</i>	<i>28 - 61 credits</i>
<i>Junior</i>	<i>62 - 94 credits</i>
<i>Senior</i>	<i>≥ 95 credits</i>

MAXIMUM CREDITS PERMITTED AND REGISTRATION STATUS

Undergraduates

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

Part Time: Students registered for less than 12 credits per semester (except summer) are considered part-time students. Part-time students pay tuition at the prevailing per credit rate, and are not eligible for most financial assistance programs.

Summer and Intersessions: Students may register for up to 7 credits during each six week summer term, and for no more than 14 credits for the combined twelve-week summer term. Six credits for a given summer term is considered full-time status, particularly for financial aid purposes. Courses taken during intersession are treated as if they were taken during the subsequent semester or summer session for the purposes of student records and credit.

Graduates

Full Time: Registration for 12 units or more categorizes graduate students as full time. Students who register for more than 20 units will be charged the per unit rate for additional units beyond 20.*

Part-Time: Students registered for less than 12 units per semester (except summer) are considered to be part-time students. Part-time students pay the per unit tuition rate, and do not qualify for most financial assistance programs.

International students (undergraduate and graduate) on F-1 or J-1 visas are required to enroll in a full-time program of study each semester.*

- * For certain types of attendance and enrollment certifications, some students who are registered for less than 12 credits or units may be certified as full-time; specifically, undergraduates who are pursuing University authorized full-time, full semester COOP work assignments; and graduate students pursuing research projects which their department head certifies in writing to the Registrar as full-time. A form to establish full-time equivalency is available from the Office of the Registrar.

POLICIES ON GRADING AND GRADES

Computing the Grade-Point Average for Undergraduate Students

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

Grade Point	Value	Description
A	4.0	Excellent
A-	3.7	Excellent
B+	3.3	Good
B	3.0	Good
B-	2.7	Good
C+	2.3	Passing
C	2.0	Passing
C-	1.7	Deficient, but passing
D+	1.3	Deficient, but passing
D	1.0	Deficient, but passing
F	0.0	Failing
S		Satisfactory
U		Unsatisfactory
W		Withdrawal
I		Incomplete
NR		Not Received*
P		Passing**

* Grade not received by Registrar in time to report it.

** Only used in optional PE courses.

In computation of the grade-point averages, courses graded W, I, S, or U are not considered, nor do they count towards the computation of total credits passed or earned. Grade-point averages are computed by multiplying the numerical grade in each course by the number of credits for each course, adding these products for the courses taken and then dividing this sum by the total number of credits represented by the courses considered.

The W and I grades are described in greater detail in subsequent sections. Grades of S or U are used to indicate progress in multi-semester research projects or theses, or for non-credit bearing remedial or other courses. Undergraduates enrolled in graduate courses may not receive plus or minus grades.

Computing the Grade-Point Average for Graduate Students

For the purposes of computing grade-point averages for graduate students and graduate courses, the following schedule is used. Note that the range of grades for graduate students is limited to A, B, C, and F.

Grade	Point Value	Description
A	4.0	Excellent
B	3.0	Good
C	2.0	Deficient, but Passing
F	0.0	Failing
W		Withdrawal
I		Incomplete
AUD		Audit
S		Satisfactory
U		Unsatisfactory
NR		Not Received

Grades S and U are used to reflect progress on continuing research efforts until they are completed, at which time the appropriate letter grade is entered on the transcript. Grades S, U, I, W, and AUD are not included in the computation of the grade-point average, which is computed as indicated for undergraduate students.

Repeating Courses

Undergraduates: If an undergraduate takes a course two or more times, only the second and subsequent grades will count towards the student's grade-point average. This policy holds regardless of the first and second grades earned, even when the second grade is lower than the first. The repeated course must be taken within one year of the first course, or at the first time it is offered, where a course is not available to repeat within one year.

Graduates: The first time a graduate student repeats a course, the lower grade will not be counted towards the grade-point average. All subsequent grades in a course repeated more than once will be included in the grade-point average, although degree credit is earned only once.

Course Withdrawal - the "W" Grade

Students may withdraw from a course or courses without academic penalty through the 10th week of the normal Fall or Spring semester. Approval by the instructor of the course is not required, but the withdrawal form must be signed by the student's major academic advisor. When the duration of the course varies from the norm, such as in 6, 9, or 12-week courses, withdrawal must be filed before two-thirds of the sessions are completed. Withdrawals must be filed with the Office of the Registrar by 5:00 PM on Friday of the week indicated. In the case of a two-week course, withdrawal must be filed by 5:00 PM of the seventh class day. Students who file a course withdrawal form with the Office of the Registrar by the scheduled deadline will automatically receive a grade of "W." Once entered on the student's record, the grade of "W" may not be changed to any other grade under any circumstances. A grade of "F" will be recorded for any student who ceases to attend a course without formally withdrawing in the required fashion by the required deadline.

Auditing Courses (Graduate Students)

Graduate students have the option of auditing courses instead of receiving units and grades for them. Regular tuition is charged, and courses are treated as part of a full-time load. An "AUD" notation is made on the student's permanent record.

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

Incomplete Grades

When for valid reasons, such as illness or other critical emergency, a student is unable to complete the course work at the usual time, the instructor may give a grade or incomplete, "I." The date for completion will be inserted next to the I grade on the grade sheet and will be communicated directly to the student by the instructor when possible. Whenever feasible, this date will not extend beyond the intersession, in fairness to students who finish course requirements on time, and to insure that students complete prerequisites necessary for taking advanced courses. On no account will this date be later than one year after completion of the semester for which the I was awarded.

The grade of I is used sparingly and only in cases with valid reasons, not merely because students have planned poorly or overloaded themselves. The I grade signifies that upon successful completion of the work, a passing grade will be issued.

An I grade lapses into a grade of F if the student fails to complete the course work within the specified completion date. If the student re-registers for a course in which an I grade was given, the I grade lapses to an F. All I grades must be converted prior to graduation.

ACADEMIC STANDING AND PROBATION

Undergraduate Students

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

The minimum number of cumulative credits to be achieved by the close of each semester of full-time study appear below in Table 1:

Table 1: Minimum Credits to be Earned vs. Semester of Full-Time Study

<u>SEMESTER</u>	<u>Minimum Credits Successfully Completed</u>
I	6
II	18
III	30
IV	44
V	58
VI	73
VII	88
VIII	104
IX	120
X	136

In calculating the number of successfully completed credits:

1. Courses with 'F' grades do not count towards the criteria of Table 1.
2. Credits bearing the grade "F" and repeated within one academic year will be recalculated using the second grade earned, thus entering into the number of credits successfully completed (assuming that the second grade is not also "F") during the semester in which it is repeated.
3. Credits with the grade of "I" will be counted toward enrollment for one year. At the end of that time, any grade of "I" that has not been changed by the instructor of record will automatically lapse to a grade of "F".
4. Credits assigned a grade of "W" do not appear in the calculation of credits undertaken, earned, or successfully completed.
5. Transfer students will enter the standard as calculated from the point at which transfer credits place them.

A second requisite for enrollment is the maintenance of a grade-point average of 2.00 or above, or performance approaching 2.00 in a steady and realistic fashion. Table II contains the absolute minimum cumulative grade-point average to be achieved by the close of each semester of full-time or full-time equivalent enrollment.

Table 2: Minimum Required Cumulative Grade Point Average by Semester

<u>SEMESTER</u>	<u>Minimum Cumulative G.P.A.</u>
I	1.30
II	1.40
III	1.50
IV	1.67
V	1.78
VI	1.88
VII	1.95
VIII	2.00
IX	2.00
X	2.00

The Dean of Students provides regular academic monitoring of all undergraduate students in a system which includes: (1) a review of each student's academic record after each semester; (2) conferral with the student's academic advisor or other representatives from the student's major department; (3) meetings with those students determined to be encountering academic difficulties; and (4) assignment of an academic action code.

Students who are determined to be having academic difficulty will be placed on **academic probation**, according to the following steps and actions:

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

Academic Probation: Students are placed on "academic probation" when their semester and/or cumulative grade-point averages fall below 2.00, but remain above the minimum standards of Table 2. Students falling into this category are notified by letter and are required to meet with the Dean of Students prior to registering for any further course work.

Final Probation: Students whose academic record indicates an unacceptable level of academic progress may be placed on "final probation". Notified by

letter of their standing, these students are required to meet with the Dean of Students to determine a program of study geared towards improving their performance. Failure to improve their performance will result in disqualification. Students on final probation may not participate in early registration.

Disqualification: The Committee of Standing, comprised of the Dean of Students and a representative of the student's major department, shall jointly disqualify from the University any student whose cumulative average or number of credits successfully completed falls below the appropriate minima shown in Tables 1 and 2.

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

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

Dean's List:

Undergraduate students who perform at a level of demonstrated excellence are recognized by their placement on the Dean's List. Undergraduate students who achieve both cumulative and semester grade-point averages of 3.40 or better, with no failures or incompletes, are commended by the Dean of Students and placed on the Dean's List. This list is posted semi-annually for full-time and annually for part-time students. Only those who complete 12 semester hours or more during a regular academic semester (or year for part-time students) with a cumulative grade-point average of 3.4 are eligible. Students who include project courses in their 12-credit-or-more programs are also eligible, provided that these courses represent no more than one-half of the credit load for a given period, and all of the aforementioned requirements are met. The Dean's List

notation appears on the student's permanent record.

Graduate Students

A graduate student is expected to progress in the studies pursued and to maintain a B (3.0) average. Failure to do so can result in being placed on "academic probation."

After posting of the spring semester grades, graduate students whose cumulative grade-point average is below 3.0 will be notified that they are on academic probation. The data for such determination will be provided to the Dean of Research and Graduate Studies by the Registrar, and copies of probation notices will go to each department, where the accuracy of grade-point average determinations will be checked. Students with GPA's lower than 3.0 will be notified in August by the Dean of Research and Graduate Studies of their standing.

A major department may request that a graduate student be placed on academic probation at any time it finds a student falling below a 3.0 cumulative GPA. The request must be signed by the department head and sent to the Office of Research and Graduate Studies.

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

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

WITHDRAWAL FROM THE UNIVERSITY

Voluntary

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

Involuntary

Polytechnic University is concerned about the health, safety, and well-being of its students. Therefore, a student who is judged to be a threat to himself or herself, or to others, may be involuntarily withdrawn from the Polytechnic. The University seeks, whenever possible, that such a student be allowed to continue as an active student if he or she agrees to involve himself or herself with appropriate care from a professional helper. Full details concerning this policy are available from the Department of Student Life.

LEAVES OF ABSENCE AND READMISSION

Undergraduate Students

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

Graduate Students

Part-time students who last attended Polytechnic within a three-year period before the semester in which they seek to be readmitted need no formal readmission, and are automatically permitted to register. Part-time students who have not attended within the past 3 years must file an application for readmission which is available from the Admissions Office.

Full-time students who desire to interrupt their studies may request a leave of absence for a specified period of time, usually not exceeding one year. Such requests, when approved by the Dean of Research and Graduate Studies,

will constitute assurance of readmission to the degree program from which the leave was taken.

Only if a part-time or full-time student has received an approved leave of absence will the time limitation on earning a graduate degree be extended by the period of the leave. Forms for requesting a leave of absence are available from the Office of Research and Graduate Studies.

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

THE FAMILY EDUCATIONAL RIGHTS AND PRIVACY ACT - THE BUCKLEY AMENDMENT

The Family Rights and Privacy Act of 1974 (FERPA), as amended (also known as the Buckley Amendment) grants to students certain rights, privileges, and protections relative to individually identifiable student education records which are maintained by the University. Specifically, these include the right to:

- inspect and review the student's education records;
- request the amendment of such records to ensure that they are not inaccurate, misleading, or otherwise in violation of the student's privacy or other rights;

- consent to disclosure of personally identifiable information contained in the student's education records, except to the extent that Polytechnic's disclosure policy and directory information permits;
- obtain a copy of the Polytechnic's policy on meeting the requirements of FERPA, which is made available through the Registrar's Office on each campus; and
- file with the U.S. Department of Education a complaint concerning alleged failure by the University to comply with FERPA.

FERPA permits the release of directory type information to third parties outside the Polytechnic without written consent provided students have been given the opportunity to withhold such disclosure.

Polytechnic reserves the right to disclose the following information related to a student, which is considered "directory information:" the student's (1) name, (2) class year, (3) date/place of birth, (4) major field of study, (5) participation in officially recognized activities and sports, including weight and height of members of athletic teams, (6) dates of attendance at Polytechnic, (7) degrees and awards received, (8) the most recent previous educational institution attended by the student, and (9) any other similar information (e.g. the title of the student's M.S. project or doctoral dissertation, distinguished academic performance). Currently registered students who wish to withhold directory information may do so by following the directions in the "Regulations on Privacy Rights for Students" brochure available from the Office of the Registrar.

TRANSCRIPTS

The issuance of transcripts, and generally the release of any information about a student is subject to the provisions of Public Law 93-380, "The Family Rights and Privacy Act" of 1974 as amended. Polytechnic has adopted regulations to implement the Act, and these can be found in the previous section.

Unless Polytechnic's disclosure policy permits otherwise, official transcripts of the scholastic record will be issued only upon the submission of a written request or upon the submission of a signed release from the student. Official transcripts will be sent directly to the school or other properly authorized parties. In no case can a student receive an *official* copy of his or her own transcript, unless specifically authorized by the Registrar. Such exceptions are strictly monitored, and are rarely given. Unofficial transcripts are available to any student upon written request. The first transcript will be issued without charge. There is a fee for each subsequent transcript issued.

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

Approved Sequences In Humanities and Social Sciences For Engineering And Computer Science Majors

WORLD LITERATURE

Introductory Courses:

HU 101
HU 200

Advanced Courses:

HU 201 *Literature of Western Civilization I*
HU 202 *Literature of Western Civilization II*
HU 203 *Literature of Western Civilization III*
HU 212 *English Literature from 1800 to Present*
HU 213 *Science and Literature*
HU 222 *Shakespeare*
HU 251 *American Literature to 1880*
HU 252 *American Literature from 1880 to Present*
HU 258 *American Thought*
HU 262 *Contemporary American Novel*
HU 264 *The Short Story*
HU 272 *Contemporary American Poetry*
HU 281 *Comedy*
HU 283 *Modern American Drama*
HU 291 *Short Fiction*
HU 295 *Literary Interpretation and Criticism*
HU 297 *English Language*
HU 301 *Special Topics in Literature*

PHILOSOPHY AND TECHNOLOGY

Introductory Courses:

Select 1 or more

HU 341 *Introduction to Philosophy*
HU 348 *Great Philosophers I*
HU 349 *Great Philosophers II*
LA 110 *Technology and Society in Historical Perspective*
LA 139 *Engineering Ethics*
LA 143 *Computers, Cultures, and Society*

Advanced Courses:

HU 302 *Special Topics in Philosophy*
HU 344 *Introduction to Logic*
HU 345 *Advanced Logic*
HU 346 *Ethical Theories*
HU 347 *Ethics and Technology*
HU 352 *Philosophy of Science*
HU 353 *Philosophy of Technology*
HU 354 *Social and Political Philosophy*
HU 363 *World Religions*
HU 364 *Philosophy of Religion*
HU 365 *Science, Technology, and Religion*
LA 140 *Ethics and Technology*
LA 141 *Materials and Social Issues*
LA 142 *The Cultures of Machines*
LA 144 *Energy Technology and Social Issues*
LA 150 *The Making of Connections*

MUSIC AND THE FINE ARTS

Introductory Courses: Select 1

HU 371 *Understanding of Music*
HU 382 *Fine Arts I*

Advanced Courses:

HU 303 *Special Topics in Music and Fine Arts*
HU 375 *Modern Music*
HU 383 *Fine Arts II*
HU 384 *Fine Arts III*
HU 389 *Art of Asia*

Modern Languages

To fulfill a concentration in modern languages, students with no prior language training must take a three-course sequence in the selected language. If prior training has been taken, a two-course sequence beginning with a 2nd-level or 3rd-level course would be appropriate. Languages usually available, based upon demand, include German, French, and Spanish.

WORLD HISTORY

Introductory Course: SS 104 Main Themes in Contemporary World History

Advanced Courses:

SS 110 *The Renaissance and Reformation*
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 through Reconstruction*
SS 124 *History of the United States from Reconstruction through the Cold Wars*
SS 126 *African-American History*
SS 128 *History of Jazz*
SS 151 *Introduction to Politics*
SS 154 *Russia, China, and the West*
SS 161 *Politics and Film*
SS 178 *Minorities in the New World*
SS 221 *The USSR Under Gorbachev*
SS 226 *Problems of American Foreign Policy*
SS 229 *Growth of the United States Constitution*
SS 345 *Colloquium in Twentieth Century Thought*
SS 347 *Colloquium in Imperialism*
SS 348 *Colloquium in the History of Socialism and Communism*
SS 362 *Special Topics in History*

HISTORY OF SCIENCE AND TECHNOLOGY

Introductory Courses:

Select 1 or more

- SS 101 *History of Western Civilization 1500-1815*
- SS 102 *History of Western Civilization 1815-1914*
- SS 109 *The Birth of Modern Europe: The Early Phase, 800-1500*
- SS 110 *The Renaissance and Reformation*
- SS 133 *Archaeo- and Ethnoastronomy*
- SS 135 *History of Science and Technology: Antiquity through Galileo*
- SS 136 *History of Science and Technology: Galileo through Darwin*
- SS 137 *History of Science & Technology: Faraday to the Present*
- SS 138 *Technology, Science, and Contemporary Society*
- SS 182 *Man and the Environment*

Advanced Courses:

- SS 330 *History and Environment*
- SS 332 *Science and Technology in America*
- SS 333 *Medieval and Renaissance Engineering*
- SS 338 *Galileo Galilei: The Man, His Research, and Times*
- SS 354 *Technological Forecasting*
- SS 357 *Technology Transfer to Developing Countries*
- SS 358 *Human Resource Development in Advanced Developing Countries*
- SS 363 *Special Topics in History of Science and Technology*

ECONOMICS

Introductory Course:

- SS 250 *Basic Economics*

Advanced Courses:

- SS 251 *Microeconomics*
- SS 252 *Macroeconomics*
- SS 254 *Economic Issues*
- SS 255 *The Contemporary American Economy: Boom and Bust*
- SS 257 *History of Economic Thought*
- SS 262 *Collective Bargaining*
- SS 263 *Labor Economics*
- SS 264 *Urban Economics*
- SS 265 *Money and Banking*
- SS 267 *The Market for Engineers and Scientists*
- SS 364 *Special Topics in Economics*

PSYCHOLOGY

Introductory Courses: Select 1

- SS 189 *Introduction to Psychology*
- LA 132 *Introduction to Behavioral Science*

Advanced Courses:

- SS 203 *Psychology of Learning*
- SS 204 *Physiological Psychology*
- SS 205 *Applied Psychology*
- SS 206 *Human Cognition and Information Processing*
- SS 208 *Experimental Psychology I*
- SS 209 *Experimental Psychology II*
- SS 210 *Environmental Psychology*
- SS 214 *Social Psychology*
- SS 215 *Abnormal Psychology*
- SS 216 *Personality Development*
- SS 217 *Psychology of Human Development*
- SS 199 *Organizational Behavior*
- SS 310 *Genes, Gender, and Society*
- SS 365 *Special Topics in Psychology*

ANTHROPOLOGY AND SOCIOLOGY

Introductory Courses:

Select 1 or more

- SS 175 *Introduction to Sociology*
- SS 182 *Man and the Environment*
- SS 185 *Anthropology: Physical*
- SS 186 *Anthropology: Cultural*

Advanced Courses:

- SS 177 *Social Problems*
- SS 213 *North American Indians*
- SS 279 *The Sociology of Human Disease*
- SS 354 *Technological Forecasting*
- SS 357 *Technology Transfer to Developing Countries*
- SS 361 *Special Topics in Anthropology and Sociology*

NOTE: SELECTED TOPICS COURSES AND GUIDED READINGS MAY BE USED TO SATISFY SEQUENCE REQUIREMENTS WHEN SUBJECT AREAS ARE APPROPRIATE AND WITH THE APPROVAL OF THE STUDENT'S FACULTY ADVISOR.

CAMPUS LIFE AND SUPPORTING SERVICES

DEPARTMENT OF STUDENT LIFE

The Department of Student Life is concerned with the holistic education and development of all Polytechnic students, both inside and outside the classroom. Responsible for the operation and maintenance of many student-oriented and student support programs and services, the Department of Student Life seeks to assist students in achieving success and enrichment in their endeavors at Polytechnic. Students needing assistance in resolving difficulties are encouraged to speak with a Student Life staff member. Some of the areas handled by this office include:

- freshman programs, such as the new student overnight, the freshman seminar (SL101), advising undeclared majors, programs for parents
- academic progress monitoring
- physical education and athletics
- student activities
- residence life and housing
- international student advising
- student leadership development
- counseling, advising, and student advocacy
- health insurance coordination
- academic and disciplinary policy administration

OFFICE OF SPECIAL SERVICES

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

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

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

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

THE LEARNING CENTER

The Learning Center is a "drop-in" facility open daily on the Brooklyn campus from 10:00 a.m. to 4:00 p.m. and on the Farmingdale campus from 9:00 a.m. to 5:00 p.m., offering help to students having difficulty in chemistry, computer science, mathematics and physics. It is not a tutoring program. A staff of qualified undergraduate and graduate students assists students who have specific problems with their studies.

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

CAREER SERVICES OFFICE

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

- becoming better informed of their career options
- identifying and pursuing their abilities and interests
- providing experiences and services which will allow students the opportunity to apply their skills and academic background in paid and non-paid work assignments
- deciding whether to pursue graduate study or full-time employment
- making a successful transition from the academic setting to the business, government and industrial sectors

Students at every academic level are encouraged to speak with professional staff concerning both their career development and job placement needs. Ongoing developmental career services include: career fairs; career exploration workshops and seminars; and individualized counseling concerning job skills (résumé writing, job search and interviewing techniques) and career decision-making.

Job placement services help students gain valuable work experience in both engineering and non-engineering positions. Full- and part-time job banks, summer job assistance and our extensive on-campus recruiting program meet the needs of job-seeking students. The demand for Polytechnic graduates is great, as evidenced by the more than 125 companies that recruit on campus each year.

These companies conduct over 1,500 interviews yearly, resulting in employment for many of our graduates. During 1990, the placement rate for Polytechnic graduates was 76%.

As the Career Services Office firmly believes that career planning and development is an on-going process, alumni are welcome to use the resources of the office when planning or making career or job changes. In addition to the corporate library, job bank and other reference periodicals and literature, individualized counseling is available on a limited basis.

COUNSELING SERVICES

At times, students can find themselves dealing with a range of situational or personal roadblocks which may interfere with their ability to succeed academically. The University is committed to assisting students in addressing those concerns in two ways. Free, short-term counseling is available on-site through the Office of Special Services. Typical areas of concern include study habits, adjustment problems, stress management and relationship difficulties.

For in-depth and long-term counseling or psychological evaluation services, referrals to off-site services are made. Fees are charged by these external organizations, with many agencies offering sliding-scale rates to match the ability of the student to pay. In addition, many agencies will accept payments from insurance carriers, if the student's policy covers counseling and evaluation services. Students seeking an off-campus referral can receive assistance from the Department of Student Life or the Office of Special Services.

NEW STUDENT ORIENTATION

Polytechnic seeks to ease the new student's transition to his or her new environment. We offer a variety of programs designed to orient and welcome new students every semester.

These programs include a new student overnight in the Fall, an on-campus international student orientation every semester, programs for parents of freshmen, and other social activities in addition to the Freshman Seminar--SL101 (see following section).

We encourage every new student to attend all Orientation events. These programs provide a vital link for securing a strong relationship with the Polytechnic environment. For example, in August of every year the new student overnight, which takes place at an off-campus facility, brings together Polytechnic faculty, administration, staff, alumni, upperclass students and new students. This unique interaction allows new students to become familiar with new faces in the Polytechnic community before they begin classes. The event is offered at no additional cost, and is open to all international students in addition to both undergraduate transfer students and freshmen.

FRESHMAN SEMINAR (SL101)

SL101 is required for all entering freshman with fewer than six transfer credits. It is an extended orientation to the academic and social challenges of higher education, and a preparation for the critical choices and decisions college students must make.

SL101 is designed to introduce freshman students to Polytechnic University and to support their efforts to achieve success in this environment. New academic challenges and responsibilities, new people and situations, new time demands and commitments are among the factors present in the transition to college. This seminar provides students with opportunities to develop new skills and resources which may enhance their chances for success. SL101's educational experience incorporates the richness of resources from both inside and outside the Polytechnic community. The seminar consists of a variety of guest lecturers, small group workshops, faculty presentations and sessions reserved for small group discussion on topics of particular interest to each group. This diversified experience sets the stage for

each new freshman at Polytechnic to explore why he or she has chosen Polytechnic and how he or she can get the best out of his or her Polytechnic education.

Topics covered in the course include:

- Study Skills--(including note taking, test taking, effective reading.)
- Time Management
- University Resources and Support Services
- Campus Involvement and Student Activities
- Effective Library Research Skills
- Career Awareness
- Effective Communication Techniques
- Priorities and Goals
- Health and Wellness (including stress management, and alcohol and drug issues.)

At the end of the seminar, the student will formally declare a major, or confirm a previously declared major.

UNDERGRADUATE ADVISORS

All undergraduate students are assigned an advisor in their respective major departments. Undecided or undeclared majors are advised by the Department of Student Life. These departmental advisors are available for individual appointments to discuss academic and related matters. A student's advisor must sign all registration, course adjustment, and course withdrawal forms.

In addition to departmental advisors, freshmen are assigned a specially selected freshman advisor, who is there to assist the student in making the transition to Polytechnic. Freshmen initially meet their freshman advisor through the Freshman Seminar (SL101) and are required to meet with their freshman advisor during the first semester at Polytechnic.

GRADUATE ADVISORS

Representatives of the various departments are assigned as advisors 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.

INTERNATIONAL STUDENTS

All international students and scholars are **REQUIRED** to contact the International Student Advisor in the Department of Student Life immediately upon arrival. Students must bring their immigration documents and passports with them for their initial meeting.

Polytechnic University has enrolled international students in both graduate and undergraduate studies for many years. Students holding visas make up nearly 15% of the Polytechnic population and are an integral part of the university. Faculty and administrators are sensitive to the needs of international students and strive to meet them. Services for international students are coordinated by the International Student Advisor, who is primarily located on the Brooklyn campus. International students on the Long Island campus may contact the International Student Advisor by telephone or go to the Department of Student Life on the Long Island campus for assistance.

Information regarding immigration compliance, housing, health insurance, special events and referrals are available through the International Student Advisor. For further information, consult those sections dealing with graduate and undergraduate admissions.

HANDICAPPED STUDENTS

Polytechnic fully supports Section 504 of the Rehabilitation Act of 1973. In this regard, it makes every effort to provide full and barrier-free program accessibility, so that handicapped individuals may fully participate in the life of the university. Handicapped students needing special arrangements or experiencing barriers should contact the Department of Student Life for assistance.

REQUIRED IMMUNIZATION

New York State recently enacted a law which requires students to show proof of immunity to measles, mumps and rubella. Polytechnic will comply fully with the provisions of this law. All students (graduate and undergraduate), born on or after January 1, 1957, taking six or more credits, must comply with this law.

Immunization status will be checked as part of the registration process. Students who are not in compliance with the law: (1) will be barred from attending class (and will not be entitled to any tuition refund); (2) will not receive grades; and (3) will be denied further registration.

For forms or information on this requirement, or to submit the required proof, please contact the Department of Student Life in Brooklyn or Farmingdale, or the Administration Office in Westchester.

ALCOHOL AND DRUGS

In conformity with New York State law, Polytechnic prohibits the unlawful possession, manufacture, use or distribution of illicit drugs and alcohol on its property or as part of any of its activities. Violations of this policy will result in disciplinary actions pursuant to the University Code of Conduct. Further-

more, Polytechnic will not protect those who violate these laws, nor will it interfere with law enforcement agencies that may pursue violators of these laws.

Students may not possess, consume or distribute alcohol on University premises or at University-sponsored activities, except in the following circumstances: by students over the age of 21, in their residence hall rooms, unless prohibited by residence hall policy; by students over the age of 21, at a University-sponsored activity where express permission to serve alcohol has been obtained from the Dean of Students.

All student organizations or groups wishing to hold events where alcohol is served must obtain the permission of the Dean of Students or designee, who will be solely responsible for making that decision and applying conditions and obligations to that permission.

ACCIDENT AND SICKNESS INSURANCE

Currently, all full-time students (graduate and undergraduate) are covered by accident insurance, at no additional charge. Complete health insurance coverage is recommended for all students and is required for international students and students living in residence halls owned or contracted by the University.

Information on the Polytechnic accident insurance (free for all full-time students) and sickness insurance (additional fee) policies is sent annually to full-time students. If you do not receive these materials, or need further information, contact the Department of Student Life. Spouses and dependents of full-time students are eligible for insurance coverage.

Polytechnic does not maintain health facilities on its campuses. In a health emergency, students should contact security and/or the Department of Student Life to arrange for emergency transportation to a hospital.

GUIDELINES ON STUDENT RELIGIOUS OBSERVANCES

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

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

STUDENT RETENTION

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

The initial cohort for the 1990 study was the group of first-time, full-time students who entered as freshmen in the Fall of 1984. Of that entering class, 23.2% received their Bachelor of Science degree within four years; 36.4% graduated within five years; and 40.0% completed their degree within six years.

ATHLETICS

For information on intercollegiate and intramural athletics, please refer to the section entitled, "Physical Education and Athletics," featured toward the end of this catalog.

Recreational activities are offered at the Gymnasium located on the Long Island Campus, and at The Eastern Athletic Club located near the Brooklyn Campus (specified hours only). Contact the Department of Physical Education and Athletics for more information.

CO-CURRICULAR STUDENT ACTIVITIES

Student activities are an integral part of the educational process. Participation in student activities fosters the development of leadership and interpersonal skills. Polytechnic believes that involvement in student activities broadens the academic experience of students who participate.

ORGANIZATIONS AND ASSOCIATIONS

There are approximately 50 student organizations, honors societies, and fraternities on the Brooklyn and/or Long Island campuses. Each group is responsible for fulfilling the purposes of the organization as set forth in a constitution or charter. Student organization documents are filed with the appropriate student governing body on the Brooklyn and Long Island campuses.

STUDENT GOVERNMENT

The student government is the student voice at Polytechnic. It is responsible for administering student activities fees, social and cultural programming, and other co-curricular activities. There are separate student governing bodies on the Brooklyn and Long Island campuses--the Student Council (Brooklyn) and the Student Government Organization (Long Island). Student government officers are undergraduate students selected annually during campus-wide elections.

PROFESSIONAL AND DEPARTMENTAL SOCIETIES

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

Professional Societies

American Institute of Aeronautics and Astronautics
American Institute of Chemical Engineers
American Society of Civil Engineers
American Society of Mechanical Engineers
American Society of Metals
Association of Computing Machinery
Institute of Electrical and Electronics Engineers
Institute of Industrial Engineers
National Society of Black Engineers
National Society of Professional Engineers
Society of American Military Engineers
Society of Automotive Engineers

Society of Hispanic Professional Engineers
 Society for Human Resource Management
 Society of Physics Students
 Society of Women Engineers

HONOR SOCIETIES

On the basis of their superior academic record and co-curricular achievement, students are selected during their junior and senior years to one of the Polytechnic chapters of a national honorary fraternity. Closely allied to the professional and technical societies, these honorary fraternities encourage and recognize outstanding scholarship and leadership.

Honor Societies

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

FRATERNITIES AND SORORITIES

Polytechnic has five social and service fraternities. Two of them own or rent property in the Brooklyn area, and offer live-in accommodations. The fraternities hold an impressive array of social functions for their own members and provide service to the University community. Fraternities coordinate blood donation drives, annual charity drives, athletic tournaments, parties, and more.

Fraternities and Sororities

Alpha Phi Omega
 Lambda Chi Alpha
 Omega Phi Alpha
 Pi Kappa Phi
 Tau Delta Phi

SOCIAL, CULTURAL, RELIGIOUS, MEDIA AND OTHER ORGANIZATIONS

There are student organizations at Polytechnic to suit every interest, whether social, intellectual, religious, musical, cultural, or athletic. Many of the organizations have a long and distinguished history.

Social, Cultural, Religious and Other Organizations

Asian Student Association
 Association of Latin American Students
 Chinese Student Association
 Christian Fellowship
 Conflict Simulation Society
 Demokritos (Greek Club)
 Haitian Student Association
 Indian Pakistan Organization
 Indian Student Association
 International Student Association
 Iranian Student Association
 Jewish Student Union
 Korean Student Association
 Malaysian Student Association
 Muslim Student Association
 National Association for Rigorous Training Unit
 Pershing Rifles
 Polytechnic Electronics & Robotics Club
 Programming Advisory Board
 Radio Club
 Resident Student Organization
 Russian Club
 Sappers
 Surf Club
 Stage Band
 Table Tennis Club
 Tae Kwon Do
 United Students Association
 Vietnamese Student Association

PUBLICATIONS

Bohican
 (Long Island campus newspaper)
 Innovations
 (Long Island campus yearbook)
 Polywog
 (Brooklyn campus yearbook)
 Reporter
 (Brooklyn campus newspaper)

RESIDENTIAL LIFE AND CAMPUS HOUSING

A residential life program is an integral part of college life and can greatly enhance your college experience. Resident students become members of a supportive peer community in an academic environment which offers the opportunity to more fully develop academically and socially. The residential life experience helps students to develop personal responsibility as it supports them in meeting their academic goals. Polytechnic is committed to providing safe and affordable housing for students who are interested in a residential life experience.

Campus housing is available for matriculated, full-time, undergraduate and graduate students. It is not appropriate for married students seeking housing for their families. Inquiries about campus housing should be made to the Student Life office on the appropriate campus.

CAMPUS HOUSING AT THE LONG ISLAND CENTER

There are two residence halls on the Long Island campus, housing a total of 90 students. The East Residence Hall primarily houses upperclassmen in four-person suites with private bedrooms, a common suite area with cooking facilities, and a bathroom. The West Residence Hall primarily houses freshmen in double rooms with common bath/shower facilities. All residents in West Hall are required to subscribe to a meal plan. Both residence halls have coin-operated laundry facilities and recreation areas—East Hall has a gameroom and West Hall has a large multi-purpose lounge.

CAMPUS HOUSING SERVICE AT THE BROOKLYN CENTER

At the Brooklyn campus, housing is offered to students in cooperation with the Richard L. Conolly Residence Hall at Long Island University, and the Leo J. Pantas Residence Hall at Pratt Institute. Both facilities have trained professional and student staff, who work and live in the residence halls. In addition to providing 24-hour security, both residence halls are well maintained.

Richard L. Connolly Hall is just five blocks, and a 10 minute walk, from Polytechnic. It houses undergraduate students; however, graduate students may choose to live at Connolly Hall as well. First-time residents are usually placed in standard double occupancy rooms. A standard 12' x 20' room has two wardrobes, chests of drawers, desks, and beds. Connolly Hall, which houses up to 600 students, is open year-round. All rooms, and most floors, are single-gender. Common bathroom and shower facilities are located on each floor. Where floors are co-ed, separate facilities are provided. The meal plan is optional. Other facilities within the residence hall include a personal computer laboratory equipped with IBM personal computers; a multi-purpose gameroom with pool table, vending machines, and television. Dining room and coin-operated laundry facilities are conveniently located on the premises.

Leo J. Pantas Hall is one and one-half miles--a 15 minute bus ride--from Polytechnic. Pantas Hall is designed to accommodate graduate as well as undergraduate students and houses up to 230 residents. Students live in two- or four-person suites consisting of two bedrooms (10' x 16')--each with its own vestibule (8' x 9') and a bathroom. Bedrooms are furnished with wardrobes, chests of drawers, drafting tables, chairs, and beds. Suites are single-gender, but floors are co-ed. The meal plan is optional. Pantas Hall is open to students during the Fall and Spring semesters. Other features of the hall include a multi-purpose lounge equipped with a television and a warm-up kitchen for social events. The campus dining room and laundry facilities are open seven days a week and a commissary is also available.

CAMPUS HOUSING REQUIREMENTS

All resident students are required to have a Health Examination Form completed by their physician certifying their good health. Additionally, resident students must have medical insurance coverage.

OFF-CAMPUS HOUSING OPPORTUNITIES

Students interested in off-campus housing may take advantage of announcements made available through the Off-Campus Housing postings on bulletin boards at each campus.

UNIVERSITY STUDENT CODE OF CONDUCT

The University Student Code of Conduct is distributed regularly to all students. This document gives notice of prohibited behavior and outlines the procedures to be followed in the event of a breach of this code. This document is dedicated to the protection and promotion of the academic enterprise.

ADMISSIONS

The course of studies at Polytechnic is academically rigorous and intellectually challenging; therefore, admission to Polytechnic is highly competitive. Candidates for admission to graduate programs are evaluated by the department to which they apply. Students seeking admission to the undergraduate programs are evaluated by the professional staff of the Office of Admissions according to criteria established in concert with the University's Committee on Admissions.

GRADUATE

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

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

Graduate admission information can be obtained from the Office of Graduate Admissions, Polytechnic University, 6 Metrotech Center, Brooklyn, New York 11201, (718) 260-3200.

ADMISSIONS PROCEDURES

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

EXAMINATIONS

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

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

INTERNATIONAL APPLICANTS

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

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

Certification of ability to meet financial obligations is also required.

STATUS

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

Regular Status

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

Conditional Status

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

Provisional Status

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

Special Status

An individual requesting permission to register for one or two courses in a specific semester is assigned special admission status. A formal application for admission may or may not have been filed with the Office of Graduate Admissions. Included in this status are individ-

uals who want to take courses for professional advancement or personal development, but who do not want to earn a degree; and part-time degree applicants with incomplete admission files. A maximum of six units or two courses may be taken in one semester and no more than nine units or three courses may be applied to a Polytechnic degree program. A special student application must be filed each semester the individual remains in this status. Permission to take courses as a special student does not imply admission to a degree program. Special (graduate) students must hold a bachelor's degree from an institution acceptable to Polytechnic.

EARLY GRADUATE ADMISSION

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

UNDERGRADUATE

THE APPLICATION PROCESS

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

BROOKLYN

Polytechnic University
Six Metrotech Center
Brooklyn, NY 11201
(718) 260-3100

FARMINGDALE

Polytechnic University
Route 110
Farmingdale, NY 11735
(516) 755-4200

Undergraduate applicants should complete the application for admissions and forward it to the Office of Admissions with either a \$40 non-refundable application fee or a fee waiver request form. Applicants should request that their secondary school and/or college forward official copies of transcripts to the Polytechnic Office of Admissions. All freshmen applicants and all transfer applicants with less than two complete years of college are required to submit test scores of the Scholastic Aptitude Test (SAT) or the American College Testing Program (ACT).

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

Full-time undergraduate study:

December 1 - for the spring semester

February 1 - for the fall semester

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

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

If accepted for admission, the applicant should submit an enrollment deposit of \$250.00 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 January 1 for the spring semester.

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

THE EARLY DECISION PLAN

Applicants who have selected Polytechnic as their first choice are encouraged to apply as early decision candidates. The application and supporting documents should be submitted by December 1. Decisions will be announced on January 15. Applicants admitted under the early decision plan agree to withdraw all applications submitted to other institutions and enroll at Polytechnic.

THE EARLY ADMISSION PLAN

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

ADMISSION AS A FRESHMAN

Examinations

Applicants for admission as freshmen are required to take the Scholastic Aptitude Test (SAT). The American College Testing Program may be substituted for the College Board examinations. Students who are admitted to Polytechnic and plan on enrolling will be required to take two placement examinations prior to opening day of classes.

The preferred secondary school course of study is:

(course)	(years)
English	4
Foreign Language	2
Science	4
<i>(Physics and chemistry strongly recommended)</i>	
Mathematics	4
<i>(elementary algebra, geometry, intermediate algebra, trigonometry)</i>	
Social Studies	3
Electives	2
<i>(technical courses such as pre-calculus, calculus, advanced laboratory science, computer science etc., preferred)</i>	

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

Interviews and Campus Tours

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

Freshman Admission with Advanced Standing

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

Specific requirements for administering college credit, for both the Advanced Placement and the International Baccalaureate Exam, French Baccalaureate or General Certificate Exam "A" levels, etc., vary from department to department. Students will be required to take a placement exam in order to determine their freshman course selection.

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 New York State guidelines which consider family size, family members who are students and family income.

Freshmen entering HEOP are required to take six weeks of remedial work during the summer prior to beginning the freshman year, to make up prerequisites and courses in which weakness is shown.

Transfer students may enter HEOP provided there is space available. Only students coming from similar programs approved by the HEOP central office are eligible to transfer into HEOP. HEOP is available at the Brooklyn center only. For further information, contact the Director of HEOP at (718) 260-3370.

ADMISSION AS AN INTERNATIONAL STUDENT

International students must meet four basic criteria for admission to Polytechnic and receipt of a valid I-20 or IAP-66:

- Academic credentials (grades, certificates, degrees) must be assessed as suitable for entry to the appropriate University program.
- The Test of English as a Foreign Language (TOEFL) is required of all students whose native language is not English.
- The Polytechnic Declaration and Certification of Finances (Affidavit of support) must be duly signed and accompanied by a bank statement signed by a bank official.
- Students holding F-1 or J-1 visas must enroll as *full-time* students.

If transfer credit is desired, candidates must include catalog or syllabus descriptions of courses completed. English translation must be provided where necessary. 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 advisor.

ADMISSION AS A TRANSFER STUDENT

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

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

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

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

Transfer credit is awarded on the basis of current standards and curriculum. Therefore, it is possible that credits which Polytechnic had previously awarded for courses taken at other universities may no longer be granted at this time. Transfer credit will not be considered for any course with less than a "C" grade. Any student who completes a course in residence at Polytechnic for which transfer credit has already been granted will automatically forfeit the transfer credit for that course.

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

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

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

ADMISSION AS A PART-TIME STUDENT

Students seeking a bachelor's degree may enroll on a part-time basis (11 credits or less) at the Brooklyn or Long Island Center taking day and/or evening courses. Please see sections on individual majors to determine whether part-time evening studies are available. Part-time undergraduate students should be aware that it is no longer possible to take a complete bachelor's degree program by attending only evening courses. Some daytime attendance is required.

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

Following notification of acceptance, students will be notified when to contact the advisor of their major department. In some cases, this may be accomplished during registration.

SPECIAL AND VISITING STUDENTS

Undergraduate students may also register for a maximum of two courses per semester on a non-degree basis. Application for admission under this special status may be completed during registration. A special non-degree status may satisfy the needs 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 applied to a degree program. Some courses, however, may be applied to a degree program with the approval of a departmental advisor. Students may enroll in up to 9 credits as a special student before formal admission is required.

COLLEGE PREVIEW

Through Polytechnic's College Preview Program, students may earn college credit during their senior year of high school by enrolling in approved undergraduate courses at Polytechnic. Courses are offered to College Preview students at substantially reduced tuition.

READMISSION

Polytechnic students who have not been in attendance for one semester or more are required to apply for readmission. Students applying for readmission will be expected to state their reasons for leaving the University, and are expected to explain why they desire to return. Official transcripts of college-level courses taken during this period of absence from Polytechnic must be submitted with the application for readmission.

FINANCIAL AID

GRADUATE

GRADUATE FELLOWSHIPS AND ASSISTANTSHIPS

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

Research Fellowships

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

Teaching Fellowships

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

Special Fellowships

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

Graduate Assistantships

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

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

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

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

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

GRADUATE TUITION ASSISTANCE PROGRAM (TAP)

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

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

- If financially dependent on parents OR if financially independent of parents and are married or have tax dependents, have a New York State Net Taxable Income of less than \$20,000.
- If financially independent of parents and single with no tax dependents, have a New York State Net Taxable income of less than \$5667.

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

- The maximum annual award is \$1200 and is reduced according to family income levels. No award is less than \$100 per year. TAP may be received for 8 semesters of graduate studies.
- Applicants must apply annually to NYSHESC using the TAP Student Payment Application. Applications are available in the Office of Financial Aid and must be submitted prior to the May 1 deadline during the award year. TAP recipients will receive an award certificate from NYSHESC which is to be presented to the Bursar's office for payment/deferment.

POLYTECHNIC LOANS

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

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

STAFFORD STUDENT LOAN PROGRAM

Graduate students may apply for a Stafford Student Loan for \$7500 per academic year with an interest rate of 8%. To be eligible for a Stafford Student Loan, students must (1) be United States citizens or eligible non-citizens, (2) be enrolled for at least six credits per semester and matriculated, (3) be making satisfactory academic progress and (4) demonstrate financial need. All applicants must complete a Financial Aid Form (FAF) to determine need. All interest and principle payments are deferred as long as student is enrolled for at least six credits per semester. Repayment begins six months after graduating or withdrawal from school. Immediate repayment is required if the borrower is enrolled less than half-time.

SUPPLEMENTAL LOANS FOR STUDENTS

All graduate students are eligible for the Supplemental Loan program. Annual limits are \$4,000 per academic year with an aggregate amount of \$20,000. To be eligible, students must (1) be United States citizens or eligible non-citizens, (2) be enrolled for at least six credits per semester, (3) be making satisfactory academic progress and (4) Supplemental Loan funds in combination with other financial assistance cannot exceed the cost of education.

A variable interest rate is established for this program. Interest will be the one-year Treasury Bill rate, plus 3.75 percent, with a maximum of 12 percent.

UNDERGRADUATE

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

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

There are three basic types of financial aid, as follows:

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

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

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

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

To Apply for Financial Aid:

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

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

To Renew Financial Aid:

Continuing students should obtain Financial Aid packets from the Office of Financial Aid between March 12 and April 16.

Students should file the Polytechnic Financial Aid Application and Verification Supplement with the Office of Financial Aid generally by April 15. A copy of the parents' and/or the student's federal and state tax returns with all required schedules, along with documentation of all untaxed income must accompany this application. Late or incomplete application material will result in a reduction or forfeiture of institutionally administered financial aid.

FEDERAL CAMPUS-BASED PROGRAMS

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

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

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

Supplemental Education Opportunity Grant (SEOG)

The SEOG is awarded to undergraduates with exceptional financial need. At Polytechnic, qualified applicants receive between \$300 and \$1,000 per year. Usually, the award will continue to be offered for four years, or up to five years for certain programs.

Perkins Loans (formerly National Defense Student Loans, NDSL)

The Perkins Loan is a low interest (5%) loan. The loans, for both undergraduate and graduate study, are made available through the Office of Financial Aid. Perkins loans are awarded as part of the financial aid package, with a range of \$1000 to \$1500 per academic year. Perkins loans are limited to \$4500 for

the first two years of college study. Total undergraduate Perkins loans may not exceed \$9000. Under the Perkins Loan, the maximum amount students may borrow is \$18,000 for all college-related expenses, for all their years of undergraduate, graduate and professional study. Upon approval of the loan, the student signs an "Affidavit of Educational Purpose" and a promissory note.

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

College Work-Study Programs

The College Work-Study Program provides part-time jobs for undergraduate and graduate students. Earnings from these jobs help students meet college-related expenses. Employment eligibility is determined by the Financial Aid Office. Work arrangements are made through the Personnel Office.

At Polytechnic, the maximum College Work-Study award is \$1000 per academic year. Jobs are arranged on-campus. Most assignments average 15 hours per week, and the work schedule is adjusted to the needs of the student and the employer. The starting rate of pay is usually \$4.50 per hour, but varies depending on the position. Students are paid bi-weekly.

FEDERAL AND STATE SPONSORED PROGRAMS

PELL Grants

The PELL Grant is a need-based grant program. Awards are determined by the U.S. Department of Education according to an "eligibility index" and by the level of appropriations available. Grants are for study leading to a first bachelor's degree and are usually the first component of all financial aid packages. Currently, awards may not exceed 60% of the cost of education, or \$2400, whichever is less.

To be eligible, students must be U.S. citizens or permanent residents, be making satisfactory academic progress, be enrolled at least half-time (the equivalent of six credits per semester), and meet federal income requirements.

If students received a PELL Grant for the first time in 1987-88, or thereafter, the PELL Grant eligibility will be limited to five full years of study.

Students may apply for the PELL Grant by completing the FAF through the College Scholarship Service. Students applying for financial aid at Polytechnic (including the Stafford Loan) are required to apply for a PELL Grant. Students must file an application by May 1 for the current academic year.

Tuition Assistance Program

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

The amount of the TAP award depends on the level of study, tuition charge and net taxable income. (This income is adjusted to reflect other family members enrolled full-time in post-secondary study.)

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

To apply for the TAP award, students should check the appropriate box on the FAF, or students may obtain an application from their high school guidance counselor, Polytechnic Financial Aid Office, or the New York State Higher Education Services Corporation, 99 Washington Avenue, Albany, New York 12255. There is no need to fill out a separate TAP application if a student has filed a New York State Financial Aid Form.

If Polytechnic University's name does not appear on the TAP certificate, a TAP Change Form must be filled out and submitted to NYSHESC. These forms are available in the Financial Aid Office at either the Brooklyn or Long Island campus.

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

Aid for Part-Time Study (APTS)

The Aid for Part-Time Study program is intended to provide State Grants to less than full-time students.

To be considered for an award, a student must (1) be working toward an undergraduate degree as a part-time student, (2) be in good academic standing, (3) be a resident of New York State, (4) be either a U.S. citizen, permanent resident alien, or refugee, (5) not have used up TAP or other New York State student financial aid eligibility for full-time study, and qualify under the New York State mandated income requirements.

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

Vietnam Veterans Tuition Awards Supplement (VVTA)

The Vietnam Veterans Tuition Award is an entitlement program. Applicants must (1) be residents of New York State since April 20, 1984, or at the time of entry into service and resumption of residency by September 1, 1988; (2) have served in the U.S. Armed Forces in Indochina between January 1, 1963 and May 1, 1975; (3) be honorably or medically discharged from the U.S. Armed Forces; (4) be enrolled in an approved undergraduate program in a degree-granting institution in New York State; and (5) have applied for the Tuition

Assistance Program (TAP) and Pell Grant awards. There are no income restrictions connected with this program.

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

To apply, students should obtain applications and other materials available at the Financial Aid Office, any Veterans Office, or by writing to the New York State Higher Education Services Corporation, VVTA, Albany, NY 12255. Applications for the Vietnam Veterans Tuition Award Supplement must be made by May 1, 1992 by part-time students. Full-time students must apply by submitting both Vietnam Veterans Tuition Supplements and the Student Payment Applications (TAP Application) by May 1, 1992.

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

Higher Education Opportunity Program (HEOP)

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

POLYTECHNIC UNIVERSITY SCHOLARSHIPS AND GRANTS

Polytechnic has a strong history of recognizing the scholastic achievements of applicants with outstanding academic credentials. Such awards are based on need, academic achievement and recommendation.

Polytechnic Scholarships are awarded to freshmen and transfer applicants with strong academic backgrounds with full-time schedules (12 credit hours per semester). Awards are determined through demonstrated financial need and merit. Students apply directly to the Financial Aid Office using the FAF. Awards range up to full-tuition. Continu-

ance of the awards demands upon the maintenance of a 2.5 or 3.0 cumulative grade point average (depending on the award) and application to the PELL and TAP programs.

The following scholarships are awarded to freshmen and transfer applicants with strong academic backgrounds regardless of need selected from among the applicant pool.

Board of Trustee Scholarships

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

Geiger/Fialkov Scholarships

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

Arts and Sciences Scholarships

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

Dean of Engineering Scholarships

Each year, the Dean of Engineering awards one \$8000/yr scholarship to a student with superior academic credentials in each of the following engineering disciplines: aerospace engineering, chemical engineering, civil engineering, computer science, electrical engineering, industrial engineering, mechanical engineering, and metallurgical engineering.

Continuance of the scholarship is based upon maintenance of a 2.5 cumulative grade-point average and application to the PELL and TAP programs. A separate application form available from the Admission's Office must be filed for these scholarships.

Engineering Department Head Scholarships

Each year, the head of each engineering department awards one \$5000/yr scholarship to a student with superior academic credentials in each of the following engineering disciplines: aerospace engineering, chemical engineering, civil engineering, computer science, electrical engineering, industrial engineering, mechanical engineering, and metallurgical engineering. Continuance of the scholarship is based upon maintenance of a 2.5 cumulative grade-point average and application to the PELL and TAP programs. A separate application form available from the Admission's Office must be filed for these scholarships.

Principal's Scholarship

All high-school principals in the New York metropolitan region are invited to nominate one of their outstanding graduates for an \$8000/yr scholarship award. Recipients are selected from among nominees by a committee of Polytechnic staff and/or faculty. Continuance of the award is based upon maintenance of a 2.5 cumulative grade-point average and application to the PELL and TAP programs. Application forms are available in the student's high school.

PROMISE Scholarships

PROMISE Scholarships in varying amounts based upon both need and scholastic achievement may be offered to students who have participated in programs of the Center for Youth in Engineering and Science (YES) while in high school, or other graduates of participating high schools. No award may be greater than the amount of tuition less any other aid for which students may be eligible. Depending upon the amount of award, continuance is based upon maintenance of a 3.0 or 2.5 cumulative grade-point average and application for PELL and TAP programs. No separate application for these scholarships is required.

Metallurgy and Materials Science Scholarships

These are awarded to academically superior freshmen and transfer applicants majoring in Metallurgy. The scholarship award is up to \$1000 per year. Continuation is based upon maintenance of a 2.5 cumulative grade point average.

Outstanding Achievement Scholarships

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

Polytechnic Grants

Polytechnic grants are available to needy students on a limited basis. Students apply directly to the Financial Aid Office by completing a Financial Aid Form (FAF), a Polytechnic Financial Aid Application and Verification Supplement, and by submitting all necessary income documentation.

NATIONAL ACTION COUNCIL FOR MINORITIES IN ENGINEERING (NACME) GRANTS

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

MINORITY SCHOLARS PROGRAM

Polytechnic Cooperative Education Minority Scholarships are awarded to superior minority students who participate in the Co-op Program. Newly admitted undergraduate students and students who are enrolled in or have completed at least one co-op course are eligible. Application is made directly to the Cooperative Education Office.

The amount of the scholarships are equal to tuition less any outside aid for which the students are eligible. Continuation of the award is based on maintaining a 2.5 cumulative grade point average and continuing participation in the co-op program.

POLYTECHNIC NATIONAL SOCIETY OF PROFESSIONAL ENGINEERS SCHOLARSHIP (NSPE)

The scholarships are awarded to academically superior freshmen majoring in Engineering. Awards are determined by NSPE and range up to \$1,500. Maintenance is based on a 2.5 cumulative grade point average.

CORPORATE AND INDIVIDUALLY SPONSORED SCHOLARSHIPS

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

The Sidney G. Albert Scholarship
The Alumni Scholarship
The L.F. Case Foundation Scholarship
The J.B. Chittenden Scholarship
The Arthur Clapp Scholarship
The Samuel & Grace B. Cohen Scholarship
The DeWitt Scholarship
The Aaron and Simcha Dubitzky Scholarship
The W.E. Duryea Scholarship
The A.S. Dwight Scholarship
The I.W. Fay Scholarship
The Polytechnic Fellows Scholarship
The J. Robert Fisher Scholarship
Kay & John Giba Scholarship
The Alex Gruenwald Scholarship
The Alfred Helwig Scholarship
National Satellite Services Inc. Scholarship
The F.M. Jabara Scholarship
The Jacob Kaplan Scholarship
The Eugene R. Kulka Scholarship
The John F. Kunc Scholarship
The Litton Industries Scholarship

The Lyons Scholarship
The P.R. Mallory Memorial Scholarship
The Raymond Mauro Scholarship
The Steven J. Meoli Memorial Scholarship
The NSC-Essie Mitchell Scholarship
The Colonel Frank Mott Scholarships
The William Nichols Scholarships
The Nippon Electric Scholarships
The Nordheimer Scholarship
The Dr. Julian R. Reasenberg Memorial Scholarship
The Julian Rogoff Scholarship
The Myron Rosenthal Scholarship
The Samuel Ruben Scholarships
The Schmidt Memorial Scholarship
The Silleck Family Scholarship
The Frank R. & Emily E. Stammer Scholarships
William Stolze Scholarship Fund
The Arnold Thompson Scholarship
Michael Tuch Foundation, Incorporated Scholarship
The Ernst & Sonya Weber Scholarship
The Warren & Mary Ann Winsche Memorial Scholarship
CA Rich - Consultants, Inc. Scholarship
Joseph Bommarito Scholarship
The Benjamin Adler Memorial Scholarship
Crompton and Knowles Chemical Engineering Scholarship
Jephson Educational Trust Scholarship
Stanley Nisenson Memorial Scholarship
Radio Club Scholarship

OTHER OPPORTUNITIES

ROTC Scholarships

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

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

Veterans Administration (VA) Educational Benefits

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

To apply, students should obtain applications available at all VA offices, active duty stations and American embassies as well as the Office of the Registrar. Completed forms should be submitted to the Registrar. A "Summary of Veteran's Benefits" booklet is available from the Registrar.

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

Students requesting VA education benefits should notify the Office of the Registrar each semester after completing registration. Students must report interrupted attendance or termination of study. Details of Polytechnic's requirements are given to all applicants. Questions concerning veterans benefits or paperwork should be directed to the Registrar's Office either in person, by telephone, or by completing a request for Veteran's Benefits Form.

Cooperative Education Program (CO-OP)

Co-op is an alternative means of financing education by combining alternate semesters of outside employment and school attendance.

All inquiries are handled through the Cooperative Education Office.

Grant Aid To Non-New York State Residents

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

Pennsylvania Higher Education
Assistance Agency
Education Building
Harrisburg, PA 17126

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

Vermont Student Assistance Corporation
156 College Street
Burlington, VT 05401

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

LOAN PROGRAMS

Refer to section describing Federal campus-based programs.

Stafford Loan Program (formerly GSL)

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

To be eligible for a Stafford Loan, students must (1) be a United States citizen or eligible non-citizens, (2) be enrolled for at least six credits per semester and matriculated, (3) be making satisfactory academic progress and (4) demonstrate financial need. All applicants must complete a Financial Aid Form to determine financial need and eligibility for a PELL Grant.

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

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

To apply, obtain Stafford applications from participating lending institutions (banks, credit unions, etc.). In addition, all students, (undergraduate and graduate) must have on file the Financial Aid Form (FAF), the Polytechnic Financial Aid Application and Verification Supplement, and all necessary income documentation. All transfer students must request financial aid transcripts from all previously attended institutions be sent to the Financial Aid Office at Polytechnic University. All new borrowers must complete an entrance interview in the Financial Aid Office prior to endorsement of loan checks. Eligible applicants will be certified and forwarded to the lender indicated and guarantee agency. To ensure that credit for approved Stafford's will be given in lieu of payment at registration, Stafford applications should be submitted to the Office of Financial Aid no less than eight (8) weeks prior to registration.

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

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

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

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

Supplemental Loans for Students

All students, except dependent undergraduates, are eligible for the Supplemental Loan program. Annual limits are \$4,000 per academic year with an aggregate amount of \$20,000.

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

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

To apply, obtain SLS applications from participating lending institutions (banks, credit unions, etc.) All students must complete the Financial Aid Form (FAF), the Polytechnic Financial Aid Application and Verification Supplement, and submit all necessary income documentation. Completed applications

should be submitted to the Financial Aid Office no less than eight weeks prior to registration for any given academic period. Certified applications are forwarded to the student's lender and guarantee agency.

Supplemental Loans for Parents

Parents may borrow up to \$4,000 per year for each financially dependent student. The total maximum aggregate for each child is \$20,000. A Financial Aid Form (FAF) is not required. However, the Parent Loan combination with other financial assistance cannot exceed the total cost of education. Repayment begins within 60 days from the date you receive the loan. The maximum repayment period is 10 years.

Supplemental Higher Education Loan Financing Program (SHELF)

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

Polytechnic University-Sponsored Loan

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

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

OTHER RESOURCES

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

TEN/TWELVE-MONTH PAYMENT PLANS

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

HOME EQUITY LOAN/HOME EQUITY LINE OF CREDIT

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

OTHER OPPORTUNITIES

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

IMPORTANT FINANCIAL AID POLICIES

- To be eligible to receive financial aid, students must be enrolled at least six credits per semester. All Polytechnic Scholarships, Polytechnic Grants, and TAP awards, however, require students to be full-time to qualify.
- Financial Aid applicants (including Stafford Loan applicants) are expected to apply for a Pell Grant and, in the case of New York residents, for the Tuition Assistance Program. Polytechnic scholarships and Polytechnic grants, in combination with Pell Grant and TAP awards, may not exceed tuition.
- Although at Polytechnic the Admissions and Financial Aid Offices are associated, admissions decisions are not affected by financial need. Academic evaluations of a student's qualifications are made without the knowledge of the applicant's financial need.
- Prospective students should not wait until they have been admitted to apply for financial aid. These are concurrent processes. Applicants should make every effort to apply for admissions and financial aid by the preferred application dates. Once students are admitted, they are reviewed for financial aid.
- Financial aid is renewable annually, based on student reapplying, continuing to demonstrate financial need where applicable, and fulfilling other requirements stipulated by the awards. To renew most Polytechnic Scholarships, students must maintain a 2.5 cumulative grade point average. To renew a Board of Trustee Scholarship, students must maintain a 3.0 cumulative grade point average.
- Standards of achievement for scholarship maintenance are established each semester. Students are reviewed after 2 consecutive semesters. Students who fall below the established criteria will be given one semester of grace to restore their GPA. If they are not successful the scholarship will be revoked. It will be reinstated when the student is successful. Scholarships cannot be received retroactively.
- Since Financial Aid and Scholarship Funds administered by Polytechnic are limited, students should be aware that it is very unwise to enroll at Polytechnic without financial aid support, on the assumption that at a later date financial aid will be available. Given the fixed amount of resources, Polytechnic deems it unethical to withdraw support from students who have based attendance at Polytechnic on the Financial Aid awarded them in order to release funds to assist new applicants. Funds from financial aid programs not administered by Polytechnic, such as the PELL Grants, TAP, and the Stafford Loan Program, are available to eligible students whether or not they have already received funds from these programs.
- Grants of Title IV Aid (Pell, Supplemental Educational Opportunity Grant, College Work Study, Perkins Loan and Stafford Loan) are contingent upon provision of the following documents:
 - 1) properly signed Financial Aid Acceptance Forms explaining the terms of the awards;
 - 2) Financial Aid Transcripts from all previously attended institutions of higher education;
 - 3) copies of students' (or parents') IRS Form 1040 or 1040A/EZ, if requested;
 - 4) signed affidavits acknowledging Selective Service Registration;
 - 5) proof of permanent residency status, and
 - 6) any other requested documents.
- Students must assume responsibility for reading, understanding and abiding by the terms of all financial aid documents they sign; they should also keep copies of them.
- Students must know each financial aid program's limits on the amount of aid and number of years they can receive such assistance, and make appropriate plans to finance that part of their education which exceeds the limits.
- Students must report any outside financial aid received or any changes in their family situation, so that the Office of Financial Aid can make proper adjustments in awards offered.
- Students must not be in default on a Perkins Loan or a Stafford Loan, nor can they owe a refund on a PELL Grant or a Supplemental Educational Opportunity Grant, if they wish to continue receiving financial aid.
- In order to continue receiving financial aid, a student must maintain full-time, matriculated (degree) status and must complete a minimum number of quarter credit hours with a minimum grade point average to be considered making satisfactory academic progress toward his/her degree as illustrated in the academic policies section of this catalog. Failure to make satisfactory academic progress may result in the loss of financial aid.
- Students who have lost eligibility for financial aid may request reinstatement due to unusual or extraordinary circumstances. Students who wish to appeal must, within 20 days of notification, submit a written appeal to the Financial Aid Committee on Academic progress. On the form, describe the reasons for the appeal and provide documentation. If necessary, students will also be expected to appear in person to meet with a member of the Committee.

PART II

DETAILS OF ACADEMIC DEGREE PROGRAMS AND CURRICULA



<u>PROGRAMS</u>	<u>PAGE</u>
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A BRIEF GUIDE TO COURSE DESCRIPTIONS

Each program section which follows contains detailed descriptions of each course offered within the program. A sample course description follows:

MA 123 Experimental Design

2½:1½:4

Principles of modern statistical experimentation, including practice in the use of basic designs for scientific and industrial experiments and testing. Single factor experiments, randomized block design, Latin squares, Graeco-Latin squares; factorial and fractional factorial experiments; surface-fitting designs.

Prerequisite: MA 224 Co-Requisite: MA 153

Also listed under IE 123

The first line gives the official *course number* for which you must register, the official *course title*, and the breakdown of credits (undergraduate) or units (graduate) for the course. In the sample description, the course meets for 2 1/2 lecture periods and 1 1/2 laboratory periods per week. If successfully completed, 4 credits are earned.

The paragraph description briefly indicates the contents and coverage of the course. A detailed course syllabus may be available on request from the office of the offering department.

"Prerequisites" are courses (or their equivalent) which *must* have been completed before registering for the described course. "Corequisites" must be completed before registering for the subject course, or may be taken concurrently.

The notation "Also listed..." indicates that the course is also given under the number shown. This means that two or more departments or programs are sponsoring the described course, and that you may register under either number, usually the one representing your major program. The classes are jointly given and held.

AEROSPACE ENGINEERING

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

THE AEROSPACE ENGINEERING PROFESSION

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

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

UNDERGRADUATE PROGRAM

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

During the first two years of study, the foundation for future professional subjects is established by courses in each of the basic sciences; physics, chemistry, and mathematics. Although the student begins training in a number of engineering science areas such as computers, mechanics, material science and strength of materials, the emphases are primarily on principles and concepts in fundamental and basic sciences.

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

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

TRANSFER STUDENTS (Undergraduates)

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

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

GRADUATE PROGRAMS

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

To obtain any graduate degree or certificate, a student must have 3.0 grade point averages or better in all graduate courses taken (whether or not some of these courses are being used to satisfy specific degree requirements) and B or better averages in all guided studies (readings, project, thesis, dissertation). Additionally, students must establish overall B averages in those departmental courses submitted in partial fulfillment of degree requirements. All courses submitted for degrees must have been completed within the time periods given in the University catalog.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE

AE 731	Analytical Methods in Thermal & Fluid Mechanics	3
AE 732	Computational Methods in Thermal & Fluid Mechanics	3
AE 740	Principles of Fluid Dynamics	3
AE 741	Compressible Flow	3
AE 742	Viscous Flow	3
AE 810	Theory of Propulsion	3
AE 971-72	Seminar in Aerospace Engineering	0
	Electives (including project or thesis)	<u>18</u>
		36

In the above master's degree program students may pursue a project (up to six units counted toward the degree) or a thesis (up to twelve units counted toward the degree) under the guidance of a faculty sponsor or may elect to complete the program solely with courses. All elective courses must be approved by a graduate advisor and should be consistent with a definable objective associated with the master's program. The Department of Aerospace Engineering offers its graduate courses only at the Long Island Campus, which is the main location of departmental research laboratories and staff. Students may take out-of-department elective courses at either the Brooklyn or the Long Island campus (subject to approval by the graduate Advisor).

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

REQUIREMENTS FOR THE ENGINEER DEGREE

Master's degrees in aerospace or mechanical engineering which meet one of the department specialization areas are generally required. Applicants with master's degrees not meeting these requirements may be conditionally admitted with deficiencies as evaluated by a departmental graduate Advisor. All candidates must complete programs of

study of at least 36 units beyond master's degrees as approved by an appropriate departmental graduate advisor. These programs of study normally include at least 24 units of work within the department; part of this work includes a design project of at least 6 but not more than 12 units. Course work may be substituted for the project if the applicants' background includes satisfactory evidence of equivalent experience as evaluated by the guidance committee. In addition, satisfactory attendance in AE 971-72 (Seminar in Aerospace Engineering) is required for two semesters.

REQUIREMENTS FOR THE DOCTOR OF PHILOSOPHY DEGREE

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

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

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

All candidates for the Ph.D. must complete a minimum of 30 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 AE 971-72 (Seminar in Aerospace Engineering) is required each semester (normally, two semesters for the M.S. and four additional semesters for the Ph.D.). All of the above requirements must be completed within time periods consistent with general University regulations.

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

FRESHMAN YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.
<i>First Semester</i>				
CM 101	<i>Gen. Chemistry I</i>	2½	0	2½
CM 111	<i>Gen. Chem Lab I</i>	0	1½	½
MA 101	<i>Calculus I</i>	4	0	4
CS 100	<i>Introduction to Programming</i>	2	0	2
HU 101	<i>Writing and the Humanities I</i>	3	0	3
SL 101	<i>Freshman Seminar</i>	1	1	0
PE 101	<i>Physical Education I</i>	0	2	0
SS 104	<i>Contemporary History</i>	3	0	<u>3</u>
				15

Second Semester

CM 102	Gen. Chemistry II	2½	0	2½
CM 112	Gen. Chem. Lab II	0	1½	½
MA 102	Calculus II	4	0	4
PH 104	Intro. to Physics I	3	0	3
HU 200	Writing and the Humanities II	3	0	3
	Hum/SS Elective ¹	3	0	3
PE 102	Physical Education II	0	2	<u>0</u>
				16

SOPHOMORE YEAR

First Semester

MA 104	Appl'd Diff. Eqns.	3	0	3
PH 105	Intro. to Physics II	3½	0	3½
PH 115	Physics Laboratory II	0	1½	½
ME 101	Graphics	1	3	2
ME 111	Mechanics I	3	0	3
HU 110	Report Writing I	3	0	3
MT 305	Mech. Props. of Metals	3	0	3
PE 103	Physical Education III	0	3	<u>0</u>
				18

Second Semester

MA 103	Calculus III	3	0	3
PH 106	Introduction to Physics III	2½	0	2½
PH 116	Intro. to Physics Lab III	0	1½	½
ME 112	Mechanics II	3	0	3
ME 121	Mech. of Materials	3	0	3
AE 341	Intro. Aero. Design	3	3	4
PH 234	Modern Physics	2	0	2
PE 104	Physical Education	0	2	<u>0</u>
				18

JUNIOR YEAR

First Semester

MA 260	Vectors and P.D.E.	3	0	3
ME 201	Thermodynamics I	3	0	3
AE 231	Fluids I	3	0	3
AE 271	Fund. Stress Anal. I	3	0	3
AE 311	Mechanics of Flight I	3	0	3
	Hum/SS Elective ¹	3	0	3
				18

Second Semester

AE 232	Fluids II	3	0	3
AE 251	Space Dynamics	3	0	3
AE 272	Fund. Stress Anal. II	2½	1½	3
AE 342	Aircraft Design I	2	3	3
EE 370	Princ. of Elect. Eng.	3	0	3
	Hum/SS Elective ¹	3	0	3
				18

SENIOR YEAR

First Semester

AE 233	Fluids II	3	0	3
ME 261	Vibrations	3	0	3
AE 281	Adv. Stress Anal. I	2½	1½	3
AE 343	Aircraft Design II	2	3	3
AE 349	Fluids Lab I	1	3	2
	Technical Elective ²	3	0	3
				17

Second Semester

AE 241	Propulsion	3	0	3
AE 312	Mechanics of Flight II	3	0	3
AE 344	Spacecraft Design	2	3	3
AE 350	Fluid Lab II	0	3	1
	Hum/SS Elective ¹	3	0	3
	Technical Electives ²	3	0	3
				16

Total credits required for graduation: 136

¹ HU/SS elective must meet the concentration requirements described in the section of this catalog entitled "DEGREE REQUIREMENTS", subsection "HUMANITIES AND SOCIAL SCIENCES REQUIREMENTS FOR ENGINEERING AND COMPUTER SCIENCE MAJORS."

² Technical Electives must be of senior-year quality and professionally relevant. Advisor approval required for all Technical Electives.

³ Consult the "DEGREE REQUIREMENTS" section of the catalog for variations in the mathematics and humanities sequence which may result based upon placement examination outcomes.

UNDERGRADUATE COURSES

AE 231 Fluids I 3:0:3

Fluids, kinematics, hydrostatics, thermodynamics. Derivations of continuity, momentum and energy equations. Flux concepts and relation to divergence theorem. Control volume equations and applications. Bernoulli equation. Discussion of vorticity and stream function. Potential flows over simple geometric configurations. *Prerequisites:* MA 103, ME 112.

AE 232 Fluids II 3:0:3

One-dimensional unsteady flow, shock tube. Prandtl-Meyer flow, oblique and normal shocks. Method of characteristics. Laval nozzle flow. Compressible airfoil theory. *Prerequisite:* AE 231, ME 201.

AE 233 Fluids III 3:0:3

Introduction to viscous flow theory. Viscous effects. Stress-strain relations, Reynolds transport theorem. Derivation of Navier-Stokes equations. Rayleigh problem and diffusion time. Similarity theory. Prandtl boundary layer equations, flow over a flat plate. Approximate methods, numerical methods. Separated flows. *Prerequisite:* AE 231.

AE 234 Fluids IV 3:0:3

Incompressible airfoil theory, circulation, lift, Kutta condition. Fanno and Rayleigh flows. 3D wing theory for subsonic and supersonic flows, transonic and hypersonic flows, computational techniques. *Prerequisite:* AE 232.

AE 241 Propulsion 3:0:3

Operation, performance, and design methods for flight vehicle propulsion systems. Airbreathing engines: turbojet, turboprop, turbofan and ramjet. Elements of nuclear and electrical rocket propulsion systems. *Prerequisite:* AE 232.

AE 242 Rocket Propulsion 3:0:3

Development and design of rocket engines. Basic principles of mechanics, thermodynamics, aerodynamics and combustion reviewed. Propellants, rocket engine elements (solid and liquid), heat transfer, cooling accessories, rocket testing and problems associated with rocket design and development. *Prerequisite:* AE 232, ME 201.

AE 251 Space Dynamics 3:0:3

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

AE 271 Fundamentals of Stress Analysis I 3:0:3

Stress, equilibrium equations, strains, compatibility conditions, stress strain relations, superposition, strain energy. Bending of beams: unsymmetric bending of arbitrary section beams, bending stresses, deflections, shear stresses on thin-walled section beams, shear center. *Prerequisite:* MA 104, ME 121.

AE 272 Fundamentals of Stress Analysis II 3:0:3

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. *Prerequisite:* AE 271.

AE 281 Advanced Stress Analysis I 2:1:3

Elastic and inelastic buckling of columns, frames, plates, shells, effective width, sheet-stringer combinations, torsional instability, energy methods for approximate solutions. Laboratory: experimental stress analysis, strain gages, shear center, tension tests, bending of beams. *Prerequisite:* AE 272.

AE 282 Advanced Stress Analysis II 3:0:3

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

AE 311 Mechanics of Flight I 3:0:3

Principles of powered flight. Development of equations of motion. Level flight performance of turbojet and propeller driven aircraft, climbing flight, ceiling, take-off and landing. Steady turning flight. *Prerequisites:* ME 112.

AE 312 Mechanics of Flight II 3:0:3

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

AE 341 Introduction to Aerospace Design 3:3:4

Introduction to lift and drag. Airfoil, wing, and body characteristics. Propulsion systems for atmospheric and space flight. Elementary performance of aircraft and spacecraft. Introduction to the preliminary design of flight vehicles for atmospheric and space missions through the use of design projects.

AE 342 Aircraft Design I 2:3:3

Preliminary design of commercial jet transport. Development of aerodynamic configuration, power plant selection, fuselage lay-out, weight and balance estimation. Performance, stability analyses, airload estimations. *Prerequisite:* AE 311.

AE 343 Aircraft Design II 2:3:3

Structural design of airplane wings based on specifications and aerodynamic requirements. Discussions of construction materials, forming, fasteners, fittings. Structural arrangement of landing gear,

fuselage, stress analysis. *Prerequisite:* AE 342, AE 271.

AE 344 Spacecraft Design 2:3:3

Design of hypervelocity vehicles. Trajectory and orbit analyses, problems of re-entry, propulsion system design, staging. Design of a boost vehicle for satellite missions, and a re-entry vehicle for earth return. *Prerequisite:* AE 251.

AE 349 Fluids Laboratory I 1:3:2

Laboratory experiments in the area of incompressible inviscid and viscous flows. Measurement techniques, conservation laws, boundary layers. *Prerequisite:* AE 231.

AE 350 Fluids Laboratory II 0:3:1

Laboratory experiments in the area of inviscid and viscous flows. Measurement Techniques: hot wire and laser Doppler anemometry. Supersonic flows, shock waves, unsteady flows. *Prerequisite:* AE 349.

AE 381-382 Senior Honors Work in Aerospace Engineering I,II

Credit to be arranged.

Independent project undertaken by qualified honors students in aerospace engineering resulting in a written report. Credit may be awarded toward technical elective requirement. Advisor approval required. Consultation with advisor well in advance of registration is recommended.

AE 391-392 Guided Studies in Aerospace Engineering I,II

Credit to be arranged.

Guided readings in specific subject areas for qualified students in aerospace engineering. Advisor approval required.

GRADUATE COURSES**AE 651 Advanced Dynamics I**

2½:0:3

Kinematics and dynamics of a particle in space; translating and rotating frames of reference. Systems of particles; plane motion of rigid bodies. Two-body central force problem. LaGrange equations with holonomic and nonholonomic constraints; applications. Also listed under ME 651.

AE 652 Advanced Dynamics II

2½:0:3

General motions of rigid bodies, Euler's equations, gyroscopic motions and stability, impulsive motions, linear oscillations of two-degree and n-degree of freedom systems, matrix formulations, applications, variational principles. *Prerequisite:* AE 651. Also listed under ME 652.

AE 682 Aero and Hydroelasticity

2½:0:3

Analysis of problems with nonconservative type forces. Divergence and flutter phenomena, flutter prevention. Applications to vibrations and instabilities in aerospace, mechanical and civil engineering. *Prerequisite:* AE Advisor's approval.

AE 704 Aerothermochemistry

2½:0:3

Fundamentals of chemical thermodynamics, fluid dynamics and chemical kinetics. Applications to combustion and emission phenomena, fluid lasers, plasmas and hypersonics. *Prerequisite:* ME 701.

AE 731 Analytical Methods in Thermal and Fluid Mechanics

2½:0:3

Classifications of differential equations of fluid and thermal mechanics. Methods of characteristics for supersonic flow and wave propagation. Potential methods including complex variable applications for transform techniques in convec-

ENGINEERING

tion and conduction. *Prerequisite:* AE Advisor's approval.

AE 732 Computational Methods in Thermal and Fluid Mechanics 2½:0:3

Numerical analyses. Finite difference approximations, error and stability analyses, numerical dispersion and damping, matrix inversion methods. Implicit and explicit procedures, SOR, ADI, hopscotch and direct solvers for evaluating linear and nonlinear diffusion and convection problems. *Prerequisite:* AE advisor's approval. Also listed under ME 732.

AE 740 Principles of Fluid Dynamics 2½:0:3

Conservation laws of mass momentum and energy. Elements of potential theory. Applications of inviscid flow to simple internal and external geometries; differential approach to fluid dynamic problems; thin airfoil theory. *Prerequisite:* AE advisor's approval.

AE 741 Compressible Flow 2½:0:3

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

AE 742 Viscous Flow 2½:0:3

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

AE 743 Turbulent Flow 2½:0:3

General theories of turbulence, Reynolds Transport theorem, turbulent heat and mass transfer, instability, transition, statistical approach to turbulence, mathematical modeling, experimental methods, analysis of turbulent external flows; jets, wakes, mixing layers, turbulence in boundary flows. *Prerequisite:* AE 742.

AE 744 Viscous Compressible Flow 2½:0:3

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

AE 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:* AE Advisor's approval.

AE 755 Experimental Methods in Thermal and Fluid Mechanics 2½:0:3

Measurement principles including mechanical, electrical, electromagnetic, thermal and optical techniques. Applications to measurements of forces, pressures, heat transfer, velocity and electron density. Schlieren, interferometry, laser, Raman scattering. *Prerequisite:* AE Advisor's approval.

AE 759 Special Topics: Fluid Mechanics 2½:0:3

Topics of particular current interest in fluid mechanics. *Prerequisite:* AE Advisor's approval.

AE 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:* AE Advisor's approval.

AE 803 Vehicle Dynamics I 2½:0:3

Atmospheric flight mechanics of airplanes, quasisteady and dynamic performance in various flight regimes, energy methods. Space vehicles, partial motion in central force field, launch and re-entry

trajectories. Land and seaborne vehicles: automobile, tracked vehicles, ship and GEM vehicles. *Prerequisite:* AE Advisor's approval.

AE 810 Theory of Propulsion 2½:0:3

Principles of modern high-speed 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:* AE advisor's approval.

AE 819 Special Topics: Aeronautics and Astronautics 2½:0:3

Topics of particular current interest in aeronautics and astronautics. *Prerequisite:* AE advisor's approval.

AE 901-904 Guided Readings, I, II, III, IV each 3 units

Open to qualified graduate students interested in special advanced topics. Directed study including analytical work and/or laboratory investigations. *Prerequisite:* written permission of departmental head.

SEMINAR, PROJECTS THESIS AND DISSERTATION

AE 971-972 Seminar in Aeronautics and Astronautics 0

Recent developments through lectures by representatives from industry, research, educational institutions. Discussions from floor. Satisfactory attendance required of master's or engineer students for two semesters; four additional semesters required of Ph.D. students.

AE 996 Project each 3 units

Engineering project pursued with guidance of faculty member. Project titles submitted in writing to department head and advisor appointed for the project. May be extended to thesis with project Advisor's recommendation. Credit only

upon completion of project. Reregistration fee: 3-unit charge. *Prerequisite: degree status.*

AE 997 M.S. Thesis *each 3 units*

Master's thesis to present results of original investigation in field of student's specialty. Thesis an extension of AE 996, on recommendation of project advisor. Continuous registration required. Maximum of twelve units of AE 996-997 counted toward degree. Reregistration fee: 3-unit charge. *Prerequisite: AE 996.*

AE 998 Engineer Project *each 3 units*

Analytical, experimental or design project under guidance of faculty member. Oral examination on project and related topics required of candidates. Continuous registration required until satisfactory project completed. Minimum of six, maximum of twelve units of AE 996-997 counted toward degrees. *Reregistration fee: 3-unit charge.*

AE 999 Ph.D. Dissertation *each 3 units*

Doctor's dissertation evincing independent study and original contributions in field of specialization. Oral examination on subject of dissertation and related topics required. Minimum of 24 units; also continuous registration at minimum of 3 units per semester required until dissertation completed. Reregistration fee: 3-unit charge. *Prerequisite: degree status.*

THE FOLLOWING GRADUATE COURSES ARE OFFERED IRREGULARLY IN RESPONSE TO STUDENT DEMAND:

- AE 623 Computational Methods in Mechanical & Aerospace Engineering I
- AE 624 Computational Methods in Mechanical & Aerospace Engineering II
- AE 714 Radiation Gas Dynamics
- AE 745 Hydrodynamics
- AE 748 Dynamics of Rarefied Gases
- AE 749 Magnetofluid Dynamics
- AE 750 Ocean Waves and Tides
- AE 751 Aerodynamics of Urban Environment I

- AE 752 Aerodynamics of Urban Environment II
- AE 753 Wave Turbulence, I
- AE 754 Wave Turbulence, II
- AE 802 Space Mechanics
- AE 804 Vehicle Dynamics II
- AE 806 Physics of the Atmosphere
- AE 811 Engine-Airplane Integration
- AE 812 Helicopter Theory

FACULTY

Pasquale M. Sforza, Professor and Head of Aerospace Engineering
B.Ae.E., M.S., Ph.D., Polytechnic Institute of Brooklyn
Theoretical and experimental fluid dynamics, aircraft and engine design

Anthony E. Armenakas, Professor
B.S., Georgia Institute of Technology; M.S., Illinois Institute of Technology; Ph.D., Columbia University;
Professional Engineer
Dynamic analysis of structures, fracture, wave propagation, numerical techniques

Robert J. Cresci, Professor
B.Ae.E., M.Ae.E., Ph.D., Polytechnic Institute of Brooklyn
Gas dynamics, heat and mass transfer, industrial aerodynamics

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

James Benton, Industry Associate Professor; B.S., M.S., Ph.D., Polytechnic Institute of Brooklyn
Computational methods, hydrodynamics, vehicle dynamics

Morris P. Isom, Associate Professor
A.B., Harvard University; M.S. Massachusetts Institute of Technology; Ph.D., Princeton University
Acoustics, gas dynamics, applied mathematics

Gabriel Oyibo, Associate Professor
B.Eng.(Aero) Imperial College, Ph.D. Rensselaer Polytechnic Institute
Aeroelasticity, unsteady aerodynamics, transonic flow

Jack E. Werner, Associate Professor
B.S., M.S., Massachusetts Institute of Technology; Ph.D., Johns Hopkins University
Low-speed aerodynamics, shock waves, fluid mechanics

Iraj M. Kalkhoran, Assistant Professor
B.S., M.S., Ph.D., The University of Texas at Arlington
Gas dynamics, high speed flows, wind tunnel testing, shock tubes

M. Volkan Otugen, Assistant Professor
B.S., Technical University of Istanbul, M.S., Ph.D., Drexel University
Experimental and theoretical fluid mechanics, unsteady and turbulent flows, optical diagnostics, combustion aerodynamics

ADJUNCT FACULTY

Martin H. Bloom, University Professor Emeritus; B.M.E., M.S., Ph.D., Polytechnic Institute of Brooklyn
Fluid and thermal studies; aerospace engineering

Sebastian V. Nardo, Professor Emeritus
B.M.E., M.Ae.E., Ph.D., Polytechnic Institute of Brooklyn
Structural mechanics, dynamics

Simon Slutsky, Professor Emeritus
B.C.E., CCNY; M.S., Columbia University; Ph.D., Polytechnic Institute of Brooklyn
Urban noise, engine noise, and vibrations

Martin Goldberg, Adjunct Professor
B.S., N.Y.U.; M.S., University of Buffalo; Ph.D., Rensselaer Polytechnic Institute
Structural mechanics

Robert S. Levy, Adjunct Associate Professor
B.M.E., City College of New York; M.M.E., Ph.D., Polytechnic Institute of Brooklyn
Airplane design

Vito D. Agosta, Professor Emeritus
B.M.E., Polytechnic Institute of Brooklyn; M.S., University of Michigan; Ph.D., Columbia University

CHEMICAL ENGINEERING

Students of chemical engineering are taught to develop knowledge and analytical skills to bridge the technological gap between scientific advances and the economical production of new and useful products.

Chemical engineers rely heavily on science, engineering methods, experience and ingenuity to invent the processes and equipment required to make these products. Chemical engineers have contributed to the development of virtually every material common to modern life. They are involved with the production of petroleum products, plastics, pharmaceuticals, foodstuffs, synthetic rubber and rocket propellants, to name a few. Their influence has been felt in developing nuclear reactors, fuel cells, automatic controls, water desalination plants, missiles, and artificial kidneys.

Students may choose a very wide range of activities, including research, process and product development, design and supervision of the construction and operation of industrial plants, technical sales and services, consulting, management and teaching. Opportunities are virtually unlimited.

The foundations of chemical engineering are the sciences, with emphasis on chemistry, mathematics, physics and the engineering sciences, including thermodynamics, fluid mechanics, kinetics and heat and mass transfer. Chemical engineering courses include the analysis, design and control of equipment, operations and processes.

UNDERGRADUATE PROGRAM

The undergraduate program in chemical engineering provides a sound foundation in science and the engineering sciences and builds on this a strong and integrated set of courses in chemical engineering. Thorough instruction is given in chemistry, physics, mathematics and in the engineering sciences basic to the understanding of physical and chemi-

cal operations and processes. Courses in engineering science include engineering thermodynamics, reaction kinetics, process dynamics, fluid mechanics, heat transfer and mass transfer.

The chemical engineering curriculum provides a background which enables the graduate to select a professional career from an extremely broad spectrum of opportunities. Graduates are prepared to take employment in a number of capacities in industry or to enter graduate school for advanced study in chemical engineering or other fields.

The Department of Chemical Engineering offers undergraduate degree programs at two campuses, Brooklyn and Long Island, with identical curricula and courses.

Students wishing to specialize in certain subject areas may do so through judicious selection of technical electives. Chemical engineering students may be particularly interested in the medical-related field, in environmental problems, in computer applications or management. For example, students interested in medical or biosystems might choose technical elective courses such as LS 105, LS 115, BE 201, BE 206, BE 610, and BE 603, while those interested in environmental studies might choose SS 182, LS 105, LS 140, CE 340, CE 341, CE 770, CE 342 and CH 752. A management emphasis might be developed by choosing MG 300, SS 251 & 252, IE 252, IE 327 and MG 601. Similarly, an emphasis in computer sciences could be arranged. Specializations can be developed with departmental advisors.

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

Polytechnic requires a 2.0 minimum average for graduation. Students must meet the academic standards of the department. For students to advance to the senior year, a 2.0 grade average must be maintained in chemical engineering courses CH 123, CH 220, CH 221, CH 250, CH 252, CH 261; the same course must not be failed twice. Students who

do not meet these requirements will not be allowed to register for senior courses. All listed prerequisites must be satisfied before the students are permitted to enroll in chemical engineering courses.

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

FRESHMAN YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.
First Semester				
MA 101	Calculus I ¹	4	0	4
CS 100	Intro. to Computer Programming	2	0	2
CM 101	Gen. Chem I	2½	0	2½
CM 111	Gen. Chem. Lab I	0	1½	½
HU 101	Writing and the Humanities I ¹	3	0	3
SS 104	Main Themes in Contemporary World History	3	0	3
SL 101	Freshman Seminar	1	1	<u>0</u>
				15
Second Semester				
MA 102	Calculus II ¹	4	0	4
PH 104	Intro. Physics I	3	0	3
CM 102	Gen. Chem II	2½	0	2½
CM 112	Gen. Chem Lab II	0	1½	½
HS	Hum./Social Science Elective. ²	3	0	3
HU 200	Writing and the Humanities II ¹	3	0	<u>3</u>
				16

SOPHOMORE YEAR**First Semester**

MA 103	Calculus III	3	0	3
PH 105	Intro. Physics II	3½	0	3½
PH 115	Physics Lab I	0	1½	1½
CH 110	Intro. Statics	1	0	1
CH 123	Chem. Proc. Anal. I	2	0	2
CM 122	Organ. Chem I	3	0	3
CM 124	Organ. Chem Lab I	½	5	2
HS	Hum./Social Science Elective ²	3	0	3
				18

Second Semester

MA 104	Appl. Diff. Eqns.	3	0	3
TE or FE	Tech. or Free Elect.	3	0	3
CH 250	Chem. Engineering Thermodynamics I	3	0	3
CM 161	Physical Chem I	3	0	3
CM 123	Organic Chem II	2	0	2
PH 106	Intro. Physics III	2½	0	2½
PH 116	Physics Lab II	0	1½	1½
				18

JUNIOR YEAR**First Semester**

CH 220	Transfer Operation I	4	0	4
CH 252	Chemical Engineering Thermodynamics II	3	0	3
CM 162	Physical Chemistry II	3	0	3
TE	Technical Elective	x	x	4
FE or TE	Free Elective	x	x	3
	Technical Elective			17

Second Semester

CH 221	Transfer Operation II	4	0	4
CH 261	Multistage Separation Proc.	3	0	3
EE 270	Principles of Electrical Eng.	3	0	3
EE 374	Instrumentation Lab	0	3	1
HS	Hum./Social Science Elective ²	3	0	3
MT 305	Engineering Prop. of Materials	3	0	3
				17

SENIOR YEAR**First Semester**

CH 301	Chem Eng. Lab I	0	6	2
CH 322	Chem Reactor Eng.	3	0	3
CH 351	Process Dynamics and Control	2	3	3
HS	Hum./Social Science Elective	3	0	3
	Technical Elective	x	x	3
				17

Second Semester

CH 302	Chem Eng. Lab II	0	6	2
CH 372	Engineering Polymeric Materials	3	0	3
CH 362	Process Design II	3	0	3
TE	Technical Elective	x	x	6
HS	Hum./Social Science Elective ²	3	0	3
				17

1 Consult the "DEGREE REQUIREMENTS" section of the catalog for variations in the mathematics and humanities sequence which may result based upon placement examination outcomes.

2 HU/SS electives must meet the concentration requirements described in the section of this catalog entitled "DEGREE REQUIREMENTS", subsection "Humanities and Social Science electives for Engineering and Computer Science majors".

ELECTIVES

Elective courses are chosen in consultation with the chemical engineering undergraduate advisor. According to the following guidelines:

- For information on humanities and social science electives, students should refer to the section of this catalog entitled "Humanities and Social Sciences Requirements for Engineering and Computer Science Majors".
- A total of 17 credits of technical electives is necessary. In fulfilling this requirement, the student must choose at least 3 credit hours of mathematics, 3 credit hours of chemistry or biosciences and 6 credit hours of chemical engineering electives from an approved list available in the chemical engineering office. The remaining 5 credit hours may be taken in any advanced level technical area in consultation with the departmental advisor.
- Junior transfer students should take CH 123 and CH 250 in junior year in place of electives. It is strongly recommended that a Chemistry elective be chosen from either CM 119 or CM 201.
- PH 106 must be co- or prerequisite.

- Students taking CS 112 (i.e. undeclared major) in freshman year will take free short course before or during Fall Sophomore semester to obtain CS 100 equivalency (FORTRAN).
- Only one FE (Free Elective) is permitted in program.

GRADUATE PROGRAMS

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

The Departments of Chemical Engineering and Chemistry jointly offer programs leading to degrees of master of science and doctor of philosophy in polymer science and engineering which is described in a separate section of this catalog.

A degree in chemical engineering is generally required for admission to graduate study. An applicant who has earned a bachelor's degree from a foreign institution is required to submit Graduate Record Examination and TOEFL scores. Students must have had differential equations. Applicants with degrees in other fields or from other colleges may be admitted with undergraduate and/or graduate deficiencies as evaluated by the graduate advisor. The program leading to the master's in chemical engineering may be used as either a terminal course for development and advanced design, or as a research degree giving preliminary graduate training for the doctorate in chemical engineering.

The doctor of philosophy in chemical engineering degree program provides advanced graduate study and research for qualified students interested in research and development.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE IN CHEMICAL ENGINEERING

Candidates for the degree of Master of Science in Chemical Engineering are to plan their programs in accordance

ENGINEERING

with the following list of requirements for full time study:

1. Required Subjects	Credits
CH 631 <i>Transport Phenomena I</i>	3
CH 632 <i>Transport Phenomena II</i>	3
CH 772 <i>Thermodynamics II</i>	3
CH 781 <i>Chemical Reactor Analysis and Design</i>	3
CH 821 <i>Process Dynamics and Control</i>	3
CH 991/ <i>Seminar in Chemical Engineering</i>	0

2. Electives: 3 courses

At least two electives must be chosen from CH 600-CH 928 while the third one may be chosen from another science or engineering department with the approval of the graduate advisor in chemical engineering.

3. CH 997 <i>Master's Thesis</i>	12
<i>Total</i>	36

Part time students can choose between the above program and the Guided Study Option which includes the following requirements:

1. Required subjects: as above	15
2. Electives: 5 courses	15

At least two electives must be chosen from CH 600 - CH 928 while the other three may be chosen from other science or engineering departments with the approval of the graduate advisor in chemical engineering.

3. CH 902 <i>Guided Study in Chemical Engineering</i>	6
<i>Total</i>	36

To meet graduation requirements, students must have an overall B average in all courses (excluding M.S. Thesis or Guided Study Project) and must not obtain more than three grades of C in required subjects.

REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN CHEMICAL ENGINEERING

Programs of study are planned individually with each candidate by members of the Department of Chemical Engineering. Systematic study toward a doctor's degree is carried out under a guidance committee appointed by the Office of Research and Graduate Studies. The

program is planned to give the student a thorough chemical engineering background accompanied by study of a minor field chosen by the candidate. The student must pass a comprehensive qualifying examination in chemical engineering and present a doctoral dissertation.

Each candidate for the doctorate must complete a minimum of 90 units (credits) of academic work past the Bachelor's degree, including a minimum of 48 units of dissertation research. Although the student may elect to take more than 48 units of Ph.D. Thesis, only 48 of those units can be counted in the required 90 units. Furthermore, of those 48 units at least 36 must be taken beyond M.S. Thesis and at Polytechnic University. A minimum of 24 graduate units beyond the Bachelor's Degree (not including Ph.D. or M.S. Thesis units) are required in Chemical Engineering subjects, of which at least 9 must be taken at Polytechnic in the required subjects. A minor is required within a science or engineering department and must consist of at least 9 units taken at the Polytechnic. The minor must meet the approval of the graduate advisor in chemical engineering. Attendance is required at Chemical Engineering Seminars for at least four semesters. To meet graduation requirements, students must have an overall B average in all courses, excluding Thesis, and must not obtain more than three grades of C in required subjects.

Candidates for the degree of Doctor of Philosophy in Chemical Engineering are to plan their programs in accordance with the following requirements:

1. Required Subjects	Units
CH 631 <i>Transport Phenomena I</i>	3
CH 632 <i>Transport Phenomena II</i>	3
CH 771 <i>Thermodynamics I</i>	3
CH 772 <i>Thermodynamics II</i>	3
CH 781 <i>Chemical Reactor Analysis and Design</i>	3
CH 821 <i>Process Dynamics and Control</i>	3
CH 991 (2 yrs) <i>Seminar in Chemical Engineering</i>	0

2. Electives: 5 courses, of which at least two must be in chemical engineering subjects.	15

To be chosen in conference with the graduate advisor in Chemical Engineering.

3. Minor: 3 courses	9

A minor must be taken from another science or engineering department with the approval of the graduate advisor in Chemical Engineering.

4. CH 999 <i>Ph.D. Thesis</i>	48
Up to twelve units of Master's Thesis can be included here.	90

UNDERGRADUATE COURSES

CH 110 Introductory Statics 1:0:1

Vector algebra. Static equilibrium of particles and rigid bodies. *Prerequisite:* PH 104 and MA 102.

CH 123 Chemical Process Analysis I 2:0:2

Introduction to chemical processes, synthesis and design. Flow sheets. Material balances. Recycle. Properties of materials. Modern computer methods. *Prerequisite:* Knowledge of programming.

CH 220 Transfer Operations I 4:0:4

Introduction to transport processes from the standpoint of the laws of conservation, rate phenomena and natural and imposed constraints. Unit operations; distributed versus lumped-parameter systems. Momentum transport and fluid flow operations in laminar and turbulent flow. *Prerequisites:* CH 124 and MA 104 or advisor's approval.

CH 221 Transfer Operations II 4:0:4

Continuation of theory of transfer operations with applications to chemical engineering systems. Energy and mass transport; heat transfer and diffusional mass transfer operations. *Prerequisite:* CH 220.

CH 250 Chemical Engineering Thermodynamics I 3:0:3

Thermodynamics principles of chemical processes. First law of Thermodynamics. Energy balances for closed and open systems. Combined energy and materials balances. Humidity and psychrometric charts. Heat capacities and heats of reaction. Equations of state for real fluids. Introduction to Second Law of Thermodynamics. *Prerequisite:* CH 123.

CH 252 Chemical Engineering Thermodynamics II 3:0:3

Thermodynamics analysis of cyclical processes. Application of First and Second Law for real fluids with equations of state. Ideal and non-ideal mixtures. Partial molar and excess properties of mixtures. Heats of mixing and enthalpy concentration diagram. Phase equilibrium calculations at low and elevated pressures by computer procedures. Chemical reaction equilibria. *Prerequisites:* CM 161 and CH 250 or advisor's approval.

CH 261 Multistage Separation Processes 3:0:3

Unified treatment of separation processes utilizing the multi-stage model and mass and energy balances, e.g., absorption, extraction, distillation. Equilibrium stages, stage efficiencies, reflux and system parameters. Graphical, analytical and digital computer techniques of modeling stressed. *Prerequisites:* CH 220 and CH 251, or advisor's approval.

CH 301-302 Chemical Engineering Laboratory I, II each 0:6:2

Experimental studies in chemical engineering. Unit operations, transport processes, thermodynamics, reaction kinetics, process instrumentation, process dynamics and controls. Design and conduct of experiments, interpretations of results, preparation of engineering reports. Data analyses done with computers. *CH 301 prerequisites:* CH 261 and CH 221. *CH 302 prerequisites:* CH 301, CH 322 and CH 351.

CH 322 Chemical Reactor Engineering 3:0:3

Application of thermodynamics and chemical kinetics to analysis and design of chemical reactors and reactor systems. Homogeneous and heterogeneous reactors of various types, uncatalyzed and catalyzed. Design of single and cascaded industrial reactors. *Prerequisites:* CH 221, CH 251 or instructor's permission.

CH 351 Process Dynamics and Control 2:3:3

Dynamic simulation of chemical processes. Frequency response techniques. Design of feedback and feedforward controllers. Introduction to nonlinear control. Self study laboratory using IBM's Advanced Control System (ACS). *Prerequisites:* CH 221, CH 261, MA 104 or advisor's approval.

CH 361 Process Design I 3:0:3

Syntheses and designs of chemical processes, with considerations of site and process selections process economics, materials of construction, data requirements and acquisition flowsheeting and subsystems. Computer utilized. Case studies. *Prerequisite:* CH 261 and Co/*Prerequisite:* CH 351.

CH 362 Process Design II 3:0:3

Designs of large chemical process systems, with special emphasis on more complex, integrated process schemes and systems optimization. *Prerequisites:* CH 322 and CH 361.

CH 372 Engineering Polymeric Materials 3:0:3

Processing, structure, properties and applications of polymers and their composites as engineering materials. Fundamentals of processing and morphology of polymers. Basic concepts of viscoelasticity, fracture behavior and, thermal and electrical properties of polymers and their composites. *Prerequisites:* CM 162 or CH 322, CM 123 and CM 124, MT 305.

CH 380-381 Chemical Engineering Project *variable credit to max. of 3 each*

Independent work in areas of interest in chemical engineering selected by students and faculty supervisors. Not open to honors or senior thesis students. CH 380 only or both CH 380 and CH 381 may be taken. *Prerequisite:* department's approval.

CH 391-392 Bachelor's Thesis in Chemical Engineering *variable credit*

Original investigations of problems in chemical engineering. A thorough search of the literature required. Special apparatus constructed as required for experimental work.

CH 396 Chemical Engineering Internships 3 credits

Supervised, creative engineering experiences of at least two months duration, typically taken during the summer, culminating in written and oral reports presented to the industrial and faculty supervisors. Faculty visitations and conferences during internships are arranged. *Prerequisite:* senior standing and advisor'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 631-632 Transport Phenomena I, II** *each 2½:0:3*

Fundamental concepts of momentum, energy and mass transport; transport in stationary and flowing systems, steady-state and transient conditions. Elementary Cartesian vector and tensor analyses; conservation equations for general cases and in macroscopic form; rate expressions. Fluid dynamics, energy transfer and diffusion; turbulent transport; transport coefficients; analogies; dimensional

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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 672 Fundamentals of Biochemical Engineering* 2½:0:3

Kinetics of enzymatic reactions. Transport phenomena in microbial systems. Designs and analyses of biochemical reactors. Principles of natural product isolations. Genetic engineering, and chemical processes. **Prerequisite:** instructor's permission.

CH 752 Air Pollution Engineering Control* 2½:0:3

Pollutant emissions control; analysis of pollutant properties, concentrations and boundary conditions; absorptive and reactive recovery processes for moving and stationary sources; formation and removal of gaseous oxides (NO_x, SO_x, CO, etc.) and of aerosols and other particulates. **Prerequisite:** advisor's approval. Also listed under CE 758.

CH 766 Process Heat Transfer* 2½:0:3

Thermal designs of industrial heat exchangers, including condensers and forced and natural circulation reboilers; process design of fired heaters; optimum uses of extended surfaces; heat transfers and power requirements of agitated jacketed vessels. **Prerequisite:** instructor's permission.

CH 771 Chemical Engineering Thermodynamics I 2½:0:3

Laws of thermodynamics, conditions for 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 potentials, standard states, ideal solutions, introduction to chemical and phase equilibria. **Prerequisite:** CH 251 or equivalent.

CH 772 Chemical Engineering Thermodynamics II 2½:0:3

Advanced treatment of chemical and phase equilibria, phase rules, Gibbs-Dunham equation, non-ideal solutions; stability of thermodynamic systems, osmotic pressures, surface tensions, thermodynamic equilibria in potential fields; introduction to irreversible thermodynamics. **Prerequisite:** CH 771 or equivalent.

CH 781 Chemical Reactor Design I 2½:0:3

Kinetics of complex homogeneous and heterogeneous reactions; determination of kinetic parameters; effects of transport processes; catalyst deactivation. Analysis and design of reactors; ideal reactors, effects of non-ideal flow; fixed-bed, fluidized-bed and multiphase reactors. **Prerequisite:** CH 322.

CH 784 Heterogeneous Catalysis 2½:0:3

Kinetics of elementary steps (adsorption, surface reaction, desorption) and overall catalytic reactions: uniform and nonuniform surfaces, structure sensitivity, metal-support interactions, transport effects. Characterization of catalysts: preparation methods, analytical techniques. **Prerequisite:** CH 781 or equivalent.

CH 819 Machine Computations in Chemical Engineering 2½:0:3

Digital computer applications in chemical engineering. Topics include programming languages such as FORTRAN, analog simulation languages such as CSMP and general simulation techniques using GPSS. Applications to material and energy balances, designs and optimizing distillation processes, heat transfer apparatus, processing flow sheets, uses of matrix methods in formulating and solving chemical engineering problems. **Prerequisite:** CS 100 or equivalent.

CH 821 Process Dynamics and Controls 2½:0:3

Instrumentation and control of chemical processes from the view-point of systems engineering. Unsteady state behavior of chemical engineering systems. Analyses of closed-loop feedback systems for control of variables of chemical processes equipment. **Prerequisite:** CH 351 or equivalent.

CH 862 Rheology of Non-Newtonian Fluids* 2½:0:3

Classifications of non-Newtonian viscoelastic fluids. Derivations of rheological equations of state from continuum mechanics points of view. Molecular viscoelastic theories: random-coil and network theories. Experimental characterizations of non-Newtonian fluids; steady and dynamic experiments, measurements of normal stress differences in shear flow. Engineering applications to polymer processing operations. **Prerequisites:** CH 631, MA 531 and MA 532 or equivalent.

CH 900-901 Selected Topics in Chemical Engineering each 2½:0:3

Topics of special current interest in chemical engineering, as announced in advance of a particular semester offering. **Prerequisite:** advisor's approval.

PROJECTS THESES AND SEMINARS

CH 902 Guided Studies in Chemical Engineering 6 units, each 2 units

Selections, analyses, solutions, and presentations of engineering reports of problems in processes or equipment design, thermodynamic studies or correlations, or other fields of chemical engineering practices under supervision of staff member. Conferences scheduled. Master's degree candidates required to submit three unbound copies of typewritten reports to advisors one week before the last day of classes. **Prerequisite:** degree status.

CH 930 Guided Studies in Polymer Science and Engineering
6 units, each 2 units

Selections, analyses, solutions, and presentations of comprehensive reports of problems involving polymeric materials, such as polymer synthesis, processing, evaluations, and equipment design. Supervision by staff members. Conferences scheduled. Master's degree candidates required to submit three unbound copies of typewritten project reports to advisors one week before last day of classes. *Prerequisite: degree status.*

CH 987 Thesis for Degree of Master of Science in Polymer Science and Engineering
9 units, each 3 units

Theses for master's degree in polymer science and engineering should give results of original investigations of problems in the chemistry and chemical engineering of polymeric materials. Theses may involve experimental research, theoretical analyses, process designs or combinations thereof. Master's degree candidates required to submit four typewritten unbound thesis copies to advisors before or on the seventh Wednesday before commencement. *Prerequisite: degree status.*

CH 989 Dissertation for Degree of Doctor of Philosophy in Polymer Science and Engineering
30 units, each 3 units

See description for CH 999. A wide variety of problems may be selected from topics in polymer science and engineering. *Prerequisite: see CH 999.*

CH 991-992 Seminars in Chemical Engineering *nc*

Recent developments in chemical engineering are presented through lectures given by engineers from industry, research and educational institutions, by staff members and by qualified graduate students. Required for two semesters of all graduate students seeking degrees.

CH 997 Thesis for Degree of Master of Science in Chemical Engineering
9 units, each 3 units

Theses for master's degree in chemical engineering should give results of original investigation of problems in chemical engineering or application of physical, chemical or other scientific principles to chemical engineering. Theses may involve experimental research, theoretical analyses or process designs or combinations thereof. Master's degree candidates required to submit four typewritten unbound thesis copies to advisors before or on the seventh Wednesday prior to commencement. *Prerequisite: degree status.*

CH 999 Dissertation for Degree of Doctor of Philosophy in Chemical Engineering
30 units, each 3 units

Dissertations must give results of independent investigations of problems in chemical engineering and may involve experimental and/or theoretical work. Theses must show ability to do creative work and that original contributions have been made to chemical engineering, which are worthy of publication in recognized journals. Candidates required to take oral examinations on subjects of theses and related topics. Doctor's degree candidates required to submit five unbound thesis copies to advisors before or on the seventh Wednesday prior to commencement. *Prerequisites: degree status and a qualifying examination on quantitative aspects of chemical engineering.*

THE FOLLOWING GRADUATE COURSES ARE OFFERED IRREGULARLY IN RESPONSE TO STUDENT DEMAND

- CH 611 Unit Processes of Chemical Technology
- CH 612 Chemical Processes and Project Evaluations
- CH 615 Applied Mathematics in Chemical Engineering
- CH 641 Particle Transport Processes
- CH 721 Mass Transfer Operations
- CH 782 Chemical Reactor Design II
- CH 791 Modern Electrochemistry
- CH 851 Process Design & Synthesis I
- CH 852 Process Design & Synthesis II

FACULTY

Allan S. Myerson, Joseph J. and Violet J. Jacobs Professor and Head, Department of Chemical Engineering B.S., Columbia University; M.S., Ph.D., University of Virginia
Crystallization, mass transfer, biochemical engineering

Robert C. Ackerman, 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

Chang Dae Han, Professor of Chemical Engineering and Director of Polymer Science and Engineering Program B.S., Seoul National University; M.S., Sc.D., Massachusetts Institute of Technology; M.S., Newark College of Engineering; M.S., New York University
Rheology, polymer processing, process control

T.K. Kwei, Professor of Chemistry and Chemical Engineering B.S., National Chiao-Tung University (China); M.S., University of Toronto; Ph.D., Polytechnic Institute of Brooklyn
Polymer-polymer miscibility, phase relationships in polymers

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

Robert J. Farrell, Associate Professor of Chemical Engineering B.S. Polytechnic Institute of Brooklyn; M.S., University of Connecticut, Ph.D. Polytechnic Institute of New York.
Process simulation, control, and optimization, chemical process design.

Jovan Mijovic, Associate Professor of Chemical Engineering
B.S., University of Belgrade; M.S., Ph.D., University of Wisconsin (Madison);
Polymer morphology, fracture properties of polymers, adhesives and composites

Leonard I. Stiel, Associate Professor of Chemical Engineering
B.S., Massachusetts Institute of Technology; M.S., Ph.D., Northwestern University
Thermodynamic properties of mixtures, properties of polar fluids

Edward N. Ziegler, Associate Professor of Chemical Engineering
B.Ch.E., CCNY; M.S., Ph.D., Northwestern University
Kinetics and reactor design, air pollution control, fluidization

Nitash P. Balsara, Assistant Professor of Chemical Engineering
B.S., Indian Institute of Technology (Kanpur), M.S., Ph.D., Rensselaer Polytechnic Institute
Polymer Phase Behavior, Scattering (light, x-rays neutrons) and diffusion

Walter P. Zurawsky, Assistant Professor of Chemical Engineering
B.A., Temple University; M.S., Ph.D., University of Illinois
Plasma polymerization, polymer adhesion

EMERITUS FACULTY

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

Donald F. Othmer, Professor Emeritus of Chemical Engineering
B.Ch.E., D.Sc., University of Nebraska, M.Ch.E., Ph.D., University of Michigan; D.Eng.(Hon.), New Jersey Institute of Technology
Energy conversion processes, thermodynamics of phase equilibria

W. Fred Schurig, Professor Emeritus of Chemical Engineering
B.Ch.E., M.Ch.E., Polytechnic Institute of Brooklyn
Unit operations, laboratory information

CIVIL ENGINEERING

Civil engineers build the structures and infrastructures of modern society. They design and supervise the construction of buildings, bridges, roads, airports, dams, irrigation systems, harbors, wastewater and water supply plants, tunnels and offshore platforms. The wide spectrum of the civil engineering profession is reflected by the technical divisions of the American Society of Civil Engineers - aerospace, air transport, construction, energy, engineering management, engineering mechanics, environmental engineering, highway, hydraulics, irrigation and drainage, materials engineering, pipeline, structural, surveying engineering, urban planning and development, urban transportation, water resources planning and management, waterway, port, coastal and ocean engineering.

Civil engineering is a multi-dimensional profession which involves a wide variety of engineering tasks and applications offering a multitude of challenging career opportunities. The wide range of professional careers involve engineering design, construction supervision, urban system planning, engineering management, research, and product technology development.

Many civil engineers pursue their professional careers in private practice as consultants or as employees of major municipal service organizations, government construction and regulatory agencies, transportation authorities, architects and urban planners. Others are employed by construction or manufacturing companies. Civil engineers act as city and regional engineers, interacting with planning officials, political authorities and the public to develop and maintain the nation's vital transportation and other infrastructure networks, improve public services, optimize the use of water and energy resources, upgrade housing and mass transportation systems, and protect the natural environment. Environmental engineering is closely linked to civil engineering but goes beyond the "design

and build" function to examine basic problems of scarce natural resources, pollution control and waste disposal. Transportation planners and engineers design, maintain and operate efficient and cost-effective mass transportation and highway systems.

Many civil, environmental and transportation engineers continue beyond the bachelor's degree to graduate studies and research at the master's, engineer's, and doctoral levels. Others branch out into law, management, planning, and other fields.

UNDERGRADUATE PROGRAM

The undergraduate program leading to the Bachelor of Science in Civil Engineering is accredited by the Accreditation Board for Engineering and Technology (ABET).

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

TECHNICAL ELECTIVES

To allow students to broaden their technical knowledge, the curriculum provides 9 technical elective credits of

appropriate coursework; at least 6 of these credits must carry civil engineering designation and be completed at Polytechnic. Approved technical electives are indicated below, including a number of graduate courses that are suitable for undergraduate students. Senior courses in other departments, and other graduate courses may be chosen, but they require the approval of a departmental advisor.

No.	Technical Electives	Credits
CE 336	<i>Timber and Masonry Structures</i>	3
CE 353	<i>CAD in Civil Engineering</i>	3
CE 606	<i>Bridge Engineering</i>	3
CE 712	<i>Water Resources Projects</i>	3
CE 726	<i>Computer Applications in Water Resources</i>	3
CE 751	<i>Environmental Health Eng.</i>	3
CE 805/	<i>Traffic Engineering I</i>	3
TR 701		
CE 827/	<i>Contracts & Specifications</i>	3
MG 827		
CE 849	<i>Environmental Geotechnology</i>	3
CE 850	<i>Ground Improvement</i>	3
IE 800	<i>Engineering Economy</i>	3
MA 153	<i>Elements of Linear Algebra</i>	3
MA 217	<i>Complex Variables</i>	3
MA 223	<i>Introduction to Probability</i>	3

ROTC students should note that juniors and seniors may substitute three of the two-credit courses MS 301, 303, 401 and 403 for six credits of technical electives.

HUMANITIES AND SOCIAL SCIENCE REQUIREMENTS

Elective courses are chosen in consultation with a civil engineering undergraduate advisor according to university and departmental guidelines:

For further information, students should refer to the section of this catalog entitled "Humanities and Social Sciences Requirements for Engineering and Computer Science Majors".

TRANSFER STUDENTS (Undergraduate)

Potential transfer students should refer to the University guidelines as shown elsewhere in this catalog. The faculty of the Civil and Environmental Engineering Department has established its own additional requirements and interpreted the University guidelines as follows:

The 136-credit curriculum is fulfilled through a combination of transfer credits, credits by examination and course credits completed at Polytechnic. Transfer credits for courses in mathematics, physics, chemistry, the humanities and social sciences are evaluated by the Admissions Office with the guidance of the faculty of the individual departments.

The length of time for a transfer student to complete the degree requirements will depend on the following factors:

- the number of transfer credits awarded
- the particular courses required to complete the degree requirements
- enrollment status, i.e., full-time or part-time

In general, as part of the 136 credit curriculum, students from accredited schools must complete a minimum of 24 credits at Polytechnic with a civil engineering designation as indicated below:

Junior Year (Day)		Senior Year (Day)	
CE 322	1st term	CE 252	1st term
		CE 317	
CE 323	2nd term	CE 332	2nd term
CE 331		CE 342	
CE 340			

Because of the sequential nature of these courses, four successive semesters are usually required. Additional credits may be required, as determined by the transfer credit evaluation, to complete the bachelor's degree requirements. International students holding degrees from schools in their own countries are required to fulfill these requirements to earn a Polytechnic bachelor's degree.

Transfer students from schools with 2-year AAS degree programs in Engineering Science can normally expect to complete the bachelor's degree require-

ments within two years, with appropriate summer school coursework immediately before the junior year.

Students from 2-year technology programs are granted transfer credits according to the schools from which they come. With careful planning, it is generally possible to complete the necessary work in three years, including summer school coursework.

PART-TIME STUDENTS (Undergraduate)

Prospective students planning to earn a degree on a part-time basis should contact an undergraduate advisor for details about this plan before enrolling. Most upper-level courses for part-time students are offered on an alternate-year basis and may be integrated with the day program using a late afternoon schedule starting at 4 pm. A sample 8-year program is shown for part-time study; courses in the first 3 years of this program are often available only on day schedules.

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

FRESHMAN YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.
First Semester				
MA 101	<i>Calculus I</i> <i>(or MA 100')</i>	4	0	4
CM 101	<i>Gen. Chem. I</i>	2½	0	2½
CM 111	<i>Gen. Chem Lab I</i>	0	1½	½
SS 104	<i>Main Themes in</i> <i>Contemporary</i> <i>World History¹</i>	3	0	3
HU 101	<i>Writing and the</i> <i>Humanities¹</i>	3	0	3
ME 101	<i>Graphics</i>	1	3	2
SL 101	<i>Freshman Seminar</i>	1	1	0
				15

Second Semester

MA 102	Calculus II (or MA 110')	4	0	4
CM 102	Gen. Chem. II	2½	0	2½
CM 112	Gen. Chem. Lab II	0	1½	½
PH 104	Intro. Physics I	3	0	3
HU 200	Writing and the Humanities II ¹	3	0	3
CS 100	Intro. to Computer Programming	2	0	2
				15

SOPHOMORE YEAR

First Semester

MA 104	Applied Differential Equations	3	0	3
PH 105	Intro. Physics II	3½	0	3½
PH 115	Physics Lab I	0	1½	½
ME 111	Mechanics I	3	0	3
CE 152	Eng. Meas. & Instr.	2½	1½	3
HU 110	Basic Report Writing I	3	0	3
				16

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.

Second Semester

MA 103	Calculus III	3	0	3
ME 112	Mechanics II	3	0	3
CE 202	Mech. of Materials	3	0	3
CE 306	Nature & Prop. Struct. Mats.	2	3	3
(First Junior Semester in Farmingdale)				
EE 370	Principles of E.E.	3	0	3
PH 106	Intro. Physics III	2½	0	2½
PH 116	Physics Lab II	0	1½	½
				18

JUNIOR YEAR

First Semester

CE 214	Computer Techniques in Engineering	2	3	3
CE 223	Fluid Mechanics (Sec. Sophomore Sem. in Farmingdale)	2½	1½	3
CE 322	Anal. of Struct. I	3	0	3
CE 352	Traffic Eng. (Sec. Sem. in Farmingdale)	3	0	3
ME 201	Thermodynamics	3	0	3
	Hum./Soc. Sci. Elect.	3	0	3
				18

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

FIRST YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.

First Semester

MA 101	Calculus I (or MA 100)	4	0	4
MA 101	Writing and the Hum.	3	0	3
HU 101	Graphics	1	3	2
				9

Second Semester

MA 102	Calculus (or MA 110)	4	0	4
PH 104	Intro. Physics I	3	0	3
SS 104	Main Themes in Contemp. World History	3	0	3
				10

SECOND YEAR

First Semester

MA 104	Appl. Diff. Eqs.	3	0	3
PH 105	Intro. Physics II	3½	0	3½
PH 115	Physics Lab I	0	1½	½
HU 200	Writing and the Humanities II	3	0	3
				10

Second Semester

MA 103	Calculus III	3	0	3
PH 106	Intro. Physics III	2½	0	2½
PH 116	Physics Lab II	0	1½	½
CS 100	Intro. to Computer Programming**	2	0	2
				8

THIRD YEAR

First Semester

ME 111	Mechanics I	3	0	3
CM 101	Gen. Chemistry I	2½	0	2½
CM 111	Gen. Chem. Lab	0	1½	½
	Mathematics Elective*	3	0	3
				9

Second Semester

ME 112	Mechanics II	3	0	3
CM 102	Gen. Chemistry II	2½	0	2½
CM 112	Gen. Chem. Lab II	0	1½	½
				6

FOURTH YEAR

First Semester

CE 202	Mech. of Materials	3	0	3
HU 110	Basic Report Writing	3	0	3
				6

Second Semester

CE 223	Fluid Mechanics	2½	1½	3
CE 322	Analysis of Struct. I	3	0	3
EE 370	Principles of E.E.**	3	0	3
				9

FIFTH YEAR**

First Semester

CE 214	Computer Techniques in Engineering	2	3	3
ME 201	Thermodynamics I	3	0	3
	Hum./Social Science Elective	3	0	3
				9

Second Semester

CE 232	Soil Mechanics	2	3	3
CE 306	Nature & Prop. Struct. Mats.	2	3	3
CE 340	Water Resources & Hydr. Eng.	3	0	3
				9

SIXTH YEAR***

First Semester

CE 152	Eng. Meas. & Instr.	2½	1½	3
	Hum./Social Science Elective	3	0	3
				6

Second Semester

CE 323	Anal. of Struct. II	3	0	3
	Steel Structures	2	3	3
	Hum./Social Science Elective	3	0	3
				9

Second Semester

CE 232	Soil Mechanics	2	3	3
CE 323	Anal. of Struct. II	3	0	3
CE 331	Steel Structures	2	3	3
CE 340	Water Resources & Hydr. Eng.	3	0	3
CE 351	Highway and Transportation Engineering (First Semester in Farmingdale)	2	3	3
	Hum./Social Science Elective ²	3	0	3
				18

SENIOR YEAR

First Semester

CE 252	Reinforced Concrete Struct.	3	0	3
CE 317	Foundations	2	3	3
CE 341	Environmental Eng. I	2	3	3
	Hum./Social Science Elective ²	3	0	3
	Technical and Math. Electives*			6
				18

Second Semester

CE 335	Project Mgmt. for Construction	3	0	3
CE 332	Design of Structural Systems	2	3	3
CE 342	Environ. Eng. II	2	3	3
	Hum./Social Science Elective ²	3	0	3
	Technical and Math. Elective*			6
				18

Minimum total credit required for graduation: 136
A minimum GPA of 2.0 also is required.

* Total of 12 credits of technical and mathematics electives, comprising 9 credits of technical electives, and 3 credits of mathematics elective covering college level material beyond MA 102.

¹ Consult catalog section "DEGREE REQUIREMENTS" for alternative math and a humanities sequence which may result from placement examination outcomes.

² HU/SS electives must meet requirements outlined "DEGREE REQUIREMENTS", subsection "Humanities and Social Science Electives for Engineering and Computer Science Majors".

SEVENTH YEAR**

First Semester

CE 341	Environmental Eng. I	2	3	3
CE 352	Traffic Eng.	3	0	3
	Technical Elective	3	0	<u>3</u>
				9

Second Semester

CE 342	Environmental Eng. II	2	3	3
CE 351	Highway & Transport. Engineering	2	3	3
	Hum./Social Science			
	Elective	3	0	<u>3</u>
				9

EIGHTH YEAR**

First Semester

CE 252	Reinf. Concrete Structures	3	0	3
CE 317	Foundation	2	3	3
	Technical Elective	3	0	<u>3</u>
				9

Second Semester

CE 335	Project Mgmt. for Construction	3	0	3
CE 332	Design of Structural Systems	2	3	3
	Technical Elective	3	0	<u>3</u>
				9

Minimum total credits required for graduation: 136

* College level material beyond MA 102

*+ Offered in alternate odd years, i.e., 1991-1992, 1993-1994 (the fifth and sixth years are interchangeable).

** Offered in alternate even years, i.e., 1992-1993, 1994-1995, (the seventh and eighth years are interchangeable).

GRADUATE PROGRAMS

The Department of Civil and Environmental Engineering offers graduate degree programs in three major discipline areas:

- Civil Engineering
- Environmental Science and Engineering
- Transportation

These programs lead to the following degrees:

Master of Science

- Civil Engineering
- Environmental Engineering
- Environmental Health Science
- Transportation Planning and Engineering
- Transportation Management

Engineer's Degree

- Civil Engineering
- Transportation Engineering

Doctor of Philosophy

- Civil Engineering
- Environmental Health Science
- Transportation Planning and Engineering

Information on graduate degree programs in Civil Engineering is presented below. The programs in Environmental Science and Engineering and in Transportation are described in separate sections of this catalog.

Civil engineering graduate programs are designed to address the critical needs of industry and government for specialized engineering education, focusing on current design practices, technological developments, project management techniques, and new engineering applications. They serve both regular full-time students and professionals who elect to be part time students.

MS degree programs in Civil Engineering are practice oriented with a strong emphasis on advanced design principles, experimental techniques, and state of the art construction technologies.

However, for specific discipline areas, engineering economics, operational system management and relevant basic sciences are major components of the academic program.

Requirements for the master's degree include prescribed courses and approved elective courses. A project must be completed; a thesis may be substituted for project and elective courses. A minimum of 36 units is required for the degree.

Engineer degrees are oriented toward civil engineers who wish to study advanced engineering techniques, construction technologies, environmental projects, engineering management, or material sciences 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 and high level original research work. A thesis must be written and defended.

Computer literacy is a requirement for all areas of specialization. In some cases, an undergraduate or graduate course may be included in the program of study to overcome deficiencies.

Students interested in graduate programs in civil engineering and in environmental science and engineering are advised to refer to the Graduate Manual (available from the office of the Department of Civil and Environmental Engineering) for information on degree requirements and the latest revisions of curricula and courses.

REQUIREMENTS FOR THE MASTER'S DEGREE

Students pursuing the M.S. in civil engineering generally have undergraduate preparation in civil engineering. Students pursuing this degree who have undergraduate or graduate degrees in other fields may qualify for this program by completing additional undergraduate engineering courses. When a student pursues both the B.S. and M.S. degrees simultaneously at Polytechnic, the bachelor's degree requirements must be completed first.

Courses in some areas of specialization are not offered on a regular basis. Students should consult with the department advisors to determine the expected scheduling of such courses.

M.S. PROGRAMS IN CIVIL ENGINEERING

M.S. programs are offered with majors in the following specialty areas: structural engineering, water resources engineering, environmental engineering, geotechnical engineering, highway engineering, and project management and construction engineering.

Departmental Requirements

The following courses are required of all students:

No.	Course	Units
CE 780	<i>Analysis of Uncertainty In Civil Engineering</i>	3
CE 996	<i>Project for the Degree of Master of Science</i>	<u>3</u> 6

Required Major Courses

Five courses in one of the majors must be completed: structural engineering, water resources engineering, environmental engineering, geotechnical engineering, highway engineering, or project management and construction engineering. At least three of these courses must be selected from the Core Courses for the major.

(15 units)

Departmental Electives

Three approved courses in civil and environmental engineering, in field(s) other than the major must be completed.

(9 units)

Other Approved Electives

At least 6 units of approved graduate elective courses must be completed.

(6 units)

Total 36 units

CORE COURSES

Structural Engineering:

CE 601	<i>Theory of Structural Analysis and Design</i>	3
CE 609	<i>Matrix Methods of Structural Analysis</i>	3
CE 614	<i>Steel Structures</i>	3

CE 625	<i>Structural Dynamics</i>	3
CE 641	<i>Reinforced Concrete Structures</i>	<u>3</u> 15

Water Resources Engineering:

CE 715	<i>Open Channel Hydraulics</i>	3
CE 716	<i>Applied Hydraulics</i>	3
CE 722	<i>Hydrology</i>	3
CE 723	<i>Groundwater Hydrology & Pollution</i>	3
CE 781	<i>Analysis of Public Works</i>	<u>3</u> 15

Environmental Engineering:

CE 737	<i>Environmental Chemistry & Microbiology I</i>	3
CE 739	<i>Environmental Chemistry & Microbiology II</i>	3
CE 742	<i>Water & Wastewater Treatment I</i>	3
CE 743	<i>Water & Wastewater Treatment II</i>	3
CE 747	<i>Analysis of Stream & Estuary Pollution</i>	<u>3</u> 15

Highway Engineering:

CE 781	<i>Analysis of Public Works</i>	3
CE 796	<i>Fundamentals of Pavement Design</i>	3
CE 797	<i>Flexible and Rigid Pavements</i>	3
CE 805	<i>Traffic Engineering I</i>	3
CE 807	<i>Traffic Engineering II</i>	<u>3</u> 15

Project Management and Construction Engineering:

CE 781	<i>Analysis of Public Works</i>	3
CE 825	<i>Project Management for Construction</i>	3
CE 827	<i>Contracts & Specifications</i>	3
CE 828	<i>Project Planning & Control</i>	3
CE 831	<i>Engineering for Construction I: Methods and Technologies</i>	<u>3</u> 15

Geotechnical Engineering:

CE 851	<i>Stress-Strain Behavior and Seepage</i>	3
CE 861	<i>Shear Strength of Soils & Limit Analysis</i>	3
CE 862	<i>Physical & Chemical Soil Behavior</i>	3
CE 863	<i>Experimental Soil Mechanics</i>	3
CE 871	<i>Foundation Engineering</i>	<u>3</u> 15

REQUIREMENTS FOR THE ENGINEER DEGREE

A master's degree in civil engineering meeting the specialization requirements for the Polytechnic master's degree is generally required for admission. Applicants with master's degrees in other engineering disciplines may be admitted with deficiencies as evaluated by the departmental advisor. A minimum of 36 units of work beyond the master's degree is required, of which at least 27 units must be completed at Polytechnic. This work must include a 12-unit design project. Engineer degrees may be earned in any area of specialization in civil engineering. The program follows:

No.	Required Subjects	Units
CE 998	<i>Project for the Degree of Engineer</i>	12
	<i>An approved elective in applied mathematics, or operations research</i>	3
	<i>Nine units of courses in areas of specialization selected with the consent of the advisor</i>	<u>9</u>
	<i>Required units</i>	24
	<i>Minimum elective units</i>	<u>12</u>
	<i>Minimum total units</i>	36

REQUIREMENTS FOR THE DOCTOR'S DEGREE

Students with exceptional scholastic ability may pursue a doctorate in civil engineering or environmental health science. An applicant for a doctorate in civil engineering must hold a master's degree in civil engineering. For a doctorate in environmental health science, a master's degree in science is a prerequisite. Applicants with degrees in other fields may be admitted with deficiencies as evaluated by a departmental graduate advisor.

All doctoral students must complete a minimum of 90 units of work beyond the bachelor's degree. Minimum requirements of formal coursework (not including guided readings, seminars, projects, or theses) are 48 beyond the bachelor's degree or 27 beyond the master's degree, of which at least 18 must be completed at Polytechnic. Ph.D. students must select a major field

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and two minor fields in consultation with the advisors.

To qualify as Ph.D. candidates, students must pass written and oral qualifying examinations. Registration for a minimum of 30 units of dissertation research is required. Registration should be continuous until the dissertation has been completed and accepted.

UNDERGRADUATE COURSES

CE 152 Engineering Measurements and Instrumentation 2½:1½:3

Comprehensive survey of experimental methods for engineering measurements in civil engineering. Overview of surveying and mapping. Fundamental techniques in leveling, angle, and direction measurement. Map projections, topographic surveys, and photogrammetry. Basic electrical measurements and sensing devices. Displacement and area measurements. Measurement of pressure, flow, and temperature. Force, torque, and strain measurements. Air pollution sampling and measurement. Data acquisition. Introduction to uncertainty analysis as applied to experiments. Reports and other presentations based on laboratory experimentation. *Prerequisite: MA 102 or MA 110*

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: ME 111. Also listed under ME 121.*

CE 214 Computer Techniques in Engineering 2:3:3

Use of higher-level computer languages and techniques in engineering. Use of computer for numerical methods involving differentiation, integration and solution of systems of equations. Computer graphics in engineering. Evaluation of one commercial software package and its applications to civil engineering. *Prerequisites: CS 100 and MA 104.*

CE 223 Fluid Mechanics 2½:1½:3

Fluid properties. Hydrostatics. Continuity, energy and momentum equations. Laminar and turbulent flow. Similitude and dimensional analysis. Incompressible flow in closed pipes. Laboratory work parallels and supplements lectures. *Prerequisite: ME 111, Corequisite ME 112.*

CE 232 Soil Mechanics 2:3:3

Geological soil-forming processes and physical and mechanical properties of soils. Plasticity, capillarity, permeability, stress distribution in soil masses, consolidation theory, settlement of structures. Laboratory studies of physical and mechanical properties of soils. *Prerequisites: CE 223 and CE 202.*

CE 252 Reinforced Concrete Structures 3:0:3

Fundamentals of analysis and design of reinforced concrete beams, columns, slabs. *Prerequisite: CE 322.*

CE 306 Nature and Properties of Structural Materials 2:3:3

Physical and mechanical properties of concrete, metals, plastics, composites and asphaltic materials related to structures. Experimental investigation of mechanical properties of selected structural materials and physical properties of cement and concrete mixes. Introduction to polymeric materials including geosynthetics. Jointly developed and taught by Department of Civil and Environmental Engineering and Department of Metallurgy and Materials Science. *Prerequisite: CM 101, 111. Corequisite CE 202 or ME 121. Cross-listed with MT 306.*

CE 317 Foundations 2:3:3

Site explorations and soil sampling; planning boring programs and interpretation of boring logs. Bearing capacities and footings and mats for granular soils and clays. Settlement of structures. Lateral earth pressure and proportions of retaining walls. Pile foundations. *Prerequisite: CE 232 and Co-Prerequisite: CE 252.*

CE 322 Analysis of Structures I 3:0:3

Analysis of statically determinate beams, frames and trusses. Deflection calculations using energy methods. Analysis of indeterminate structures using superposition. Determinate and indeterminate influence lines. Slope deflection. *Prerequisite: CE 202.*

CE 323 Analysis of Structures II 3:0:3

Analysis of statically indeterminate linear frames by moment distribution. Matrix analysis of structures using force and stiffness methods. Computer applications. *Prerequisite: CE 322.*

CE 331 Steel Structures 2:3:3

Design of steel beams and girders, tension members, columns. Bolted, riveted and welded connections. *Prerequisite: CE 322.*

CE 332 Design of Structural Systems 2:3:3

Comprehensive design integrating site planning, environmental, geotechnical and structural engineering, specifications, estimating construction and scheduling activities including a project report. Lectures, workshop sessions and final project presentation simulating multidisciplinary design office experience. *Prerequisites: CE 323, CE 252, CE 317 and CE 331.*

CE 335 Project Management for Construction 3:0:3

The participants, processes and techniques required to maintain the life cycle of a construction project. Planning of construction operations, including cost estimating and economic evaluation of alternatives. Analysis of the construction bid process, contracting, and related issues on ethics in project engineering. Productivity, safety and quality on the constructed project. Time scheduling of the project, including CPM and PERT. Trends in computer analysis of project information. *Prerequisite: Senior Status.*

CE 336 Timber and Masonry Structures 3:0:3

Properties and classification of structural lumber. Design of timber connectors. Design and erection of residential and industrial timber buildings. Beams, frames, columns and trusses of sawn lumber and glued-laminated construction. Manufacture and properties of concrete masonry units. Properties of mortar and grout. Design and construction of load-bearing reinforced and unreinforced masonry structural elements. *Prerequisite:* CE 322.

CE 340 Water Resources and Hydraulic Engineering 3:0:3

Fluid Measurements. Hydrologic techniques. Surface water and ground water supplies. Open channel flow. Water transmission and distribution. Wastewater and storm water drainage. Development of water resources projects. *Prerequisite:* CE 223.

CE 341 Environmental Engineering I 2:3:3

Water and wastewater quantities. Water quality. Water and wastewater treatment, stream assimilation, public health and environmental problems. Laboratory analyses of water and wastewater samples, treatment process tests. *Prerequisites:* CE 223 and CE 340.

CE 342 Environmental Engineering II 2:3:3

Integrated lecture and design periods covering water distribution systems, water filtration units and principal components of wastewater treatment plants for small communities. Introduction to air quality and solid waste problems. *Prerequisites:* CE 340 and 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 223.

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 152.

CE 352 Traffic Engineering 3:0:3

Development and use of traffic engineering techniques to aid in planning, functional design and control of highway and street systems. Traffic studies, accident analysis, capacity analysis, sign and coordination, etc. Practical applications. *Prerequisite:* Junior status.

CE 353 CAD in Civil Engineering 2:3:3

Thorough exposure to architectural CAD in civil engineering design. Fundamentals of CAD, its uses, and types of CAD equipment and software. Principles of transformations, geometric modelling and drafting. Interactive computer graphics, 3-D modelling, and effect of color. Application of CAD to engineering analysis. Incorporation of CAD in project data management. Laboratory assignments to reflect coursework. *Prerequisites:* ME 101 and Senior status.

CE 391-392 Bachelor's Thesis in Civil Engineering each 2 credits

Original research, design or plan for an approved engineering project. Thesis gives students the opportunity to apply knowledge and training gained in courses by approaching and successfully solving comprehensive problems. Conferences held regularly with an appointed member of the faculty. Thesis registration required each semester. Students must register for thesis until completed. *Prerequisite:* Senior status.

CE 396 Civil Engineering Internship 2:0:2

Supervised, creative civil engineering work of at least two months' performance judged on the basis of written and

oral reports presented to industrial and faculty supervisors. Regular faculty visitations and conferences arranged during internships. Open to students who have completed their junior year and have departmental approval prior to beginning the internship experience. *Prerequisite:* Department Head's approval.

CE 398 Project in Civil Engineering 2 or 3 credits as arranged

Solution to civil engineering problem or detailed study of an advanced area of civil engineering under close supervision of an advisor. Before undertaking the project, interested students must submit a detailed written proposal of the problem they intend to investigate to the course director, along with the number of credits for which they wish to register. Results of the project must be submitted to the Department as a formal report.

GRADUATE COURSES**GENERAL****CE 598-599 Special Topics in Civil Engineering** 2½:0:3

Specialized current topics of interest of an interdisciplinary nature. Offered at irregular intervals. Advance announcements include course description and prerequisites.

CE 780 Analysis of Uncertainty in Civil Engineering 2½:0:3

Brief review of basic concepts including problem identification, definitions of statistical parameters and principles of probability. Applications utilizing techniques of frequency distribution, regression and correlation, time series analysis, significance testing, elementary decision theory, sensitivity and risk analysis, reliability assessments. All topics emphasize applications to civil engineering practice and research, and include problem solving in such areas as hydrology, structures, geotechnical, transportation and environmental engineering. Student specialty areas will be considered in selection of problems for study.

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CE 781 Analysis of Public Works 2½:0:3

Methods for the identification, formulation, preliminary appraisal, and detailed analysis of individual projects and systems of civil engineering projects. Different approaches appropriate for government agencies, public utilities, industrial firms, and private entrepreneurs. Planning considers projects that satisfy single and multiple purposes and objectives, meet local and regional needs and take advantage of opportunities for development. Financial and economic analyses, including sensitivity and risk analysis. Mathematical models for evaluation of alternatives and optimization. Impacts of projects: environmental, social, regional economic growth, legal and institutional, and public involvement. Also listed under MG 830.

CE 790 Fire Protection Engineering 2½:0:3

Overview of fire problems in the United States. Statistics, trends and fire experiences of interest to engineers. Chemistry and physics of fire phenomena, including ignition, flammability, heat transfer, products of combustion and modes of fire growth and extension. Properties and behavior of materials at elevated temperatures. Performance of structures exposed to fire and failure mode analysis. Laboratory and full-scale testing of construction materials, components, assemblies and structures. Building codes, fire codes and standards. Measures for fire protection: detection, alarm and communication systems and systems for fire suppression and smoke control.

CE 791 Infrastructure Systems Analysis 2½:0:3

Methodologies and procedures for macro-level analysis of engineered infrastructure systems. Introduction to computer-based techniques for optimization of design, operation and maintenance of infrastructure subsystems. Demographic, system loading and capacity analyses for water distribution, wastewater collection and disposal, solid wastes collection, street sweeping, snow removal and other municipal service systems. Infrastructure financing and capital budget process. Life cycle and benefit-cost analyses

applied to infrastructure renewal. *Prerequisite:* CE 214 or equivalent.

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Prerequisites for all courses: MA 104, CE 323

CE 601 Theory of Structural Analysis and Design 2½:0:3

Theories of structural analysis and its relationship to design. Classical structural mechanics, matrix procedures and numerical methods of solution. Analysis of statically indeterminate beams, frames, and trusses using force and displacement methods. Emphasis on elastic supports, movement of supports and temperature effects. *Prerequisite:* CE 323.

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 advisors 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 606 Bridge Engineering 2½:0:3

Types of bridges. Geometric design of bridges. Construction materials. Construction techniques. Simplified bridge analysis. Special problems in the design of steel and reinforced concrete bridges. Bridge maintenance techniques. Bridge inspection policy. Bridge rehabilitation procedures. Bridge management systems. Effects of wind and earthquakes on long-span bridges. *Prerequisites:* CE 252, 323, 331.

CE 609 Matrix Methods of Structural Analysis 2½:0:3

Basic concepts of matrix methods in structural analysis. The direct stiffness method applied to trusses and frames. Force and displacement transformations. Complete solutions of structural problems by chain matrix operations. Assembly of stiffness and flexibility matrices of an entire structure. Computer program development for structural analysis, with particular emphasis on the direct stiffness method. *Prerequisite:* CE 601.

CE 611 Limit Analysis of Structures 2½:0:3

Plastic analysis of shafts, beams and frames. Failure mechanisms and collapse loads. Upper- and lower-bound theorems. Cyclic loading and shakedown problems. Optimization, minimum weight design. Yield conditions and flow rules. Limit loads of plates. *Co/Prerequisite:* CE 601.

CE 613 Stability of Structures 2½:0:3

Stability concepts. Investigation of buckling of structural configurations composed of beams, plates, rings, and shells. Effects of initial geometric imperfections, load eccentricities, and inelastic behavior. Application of energy methods and numerical techniques. *Prerequisite:* CE 601.

CE 614 Steel Structures 2½:0:3

Compression members; elastic and inelastic buckling of columns and plates. Beams: laterally supported. Torsion of open and closed sections. Warping. Lateral torsional buckling of beams. Biaxial bending. Plate girders; stability of webs and flanges. Combined bending and axial load, instability analysis. Design of rigid and semirigid mechanisms of continuous beams and rigid frames. Elastic/plastic design criteria. *Prerequisite:* CE 331 or equivalent.

CE 616 Finite Element Methods 2½:0:3

Derivation of element stiffness matrices. Construction of general stiffness matrices in global coordinates. Application to

problems in plane stress, plane strain, plates, and shells under various loads. Emphasis on computer applications. *Co/Prerequisite: CE 609.*

CE 617 Introduction to Modern Concepts of Structural Safety 2½:0:3

Introduction to modern concepts of structural safety limit states designs based on reliability analysis. Design code formats. Risk analysis. Semi-probabilism. Safety index analysis. Code optimization. Single load stochastic models; extreme value and holding time analysis. Combined load analysis; scalars, vectors. Basic system reliability. Conditional analysis, modeling errors and engineering judgment. *Prerequisite: CE 780.*

CE 621 Advanced Mechanics of 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.

CE 625 Structural Dynamics 2½:0:3

Dynamic response of single degree of freedom systems. Theory of vibration of finite degree of freedom systems. Influence coefficient method. Analytical and numerical solution of dynamic response problems. Nonlinear analysis of single degree of freedom system. Emphasis on computer analysis of large complex systems. *Prerequisite: CE 609.* Also listed under ME 741.

CE 626 Applied Structural Dynamics 2½:0:3

Review of classical structural dynamics. Introduction to linear random vibrations. Power spectra, auto and cross-correlation functions. Wind loads, galloping, flutter, buffeting, vortex shedding. Response of civil engineering structures to wind effects. Seismic loads. Linear and nonlinear response spectra. Ductility. Simplified seismic analysis and design of structures. *Prerequisite: CE 625.*

CE 632 Piping System Analysis and Design 2½:0:3

Use of displacement energy, complementary energy and thermoplastic 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 bimaterials and layered elements. *Prerequisite: CE 601 or equivalent.*

CE 641 Reinforced Concrete Structures 2½:0:3

Ultimate strength design of reinforced concrete members. Biaxial bending and slender effects of reinforced concrete columns. Limit design, redistribution of moments. Design of slabs using yield line theory. Deep beams and shear walls. Analysis and design for torsion. *Prerequisite: CE 252 and Co/Prerequisite: CE 601.*

CE 643 Prestressed Concrete 2½:0:3

Principles and materials for prestressed concrete. Flexural strength of prestressed members. Design of pretensioned and post-tensioned beams, columns, and slabs. Effect of short-term and long-term deformations. Analysis and design of prestressed concrete structures. *Prerequisite: CE 641.*

CE 645 Fracture Mechanics-Modelling and Design 2½:0:3

Fracture mechanics combines solid mechanics and materials science in order to study and design against the fracture of engineering materials in service. Applications include the study of shear banding in soils, pressure vessel and pipeline failures, cracks in concrete and steel structures, fracture of rails, fatigue failure of machine components, and the design of advanced fracture resistant materials. This course will emphasize the modelling of fracture processes and the use of fracture mechanics in engineering design. *Prerequisite: Permission of department advisor.* Also listed under ME 735, MT 645

WATER RESOURCES ENGINEERING

Prerequisite for all courses: MA 104, CE 223

CE 712 Water Resources Projects 2½:0:3

Feasibility-level planning and design studies for water resources projects, including water conveyance works; concrete dams and associated waterways; pumping stations; hydroelectric, irrigation, navigation, and flood mitigation projects. Subjects considered include layouts, dimensions and capacity of facilities, hydraulic and structural forces, and stability analysis. *Co/Prerequisite: CE 340 or CE 715, or permission of instructor.*

CE 715 Open Channel Hydraulics 2½:0:3

Theory and computations for uniform flow, gradually varied flow, rapidly varied flow, unsteady flow in prismatic and non-prismatic channels.

CE 716 Applied Hydraulics 2½:0:3

Similarity, dimensional analysis and modeling techniques as applied to hydraulic systems. Pumping systems including hydraulic transients and flow of air, liquids, sludge. Cavitation. *Co/Prerequisite: CE 340 or CE 715.*

CE 722 Hydrology 2½:0:3

Hydrologic cycle. Meteorological considerations. Analyses of precipitation, runoff, unit hydrographs, flood routing and reservoir storage. Principles of groundwater hydrology. Introduction to frequency analysis of floods and droughts. *Prerequisite: Undergraduate degree in engineering or science.*

CE 723 Groundwater Hydrology and Pollution 2½:0:3

Characteristics of confined and unconfined flow of water through porous media; groundwater and well hydraulics; quality of ground water; environmental influences; groundwater pollution; management aspects of groundwater; and groundwater modelling. *Prerequisite: CE 340 or instructor's permission.*

ENGINEERING

CE 724 Advanced Groundwater Hydrology and Pollution

2½:0:3

Mass and heat transport in porous media. Unsaturated flow and transport. Numerical solutions of governing equations. Stochastic analysis. Groundwater quality monitoring and simulation. Wellhead protection, gas extraction systems, granular carbon absorbers, bioremediation. *Prerequisite* CE 723 or equivalent.

CE 725 Water Resources Mathematical Modeling

2½:0:3

Studies of hydraulic, hydrologic, water quality and systems models as applied to rivers and streams, embayments, estuaries and basins. Review of basic equations of flow applicable to these models. Appropriate modeling techniques using computer-based solutions reviewed with emphasis on time-varying boundary conditions and problems of calibration and verification. One, two and three-dimensional models considered. Stormwater models and water resource systems modeling. *Prerequisite*: Course in computer programming and *Co-Prerequisite*: CE 715.

CE 726 Computer Applications in Water Resources

2½:0:3

Applications of commercial software in water resources planning and design. Class meets in a computer classroom and hands-on experience is offered. Examples include analysis of flood hydrographs, open channel flow, river hydraulics, pipe networks, watershed hydrology, storm water management, and groundwater flow and transport. *Prerequisite*: CE 340.

CE 727 Urban Hydrology

2½:0:3

Urban climate. Rainfall: IDF methods, spatial variability, design hyetographs. Hydrologic routing. Hydraulic routing. Urban water quality. Probabilistic modeling. Use of computer models. *Prerequisite*: CE 722 or equivalent.

CE 728 Optimization Methods in Water Resources

2½:0:3

Advanced theory of mathematical programming and optimal control with applications in planning and operation of

water resource systems. *Prerequisite*: CE 722 or equivalent.

CE 735-736 Special Topics in Water Resources and Hydraulic Engineering I, II

2½:0:3

Topics in water resources and hydraulic engineering such as hydroeconomic models; finite difference and finite element models; synthetic hydrology; conjunctive use of surface water and ground water; desalinized and recycled water; thermohydrologic and hydrometeorological problems; flushing of estuaries; hydrodynamics of oil pollution, sludge dumping, and sediment movement; environmental design of hydraulic structures, problems of macro projects. *Prerequisite*: permission of instructor.

ENVIRONMENTAL SCIENCE AND ENGINEERING

CE 737 Environmental Chemistry and Microbiology I

1:2:3

Introduction to the chemistry and microbiology of polluted and natural waters, including applications of principles developed.

CE 739 Environmental Chemistry and Microbiology II

1:2:3

Advanced topics in chemistry and microbiology of polluted and natural wastewater treatment.

CE 742 Water and Wastewater Treatment I

2½:0:3

Physical, chemical and biological principles involved in process design and treatment of water and wastewater. Topics include aeration, filtration, softening, chemical treatment, coagulation, flocculation, desalination, taste and odor control. *Co-Prerequisite*: CE 737.

CE 743 Water and Wastewater Treatment II

2½:0:3

Continuation of CE 742. Topics include sedimentation, adsorption, aerobic and anaerobic biological treatment, sludge treatment and disposal. *Co-Prerequisite*: CE 739.

CE 745 Water and Wastewater Treatment Laboratory

1:2:3

Laboratory processes in water and wastewater engineering, dealing with physical, chemical and biological methods and principles. Processes include disinfection, softening, sedimentation, oxygen transfer, coagulation, adsorption, filtration, aerobic and anaerobic biological treatment systems. Warburg analysis of waste. *Co-Prerequisite*: CE 743.

CE 746 Industrial Waste Treatment

2½:0:3

Sources of industrial wastewaters and their treatability by physical, chemical and biological processes. Problems and solutions involved in combining municipal and industrial waste treatment. Status of government regulations imposed on industries in prevention of water pollution.

CE 747 Analysis of Stream and Estuary Pollution

2½:0:3

Dispersal and decay of contaminants introduced into lakes, streams, estuaries, oceans. Effects of pollutants on chemical quality and ecology of receiving waters.

CE 748 Sanitary Engineering Design

1:2:3

Design of water supply and wastewater treatment systems. Topics of special interest. *Co-Prerequisite*: CE 743.

CE 751 Environmental Health Engineering

2½:0:3

Theory, methodology and instrumentation associated with environmental health. Topics include epidemiology, food vectors, radiation, pest control, heating, ventilation, noise, illumination, hazards of home and community environment, other subjects which affect public health.

CE 752 Air Pollution

2½:0:3

Causes and effects of air pollution. Methods of sampling. Interpretation of data. Meteorological aspects. Methods of air pollution control.

CE 753 Hazardous/Toxic Waste Management 2½:0:3

Methods in the management of hazardous/toxic waste sites. Topics covered include health and safety, legal aspects, contamination of the environment, treatment processes, toxicology and risk assessment.

CE 758 Air Pollution Engineering Control 2½:0:3

Pollutant emissions control; analysis of pollutant properties, concentrations and boundary conditions; absorptive, and reactive recovery processes for moving and stationary sources; formation and removal of gaseous oxides (NO, SO, CO, etc.) and of aerosols and other particulates. *Prerequisite: Instructor's permission.* Also listed under CH 752.

CE 767 Environmental Impact Evaluation 2½:0:3

An examination of legal and technical requirements in the preparation of environmental impact evaluations. Considerations include: legal and technical requirements, the procedure and the interdisciplinary nature of the analysis. Topics include overall impact evaluation, problem definition, quantification of impact, methods used in analysis, field evaluations, mitigations, hearing procedures and management. Practical examples and case studies are used.

CE 770 Solid Waste Management 2½:0:3

Engineering aspects of solid waste collection, transport and disposal, including incineration, sanitary landfill, composting, recovery and reutilization, economic evaluation of factors affecting selection of disposal methods.

CE 771-772 Special Topics in Environmental Engineering I, II 2½:0:3

Current topics including nitrification in natural and treated waters, hazardous and toxic wastes, organic removal from water supplies, water reuse, specialized aspects of biological wastewater treatment, environmental health, solids disposal, and modeling natural waters and

treatment systems. *Prerequisite: permission of the instructor.*

TRANSPORTATION AND HIGHWAY ENGINEERING

Prerequisites for all courses: MA 104.

CE 796 Fundamentals of Pavement Design 2½:0:3

Pavement types, design factors, traffic load analysis, pavement materials, stresses in flexible and rigid pavements, economic factors, pavement strategies, and design of flexible and rigid pavements. *Prerequisite: CE 351.* Also listed under TR 722.

CE 797 Flexible and Rigid Pavements 2½:0:3

Advanced course in design and evaluation of flexible and rigid pavements for highway and airports: system approach, stochastic process, pavement condition and performance, advanced traffic load analysis, subgrade investigation, properties of subbase, base, asphaltic, and concrete courses, climatic and environmental effects, design strategies, design of highways and airport pavements and pavement evaluation. *Prerequisite: CE 796.* Also listed under TR 723.

CE 804 Travel Demand Forecasting 2½:0:3

Theory and application of travel forecasting methods to predict the amount and nature of travel in transportation systems. *Co-Prerequisite: TR 600 or equivalent.* Also listed under TR 601.

CE 805 Traffic Engineering I 1:3:34

First course in a two-semester sequence covering the basic aspects of traffic engineering. Driver, roadway, vehicle, and traffic stream characteristics, and their influence on operations, controls and design. Traffic studies and data analysis; volume, speed, delay, density, accidents, etc. Concepts of traffic capacity and level of service analysis. Capacity and level of service analysis of limited access facilities; freeways, freeway components, two-lane rural highways, multilane highways. Laboratories emphasize the use of spreadsheets in data analysis and the use

of computer packages for capacity and level of service analysis. Also listed under TR 701.

CE 807 Traffic Engineering II 1:3:3

Second course in a two-semester sequence covering the basics of traffic engineering. Traffic control, operations, and management. Characteristics of signs, signals, and markings. The "Manual on Uniform Traffic Control Devices" and its use. Intersection control. Signal systems and coordination. Pretimed and actuated control. Design of street hardware. Traffic flow regulations and their implementation. Intersection and arterial analysis. *Prerequisite: CE 805 or Instructor's Permission.* Also listed under TR 702.

CE 812 Transportation Economics and Finance 2½:0:3

Basic principles of present worth, single payment and uniform series, sinking funds, annualized costs. Differences in the public and private sectors of transportation: profit, depreciation, return of capital. Benefit-cost analysis. Rate of return. Bond issues. Formulation and use of unit costs in highways, transit, and other modes. History of financing of road systems, transit, and trucking. Privatization. Balance sheets, financial control, cash flow. Preparing a private venture business plan. Also listed under TR 750

CE 813 Pavement Materials Laboratory 1:3:3

Practical course on testing of pavement materials: physical and indicative tests, soil classifications, CBR test, tests on asphalts, Marshall test, Hveem tests, fatigue testing, application of results in a design problem. *Prerequisite: CE 796.* Also listed under TR 724.

CE 814 Advanced Pavement Technologies 2½:0:3

Advanced course on evolution and innovative recent paving technologies: AASHO road test, pavement management system, concrete block pavements, pavement recycling, geotextiles in pavements, pavement rehabilitations, bituminous materials, modern materials. *Prerequisites: CE 797, CE 813.* Also listed under TR 725.

ENGINEERING

CE 821 Design of Traffic Facilities 2½:0:3

Functional and preliminary design principles and analyses for freeways and arterials. Interchange design for freeway facilities and design of at-grade intersections, using principles of channelization. Design of parking garages and parking lots. Also listed under TR 710.

CE 833 Characteristics of Transportation Demand and Systems 2½:0:3

An overview of transportation demand, modal characteristics, and an introduction to material needed for transportation studies. Transportation as an industry. Decision on home-work locations. Review of census data. Introduction/review of analysis of transportation related data. Discussion of critical issues in transportation. Also listed under TR 600.

CE 834 Urban Transportation Planning 2½:0:3

Transportation system planning from regional to local scales. Problem identification, issues and needs. Planning, design and operation of transportation systems. Evaluation of transportation system performance and impact. *Prerequisite:* TR 601 or equivalent. Also listed under TR 602.

CE 835 Computer Applications and Analytic Techniques in Traffic and Transportation 2½:0:3

Model-building in transportation by use of analytic techniques and computer tools such as spreadsheets, statistical analysis, and existing transportation and traffic engineering packages. Emphasis in computer applications is on personal computers and existing software packages. Analytic techniques are addressed on three levels: (1) basic concepts; (2) case studies; and (3) review of literature. Modeling of trip generation, transportation safety, and other topics by deterministic analysis. Sensitivity analysis. Cost-utility analysis. Surveys and errors in surveys. Transportation packages including NETSIM, TRANSYT, TRAF, and Assignment packages. *Prerequisites:* TR 702 and TR 600. Also listed under TR 603.

CE 836 Transportation Workshop 0:5:3

Comprehensive projects designed to assure student's understanding of basic principles and their applications, drawing on knowledge from the M.S. requirements. Typically, two to four design or evaluation projects are completed, some of which are group projects. Written reports and oral presentations required. Projects or sub-assignments are based upon the degree the student is pursuing. *Prerequisite for M.S. (TP & E) students:* TR 601 and TR 701. *Corequisite:* TR 702. *Pre-or Co-requisites for M.S. (TM) students:* IE 620, TR 750, TR 660. Also listed under TR 629.

CE 837 Public Transportation 2½:0:3

Needs for public transportation in urban areas. Characteristics of public transportation services: commuter rail, rail transit, light rail transit, express and local buses, commuter paratransit modes, taxi and other paratransit services. Planning and operations of transit routes and systems. Transit service performance measures. Functional design of transit stations, park and ride facilities and transit rights-of-way. Also listed under TR 660.

CE 838 Design of Rail Facilities 2½:0:3

Design of systems for moving passengers and freight on rails. Roadbeds, alignment, yard, stations, signal communications, and protection devices. Design of light-rail transit facilities. Also listed under TR 665.

CE 839 Port Planning and Design 2½:0:3

Planning of marine terminal facilities for freight and passengers. Harbor and port capacity analysis. Functional design and control of ports. U.S. port terminal needs for containers and bulk freight. Port operations. Also listed under TR 672.

CE 840 Planning and Design of Terminals 2½:0:3

Passenger and freight terminals with emphasis on system description of these

facilities. Land, marine and air terminals. Methods for determining the levels of service for pedestrian flows. TOFC and truck terminals are also covered. Also listed under TR 670.

CE 841 Airport Planning and Design 2½:0:3

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

CE 843 Transportation Policy 2½:0:3

Analysis of the major policies, regulations, and controls established or imposed by government at all levels- federal, state, local- which currently impact on the transportation industry. (All modes considered). Case studies used extensively. Also listed under TR 759.

CE 844 Management of Transit Maintenance and Operations 2½:0:3

Management of functional transit systems aspects, including design and monitoring of maintenance functions to provide viable operating fleets and right-of-way, and management of daily operations, including scheduling, run-cutting, dispatching, and street management. Also listed under TR 760.

CE 845 - CE 846 Selected Topics in Transportation I, II each 2½:0:3

Periodic presentation of topical materials of current interest. Topics presented are: site development and site impact; decision-making in transportation; computer packages in transportation; transportation systems safety. *Prerequisite:* academic advisor's approval. Also listed under TR 860-861.

CE 847 Traffic Safety Engineering 2½:0:3

Applications of system-safety engineering principles to the driver-vehicle-environment.

ment system to achieve higher levels of human safety (reduced accident occurrence and reduced severities of injuries). Proven, practical approaches are applied in the removal hazards and hazardous conditions in every stage of the highway system activity cycle, including planning, engineering, design, operation, maintenance. Also listed under TR 865.

CE 881-882 Special Topics in Geotechnical Engineering & Pavement Technology I, II 2½:0:3

Current topics of interest such as theoretical determination of pile capacities, sheet pile bulkheads and trench problems, stress on tunnels, theoretical approaches to soil stability and settlement, soil reinforcement applications, pavement performance and rehabilitation, pavement management systems, pavement improvement techniques, pavement performance evaluation, recycling technologies, pavement on sensitive soils. *Prerequisite:* CE 851, CE 861, CE 871 or CE 797 depending on subject area.

PROJECT MANAGEMENT AND CONSTRUCTION ENGINEERING

CE 798-799 Special Topics in Infrastructure Systems and Construction 2½:0:3

Current topics of interest such as methodologies and procedures for analysis of existing infrastructure systems, geographic information data and management systems, photogrammetric and remote sensing techniques and utilization and design of infrastructure facilities and systems. Intelligent buildings and other modern constructed works. Temporary structures for construction and problems in construction engineering. New approaches in construction management.

CE 820 Project Management 2½:0:3

Specific management concepts and techniques related to management of special projects in research and development, construction, engineering, and data processing. Functional and administrative structures, coordination of activities, manpower planning, feasibility analyses, negotiations and contracts. Also listed under MG 820.

CE 825 Project Management for Construction 2½:0:3

Topics specific to the development and coordination of large projects, including; organizational structures, management functions, pricing and estimating project costs, bidding and contracting, risk allocation, scheduling, time and cost control, labor relations, quality management, as well as project life cycle activities. Also listed under MG 825.

CE 826 Construction Cost Estimating 2½:0:3

Estimates, and costs from the viewpoint of contractor or construction engineer, details of estimating, emphasis on labor, material, equipment, overhead costs. Also listed under MG 826.

CE 827 Contracts and Specifications 2½:0:3

Principles of contract law as applied to the construction industry; legal problems in preparing and administering construction contracts. Also listed under MG 827

CE 828 Project Planning and Control 2½:0:3

Network planning techniques for project management and resource allocation. Emphasis on PERT, LOB, CPM and probabilistic generalized networks. Heuristic models for multi-project scheduling and resource leveling. Network development, computer adaptation, progress reports and project monitoring. *Prerequisite:* knowledge of computer programming. Also listed under MG 810 and IE 620.

CE 829 Construction Operations Analysis 2½:0:3

Evaluation and model development of productivity, safety, quality, and materials handling in construction operations. Principal methods for analysis and pre-planning of work activities, including the use of work sampling, questionnaires, and surveys. The implementation of video/timelapse photography in field studies, and the incorporation of crew balances, flow diagrams, process charts, and five-minute ratings for task measurements. The introduction of task analysis, including queuing theory, to the model-

ling and analysis of construction operations. Introduction to construction simulation. Field implementation and projects. *Prerequisite:* degree in civil engineering, or permission of the instructor.

CE 830 Information Systems in Project Management 2½:0:3

Development of a strong understanding of contemporary tools for managing the vast array of information in the project life cycle. Information handling is reviewed both from the perspective of knowledge acquisition and knowledge representation. Information analysis as qualitative and quantitative. Interpretation of knowledge as deterministic versus stochastic. Introduction to decision making under risk. The implementation of spreadsheets, databases and expert systems as information systems communication tools for project information handling. A review of technologies such as CAD databases, geographic information systems, decision support systems and videogrammetry as tools for project automation. *Prerequisite:* Degree in civil engineering or permission of the instructor.

CE 831 Engineering for Construction I: Methods and Technologies 2½:0:3

Planning, design and equipment for new construction and for infrastructure rehabilitation. Engineering fundamentals of earth moving, soil stabilization, and compaction. Methods for tunneling through rock and earth, as well as rock blasting. Foundation grouting, piles and pile driving equipment. Dewatering systems and pumping equipment. Factors affecting the selection of construction equipment. Review of conventional construction equipment and trends in robotics. *Prerequisite:* Degree in civil engineering, or permission of instructor.

CE 832 Engineering for Construction II: Design 2½:0:3

In-depth analysis of design methods for construction operations. Earth pressure analysis and structural analysis. Design for sheet pile walls, cofferdams, underpinning systems, tieback systems, and pipejacking systems. Details of a dewatering system design. Special studies in constructability and value engineering. *Prerequisite:* CE 831, or permission of the instructor.

ENGINEERING

GEOTECHNICAL ENGINEERING

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

CE 849 Environmental Geotechnology 2½:0:3

Chemical phase transfer. Acids and bases in soils. Chemical reactions in soils. Identification, clay mineralogy. Hydraulic conductivity, diffusion and unsaturated flow. Well hydraulics. Contaminant transport. Flow potentials. Seepage barriers. Bioremediation. *Prerequisites: CE 223, CE 232.*

CE 850 Ground Improvement 2½:0:3

Classification of available technologies. Performance criteria. Physical and chemical soil behavior; testing and design parameters. Reinforced soil retaining systems; metal reinforcement and geotextiles. Chemical, thermal and physical ground treatment. Densification by vibro/dynamic ground replacement. Soil nailing and ground anchors. Design methods. Case histories. Environmental applications; seepage barriers, remediation. New trends in ground improvement. *Prerequisites: CE 232, CE 317.*

CE 851 Stress-Strain Behavior and Seepage 2½:0:3

Conjugate stress relationships in infinite slopes in granular and cohesive soils. Studies of classical works of Rankine, Coulomb, Kerisel and others for determining pressure distributions on rigid structures retaining soil masses. Effects of ground water seepage, surcharge loading. Analysis and design of rigid-type retaining structures and sheet piles. Soil reinforcement applications for retaining structures.

CE 861 Shear Strength of Soils and Limit Analysis 2½:0:3

Index properties of soils. Stress distribution in homogeneous and layered elastic half-space due to surface loading. Permeability, capillarity, absorption and soil-water tension. Flow networks. Theory of wells and use of well data in field measurement of permeability. Consolidation of soils. Strength of soils.

CE 862 Physical and Chemical Soil Behavior 2½:0:3

Strength of soils, laboratory tests, effective strength parameters, total and effective stress paths. Applications of soil strength in stability analysis of embankments. Critical state soil mechanics, constitutive relations for soils. *Prerequisite: CE 861.*

CE 863 Experimental Soil Mechanics 1:2:3

Critical evaluation of standard testing procedures for identification and classification tests. Detailed examinations of permeability, capillarity and seepage phenomena using soil samples and electric analogs. One-dimensional consolidation test. Treatment of shear strength and the static triaxial compression test and its several variations. Special tests. *Prerequisite: CE 861.*

CE 871 Foundation Engineering 2½:0:3

Soil sampling and exploration procedures. Analytical procedures for determining bearing capacity as a function of stability and settlements. Plate-loading test shallow footing design. Analysis and design of mat footings. Design of deep foundations; piles, piers and caissons.

CE 881-882 Special Topics in Geotechnical Engineering & Pavement Technology I, II 2½:0:3

Current topics of interest such as theoretical determination of pile capacities, sheet pile bulkheads and trench problems, stress on tunnels, theoretical approaches to soil stability and settlement, soil reinforcement applications, pavement performance and rehabilitation, pavement management systems, pavement improvement techniques, pavement performance evaluation, recycling technologies, pavement on sensitive soils. *Prerequisite: CE 851, CE 861, CE 871 or CE 797 depending on subject area.*

CE 892 Soil Dynamics and Earthquake Engineering 2½:0:3

Single- and multi-degrees of freedom systems. Wave propagation in homogeneous and layered half-spaces. Behavior of dynamically loaded soils. Basic concepts of seismology; earthquake distribution, type, magnitude, intensity, energy and seismic regionalization. Response spectrum. Effect of earthquakes on soil and response of structures to earthquakes as influenced by soil formation. Design of dynamically loaded foundations and earth structures. The liquefaction problem. *Prerequisite: CE 861.*

CE 893 Rock Mechanics and Underground Structures 2½:0:3

Intact rock and rock mass description and engineering properties; static ground-structure interaction, stability and wedge analysis, underground structures in rock and soft soil.

CE 895 Performance Monitoring and In-Situ Testing 2½:0:3

Introduction to soil and rock behavior. The "observational" method. Geotechnical instrumentation: types, applications, uncertainty. Planning a monitoring program. Case histories. The need for in-situ parameters. Penetration testing. Pressuremeter. Dilatometer. Stepped blade. Wave based methods (mechanical and electromagnetic). Case histories and controlled laboratory studies. New trends in monitoring and in-situ testing. *Prerequisites: CE 232, CE 317.*

GUIDED READINGS, SEMINARS, PROJECTS AND THESES

Note: Students should obtain a copy of the University's "Regulations on Format, Duplication and Publication of Reports, Theses and Dissertations" available from the Office of Research and Graduate Affairs.

CE 901 Guided Readings in Civil Engineering 3 units

Individual study of selected literature in civil engineering under guidance of a faculty advisor. Acceptable written report or successful completion of examination required. Only one registration permitted, except with department head's approval. *Prerequisite: Instructor's approval.*

CE 903-904 Readings in Transportation I, II each 2½:0:3

Special problems in transportation under the direct supervision of faculty members. *Prerequisite: academic advisor's approval.* Also listed under TR 901-902.

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 954-955 Transportation Seminar I, II nc

Relevant topics in transportation by guest speakers. Presentations and discussions of on-going research by course participants and faculty. *Prerequisite: academic advisor's approval.* Also listed under TR 951-952.

CE 957 Master's Project in Transportation Planning and Engineering each 3 units

An independent project leading to a comprehensive report demonstrating professional competence. Reports must be orally defended and be submitted in acceptable (unbound) written form. *Prerequisites: degree status and academic advisor's approval.* Also listed under TR 962.

CE 958 Master's Internship in Transportation each 3 units

Internships with relevant transportation organizations, leading to report demonstrating students' professional competence. Students are examined orally and reports must be orally defended and be submitted in acceptable (unbound) written form. *Prerequisites: degree status and academic advisor's approval.* Also listed under TR 963.

CE 959 Master's Project in Transportation Management each 3 units

An independent project leading to comprehensive report demonstrating professional competence. Projects must be orally defended and be submitted in (unbound) written form. *Prerequisites: degree status and academic advisor's approval.* Also listed under TR 966.

CE 996 Project for Degree of Master of Science 3 units

Analytical, design or experimental studies in civil or environmental engineering under guidance of a faculty advisor, and following Department guidelines. Written report required. *Prerequisite: degree status and project advisor's approval.*

CE 997 Thesis for the Degree of Master of Science 3 units

Original investigation or design in the student's principal field of study prepared under close supervision of a faculty advisor. Candidates must successfully defend thesis orally. Registration for a minimum total of six (6) units required. Maximum of 12 units counted toward degree. Allowable registration per semester 3-12 units. *Prerequisite: degree status and thesis advisor's approval.*

CE 998 Project for Degree of Engineer 3 units

Comprehensive planning and design of civil engineering project under guidance of a faculty advisor. Emphasis on current techniques. Written report in prescribed format to be submitted on completion of project. Oral examination on project subject must be passed. Registration for minimum total of 12 units required. Maximum of 12 units counted toward degree. Preferred registration per semester, 3-6 units; allowable registration 1-12 units with approval of department head. *Prerequisites: degree status and project advisor's approval.*

CE 999 Dissertation for Degree of Doctor of Philosophy 6 units

Independent original investigation demonstrating creativity and scholarship worthy of publication in recognized engineering journals. Candidates must successfully defend their theses orally. Registration for minimum of 30 thesis units required prior to defense. Registration should be continuous. Preferred registration per semester, 6 units; allowable registration 3-18 units with approval of department head. *Prerequisites: degree status, completion of qualifying examinations and thesis advisor's approval.*

FACULTY

Ilan Juran, Professor of Civil Engineering, Head of Civil and Environmental Engineering Department. B.S.C.E. Technion (Israel); Ph.D., D.Sc. University of Paris VI, Ecole National des Ponts et Chaussees. *Geotechnical engineering, soil improvement technologies, geosynthesis engineering, In-situ soil testing*

John C. Falcocchio, P.E., Professor of Transportation Engineering; B.C.E., M.S., Ph.D., Polytechnic Institute of Brooklyn, Certificate in Highway Traffic Engineering, Yale University. *Transportation planning; public transportation; travel demand; traffic engineering; transportation system evaluation; transportation systems management*

Alvin S. Goodman, P.E., Professor of Civil Engineering B.C.E. CCNY; M.S.C.E. Columbia University; Ph.D. New York University *Comprehensive water resources planning; water supply studies; hydrologic estimates; systems analysis of water resources; groundwater mathematical models; conjunctive use of surface and ground water*

Herbert S. Levinson, P.E., Research Professor of Transportation B.S.C.E. Illinois Institute of Technology; Certificate in Highway Traffic Engineering, Yale University. *Traffic operations, traffic engineering and capacity, highway engineering, transportation policy*

William R. McShane, P.E., Professor of Industrial and Systems Engineering; Director, Transportation Training and Research Center. B.E.E., Manhattan College; M.S., Ph.D., Polytechnic Institute of Brooklyn *Traffic engineering, highway capacity, expert systems in transportation, PC applications and models, economics and finance.*

Roger P. Roess, Professor of Transportation Engineering and Dean of Engineering

B.S., M.S., Ph.D., Polytechnic Institute of Brooklyn
Traffic capacity and design; traffic engineering; public transportation; transportation economics

Alan H. Molof, Associate Professor of Environmental Engineering B.S.Ch.E. Bucknell University; M.S.E. (Ch.E.) M.S.E. (Sanitary Engineering) Ph.D. University of Michigan *Water and wastewater treatment processes; river and stream pollution; industrial waste treatment; hazardous/toxic waste management*

Matthew W. Stewart, P.E. Associate Professor of Civil Engineering B.C.E., M.C.E., Polytechnic Institute of Brooklyn; *Hydraulic design; fluid meters; water resources planning*

Nabil Fares, Assistant Professor of Civil Engineering B.S.C.E., M.S.C.E., Ph.D., Massachusetts Institute of Technology *Solid mechanics; fracture mechanics; boundary element methods; finite deformation theory; composite materials.*

Dimitrios G. Goulias, Assistant Professor of Civil Engineering M.S.C.E., Università Degli Studi Della Calabria, Italy; M.S.C.E., University of Michigan; Ph.D., University of Texas, Austin *Highway engineering; pavement design performance evaluation; pavement management; non-destructive testing*

Dong-Soo Kim, Assistant Professor of Civil Engineering B.S.C.E., M.S.C.E. Seoul National University Ph.D., University of Texas, Austin *Geotechnical engineering, soil dynamics, pavement materials testing and evaluation*

Feng-Bao Lin, P.E. Assistant Professor of Civil Engineering B.S.C.E., M.S. Struct. E. National Taiwan University; Ph.D. (Structural Mechanics), Northwestern University. *Constitutive modeling of engineering materials; fracture mechanics; nonlinear finite element analysis; design of steel and concrete structures.*

Aly S. Nazmy, Assistant Professor of Civil Engineering B.Sc., M.Sc. in Struct. E., Ain Shams University (Egypt); M.A., Ph.D. (Structures/Mechanics), Princeton University *Structural dynamics and earthquake engineering; earthquake and wind-resistant analyses of cable-stayed and suspension bridges; nonlinear structural analysis and dynamics of large-scale structures, particularly long span bridges; finite element methods*

Sotiris A. Pagdadis, Assistant Professor of Civil Engineering B.S.Eng. (A.S.E.), M.S. Eng.(E.M.), Ph.D. (CE) University of Texas, Austin *Construction engineering and management; artificial intelligence, database management, CAD; construction operations and simulation for constructibility review, infrastructure rehabilitation and quality management; new technologies for construction automation*

Angelos L. Protopapas, P.E. Assistant Professor of Civil Engineering Dipl. Eng. (C.E.), National Technical University of Athens (Greece); M.S. (Operations Research & Computer Sc), University of Athens (Greece); M.S.C.E., Ph.D., Massachusetts Institute of Technology *Surface and groundwater hydrology and pollution; water resources systems; urban hydrology; fluid mechanics; irrigation*

Chikashi Sato, Assistant Professor of Environmental Engineering B.S.Ch.E., Fukushima National College of Technology (Japan); M.S. (EHE), University of Kansas; Ph.D., University of Iowa *Water and wastewater treatment processes; transport of toxic chemicals in surface and groundwaters; water quality and ecological studies of water bodies and watersheds; environmental health engineering*

Theva S. Thevanayagan, Assistant Professor Civil Engineering B.S. Peradeniya University (Sri Lanka); M.S.C.E., Ph.D. Purdue University. *Geotechnical engineering; environmental geotechnology; numerical modelling of soils; physico-chemical behavior of soils; in-situ testing*

C-Y John Yoon, Assistant Professor of Civil Engineering

B.S.C.E., M.S.C.E., Massachusetts Institute of Technology; Ph.D., University of California, Berkeley

Computer aided structural analysis and design; object oriented programming and data base designs for engineering systems; integration of engineering software systems; non-linear finite element analysis of large structures

Elena V. Shenk, Instructor in Transportation Engineering

B.A. State University of New York, Oneonta; M.S. Polytechnic Institute of New York

Traffic engineering; transit and economics; AI applications; software systems for transportation applications

Jose M. Ulerio, EIT Instructor of Transportation Engineering; Special Assistant to the Dean of Engineering
B.S., M.S., Polytechnic Institute of New York

Highway engineering; highway capacity; transportation assignment; transportation demand estimation; CAD and CAE applications

VISITING FACULTY

Janet K. Yates, Visiting Assistant Professor of Civil Engineering

B.S.C.E., M.S.C.E., University of Washington; Ph.D. Texas A & M University.

Construction engineering and management, construction databases, decision support capabilities, constructibility and international finance, software systems for project management

EMERITUS FACULTY

Paul R. DeCiccio, P.E. Professor Emeritus of Civil Engineering:

Director of Fire Research
B.C.E., M.C.E., Polytechnic Institute of Brooklyn
Urban Systems; Fire Safety

Albert H. Griswold, P.E. Professor Emeritus of Civil Engineering

B.S.C.E., University of Connecticut; M.S.C.E., Columbia University
Mechanics

Stephen T. Mikochuk, Professor Emeritus of Civil Engineering

B.C.E. Manhattan College; M.S. Rutgers-The State University
Geotechnical Engineering

James E. Miller, Professor Emeritus of Meteorology

A.B., Central Methodist College; M.S., New York University
Meteorology and Oceanography

Henry F. Soehngen, P.E., L.S. Professor Emeritus of Civil 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

Robert C. Veit, Professor Emeritus of Civil Engineering

C.E., M.C.E., Polytechnic Institute of Brooklyn
Structures

Ping Chun Wang, P.E. Professor

Emeritus of Civil Engineering
B.S.C.E., National Central University of China; M.S.C.E.; Ph.D., University of Illinois
Structures

Chilton A. Wright, Professor Emeritus of Civil Engineering

C.E., M.C.E., Ph.D., Cornell University
Hydraulic Engineering

ADJUNCT FACULTY

Raul R. Cardenas, Jr., Adjunct Professor of Environmental Engineering

B.A., University of Texas; M.S., Ph.D., New York University

Joseph C. Cataldo, P.E. Adjunct Professor of Civil Engineering

B.C.E., M.S.C.E., Ph.D., CCNY

Philip A. Habib, P.E. Adjunct Professor of Transportation Engineering

B.E. City College of New York; M.S., Ph.D., Polytechnic Institute of Brooklyn

Michael Horodniceanu, P.E. Adjunct Professor of Transportation Engineering

B.S. Technion Israel Institute of Technology; M.S. Columbia University; Ph.D. Polytechnic Institute of New York

Mohammad Karamouz, P.E. Adjunct Professor of Civil Engineering

B.S.C.E., Pahlavi University (Iran); M.S.C.E., George Washington University
Ph.D., Purdue University

Walter Kraft, P.E. Adjunct Professor of Transportation
B.S.(CE) M.S.(CE) Newark College of Engineering, D.Engr. Sc. New Jersey Institute of Technology

Anthony J. Rizzi, P.E. Adjunct Professor of Civil Engineering
B.S.E., M.S.C.E., CCNY

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

Sidhartha Bagchi, P.E. Adjunct Associate Professor of Civil Engineering
B.A., Calcutta University; B.E.C.E., Calcutta University; M.E.C.E., Calcutta University; Ph.D., Polytechnic Institute of New York

Alfred Berg, P.E. Adjunct Associate Professor of Civil Engineering
B.S.C.E., M.S.C.E., New Jersey Institute of Technology

Ingo Fox, P.E., Adjunct Associate Professor of Civil Engineering
C.E. University of Chile; M.S. Eng. D.I.C. Imperial College, London University

Bernard A. Grand, P.E. Adjunct Associate Professor of Civil Engineering
B.C.E., CCNY; M.S.C.E., Massachusetts Institute of Technology

Rita Meyniger, Adjunct Associate Professor of Environmental Engineering
B.S.C.E., Newark College of Engineering; M.S.C.E., New York University

Andre Touma, P.E. Adjunct Associate Professor of Civil Engineering
B.S.C.E. Damascus University (Syria); M.S. Imperial College (England); Ph.D., Duke University

Murray Weber, P.E. Adjunct Associate Professor of Civil Engineering
B.C.E., CCNY; M.C.E., Polytechnic Institute of Brooklyn

Irwin Weinbaum, P.E. Adjunct Associate Professor of Civil Engineering
B.C.E., CCNY

Louis D'Amico, Adjunct Assistant Professor of Civil Engineering
B.S.C.E., Polytechnic Institute of New York

Kamal A. Gadalla, P.E. Adjunct Assistant Professor of Civil Engineering
B.S.C.E., Alexandria University; M.S.C.E., Engr., Polytechnic Institute of New York

William F. Graner, P.E. Adjunct Assistant Professor of Environmental Engineering
B.S.C.E., Ph.D., Polytechnic Institute of New York; M.C.E., New York University

Paul W. Grosser, P.E. Adjunct Assistant Professor of Civil Engineering
B.E., M.E., Stevens Institute of Technology; Ph.D., Polytechnic Institute of New York

Agemmemnon Koutsospyros, Adjunct Assistant Professor of Environmental Engineering
Dipl. E. Chem. Eng., National University of Athens (Greece)
M.S.C.E., Ph.D., Polytechnic University

J.Jong Lou, P.E. Adjunct Assistant Professor of Civil Engineering
B.S.C.E., National Taiwan University; M.S.C.E., Colorado State University; Ph.D., Northwestern University

Ahmad Rahimian, Adjunct Assistant Professor of Civil Engineering
B.S.S.E., Arya-Mehr University of Technology (Iran); M.S.C.E., Ph.D., Polytechnic Institute of New York

Gabriel D. Rossetti, P.E., P.P. Adjunct Assistant Professor of Civil Engineering
B.S.C.E., New England College
M.S.C.E., M.S. (Management)
Polytechnic Institute of New York

Zohreh Shahvar, Adjunct Assistant Professor of Civil Engineering
B.S. (Agr. E.) University of Tehran (Iran); M.S. (Water Resources); Ph.D. (Agr. E.), Iowa State University

Sri K. Sinha, P.E., Adjunct Associate Professor of Civil Engineering
B.S.C.E. Patna University; M.S., CCNY

John T. Tanacredi, Adjunct Assistant Professor of Environmental Engineering
B.S. Richmond College, M.S., Hunter College Ph.D., Polytechnic University

Nicholas Ayoub, P.E. Lecturer in Civil Engineering
B.S.C.E., M.S.C.E., University of Buffalo

Anselmo Braun, Lecturer in Transportation
B.S., (Architecture), M.Sc. (Transportation Planning), Universidade Federal do Rio Grande do Sul (Brazil); M.S., Ph.D., Polytechnic Institute of New York

Paul Cohen, Lecturer in Transportation
B.A., City College of New York; M.S. University of Illinois

Mohammad K. El-Choum, Lecturer in Civil Engineering
B.S.C.E., M.S.C.E., Polytechnic Institute of New York;
M.S. (Computer Sc.), CUNY - Staten Island;
Ph.D., Columbia Pacific University

Edward E. Lockley, P.E. Lecturer in Civil Engineering
B.S.C.E., Polytechnic Institute of New York
M.S., M.P.A., Long Island University

Michael J. Sakala, P.E. Lecturer in Environmental Engineering
B.S., Drexel University
M.S.C.E., Polytechnic Institute of New York

Gennaro E. Sansone, Lecturer in Transportation
B.S.E.E., Kansas State University; M.B.A., Iona College

Raymond Schaeffer, Lecturer in Transportation
B.S.(CE), M.S.(Transportation), Swiss Federal Institute of Technology

COMPUTER ENGINEERING

The Computer Engineering Program is an interdepartmental program administered jointly by the Departments of Electrical Engineering and Computer Science within the School of Electrical Engineering and Computer Science. For more information about the School and Departments, consult the **Academic Departments** section found in Part I of the Catalog. The Program listings for Computer Science, Electrical Engineering, Electrophysics, Information System Engineering, and Systems Engineering may also be of interest.

The Computer Engineering Program focuses on computer system design with integrated understanding of computer hardware and software. Courses are drawn from EE and CS class, labs and projects. Students take courses in solid-state devices and circuits, microprocessors, pulse circuits, switching/logic design, and computer architecture.

Computers are used today for a variety of purposes. Office automation, financial data processing, and scientific computation are only some of the applications for computers. Computers find their way into our daily lives in many ways. For example:

- Automotive Electronics
- Image Processing
- Voice Recognition
- Digital Communications
- Automated Manufacturing
- Design of Circuits and Chips
- Air-Traffic Control Systems
- Energy Control Systems
- Robotics
- Electromedical Equipment
- Publishing
- LAN (Local Area Networks)
- Banking Systems
- Power System Analysis

Polytechnic University recognizes that people are needed to design the computers, computer-controlled systems, and devices that affect our everyday lives. The Computer Engineering curricu-

lum provides the fundamental knowledge and techniques that graduates will need to be competent in (1) the design of computer systems, and (2) the advanced use of computers. A computer engineer will be equally comfortable working with computer hardware and software.

The BS CompE program contains a technical concentration consisting of three technical electives and a concentration laboratory/project which allows the student to develop a professional specialization. A careful selection will stimulate learning, develop depth, prepare for continuing education, and attract prospective employers. Your project will be a mature piece of work, your own achievement, developed with the guidance of your advisor. You will prepare a proposal, create your design, test it, revise it, write a professional report, and present your results publicly. The suggestions below are examples, and many others may be constructed with advisor approval.

- Advanced Hardware Design
- Computer Communications Networks
- Control and Robotics
- Data Communications
- Microcontroller System and Interface Design
- VLSI Design
- Advanced Computer Architecture
- Artificial Intelligence and Expert Systems
- Computer Graphics
- Digital Image Processing
- Software Design and Engineering
- Computer Electronics

The B.S. (Computer Engineering) is accredited by the Accreditation Board for Engineering and Technology (ABET).

Curriculum of Study for the Bachelor of Science Degree in Computer Engineering (for Freshmen entering in 1989 or later)

FRESHMAN YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.
First Semester				
CS 200	<i>Programming Methodology (Pascal)*</i>	3	c	3
MA 101	<i>Calculus I (or MA 100)*</i>	4	0	4
HU 101*	<i>Writing and Hum. I (or 103)*</i>	3	0	3
SS 104*	<i>Contemporary World History</i>	3	0	3
CM 101	<i>Gen. Chemistry I</i>	2½	0	2½
CM 111	<i>Gen. Chem. Lab I</i>	0	1½	½
SL 101	<i>Freshman Seminar</i>	1	1	0
CP 101	<i>Intro. to Coop (Optional)</i>	1	0	0
PE 10x	<i>Sports and Teams (Optional)</i>	0	2	0
				<u>16</u>

Second Semester

HU 200*	Writing and Humanities II*	3	0	3
HU 119*	Public Speaking (or 120)	1½	1½	2
PH 104	Physics I* (Mechanics)	3	0	3
CM 103	Chemistry for Engineers	1½	0	1½
CM 113	Chemistry for Engineers Lab	0	1½	½
MA 102	Calculus II (or MA 110)*	4	0	4
CS 201	Data Structures (Pascal)*	3	c	3
PE 10x	Sports and Teams (Optional)	0	2	0
				17

ENGINEERING

SOPHOMORE YEAR

First Semester

HU 110*	Basic Report Writing I*	3	0	3
EE 101	Electric Circuits I*	4	0	3
EE 193	Sophomore EE Lab I	1/2	1 1/2	1
MA 104	Appl. Differential Equations	3	0	3
CS 205	Assembly & Machine Language*	3	bc	3
PH 105	Physics II (EMT & Heat)*	3 1/2	0	3 1/2
PH 115	Physics Lab I	0	1 1/2	1/2
PE 10x	Sports and Teams (Optional)	0	2	0
				17

Second Semester

LA 139*	Engineering Ethics	2	0	2
EE 102	Elect. Circuits II*	3	0	3
EE 194	Sophomore EE Lab II	1/2	1 1/2	1
MA 103	Calculus III	3	0	3
CS 236	Switching & Logic Design*	3	0	3
PH 106	Physics III (Waves, Optics, Sound)	2 1/2	0	2 1/2
PH 116	Physics Lab. II	0	1 1/2	1/2
PH 234	Intro. to Modern Physics	2	0	2
PE 10x	Sports and Teams (Optional)	0	2	0
				17

JUNIOR YEAR

First Semester

HU/SS*	Concentration Elect.	3	0	3
MA 223	Intro. to Probability	3	0	3
CS 337*	Comp. Architecture*	3	d	3
CS 212	C Programming and Software Development	3	cd	3
EE 109	Solid State Devices and Circuits I	4	0	4
EE 195	Junior EE Lab I	1	3	2
PE 10x	Sports & Teams (optional)	0	2	0
				18

Second Semester

	CompE Concentration I			3
EE 110	Solid State Devices and Circuits II	3	0	3
CS 275	Theory of Computation	3	0	3
CS 316	Microprocessors	3	d	3
MA 358	Num. Methods or Lin. Alg. (or MA 153)	3	3	3
CS 296	Computer Lab I	2	3d	2
PE 10x	Sports & Teams (optional)	0	2	0
				17

SENIOR YEAR

First Semester

HU/SS*	Concentration Elect.	3	0	3
HU/SS*	Concentration Elect.	3	0	3
EE 113	Solid State Pulse Circuits	3	0d	3
	CompE Concentration II			3
CS 297*	Comp. Design Lab II	1	6d	3
CS 395*	Intro. to Concentration Project	1/2	1 1/2	1
PE 10x	Sports and Teams (optional)	0	2	0
				16

Second Semester

HU/SS	Concentration (or Free) Elective	3	0	3
CS 238	Operating Systems (with Design)	3	d	3
	• CompE Concent. III			3
	• Free Elective			3
	• Concent. Project CompE	d		3
PE 10x	Sports & Teams (optional)	0	2	0
				18

Total credits for graduation: 136

* See FOOTNOTES in Electrical Engineering Curriculum Section of this Catalog for importation restrictions.

* C- required, C if repeated
Courses marked "c" use computers
Courses marked "d" include design

CONCENTRATIONS FOR THE BS CompE

The Technical Concentration required for the BS CompE is composed of three Technical Concentration Electives plus 4 credits of Concentration Lab/Project; the total is usually 13 credits. The Concentration is selected with advisor approval to develop a specialization. Not all concentrations will be offered on all campuses or every year.

BS CompE students who will be second semester juniors or seniors must be especially careful in selecting their three related Concentration courses and Project, as described below. Students must seek written approval for these four courses before registering.

Concentrations are described below, including the three courses and the project. Others may be constructed with advisor approval. Graduate electives may be used by students with at least a B average in related courses, and usually a 2.7 GPA. Courses are described in the Catalog or on Departmental bulletin boards.

Students planning to earn a Master of Science in Electrical Engineering should take the Electrical Engineering Option below.

Suggested Concentrations Suitable for the BSCompE, provided prerequisites are met:

Advanced Computer Architecture: (CS238 must be shifted from Senior Spring to Junior Spring). CS613/14 Architecture I, II; CS623 Operating Systems I; CS395/398 Project. (Also recommended is CS901 if it includes parallel processing).

Artificial Intelligence and Expert Systems: CS661 Artificial Intelligence I; CS633 Information Retrieval and Natural Language Processing or CS663 (formerly CS480) Lisp and the Structure of Computer Programs; CS662 Artificial Intelligence II or CS665 Expert Systems and Knowledge Engineering; and CS395/398 Concentration Project. (Also recommended are CS664 Computer Vision and CS9yy Neural Networks).

Computer Graphics: CS603 Design and Analysis of Algorithms, CS613 Computer Architecture I, CS653 Interactive Computer Graphics, CS395/398 Concentration Project. (ME331 CAD in Mechanical Design could be chosen as a Free Elective).

Digital Image Processing: EL512 Digital Image Processing I; EL612 Digital Image Processing II; CS395/EE216 Image Processing Laboratory; EE216 Concentration Project; and a selection from MA153 Linear Algebra, IM602 Optics, and CS9xx Computer Vision).

Advanced Hardware Design: CS613 Computer Architecture I; EL635 Principles of Communication Networks, IE365 Human Factors in Engineering Design; CS395/EE212 VLSI Lab.

Computer Communication Networks: EE392 Communication Networks; EL635 Principles of Communication Networks; EL735 Communication Networks I (B- in MA223 required, or EL531); CS395/398 Concentration Project. (Also recommended are EL738 Algebraic Codes and 739 Information Theory).

Control and Robotics: EE103 Laplace and z Transforms; EE104 Control; EL59x Robotics; CS395/EE214 Control/Robotics Lab.

Data Communications: EE103 Laplace and z-Transforms, EE140 AM/FM/Pulse Code Systems, EE141 Signal Processing; CS395/398 Concentration Project. (Also recommended are EL635 Communication Networks and EL733 Digital and Data Communications).

Electrical Engineering: EE165 Fields and Waves I; EE103 Laplace and z-Transforms; EE140 AM/FM/Pulse Code Systems; CS395/EExxx Concentration Project; and preferably EE104 as the Technical Elective.

Microcontroller System and Interface Design: including the use of SSI, MSI, and LSI chips; EE115 Advanced (Computer) Electronics; CS613 Computer Architecture I; CS623 Operating Systems I; and CS395/398 Concentration Project; or CS395/EE202 (with a project related to the Concentration).

VLSI Design: EE165 Fields and Waves-I; MT375 Semiconductor Technology or EE167 Quantum and Solid State Electronics; EE115 Advanced Digital Electronics; CS395/EE212 VLSI Lab. (Also recommended is EE645 Integrated Circuit (VLSI) System Design).

COMPUTER-AIDED DESIGN

In the classroom, design principles are discussed. Sometimes the device is built in the laboratory to test it, but more often the engineer makes a mathematical simulation of very high accuracy using a computer. Circuits for the touchtone

telephone were designed this way, for example.

The computer-aided design (CAD) facilities and programs available to students included SPICE for transistor circuit design; communication filter and network design; power system load flow; logic-circuit testing and simulation; integrated-circuit chip layout; control-system design; image processing; optimal expansion of power systems; microwave element design; printed circuit board layout; and others as needed for courses or designed by students working on a project.

PART-TIME UNDERGRADUATE PROGRAM

Some of the courses required in the undergraduate computer engineering program can be completed in the evening by attending classes Monday through Thursday from 5:55 p.m. to 10 p.m. (10:40 p.m. summer), on a part-time basis. Such undergraduate evening courses are offered at both the Brooklyn and Farmingdale campuses, but evening students may have to take day courses to complete the degree.

Polytechnic University is unique in offering identical programs and diplomas to full-time and part-time students. Day and evening sections of courses have identical content. Full-time and part-time students attend the same classes, and are subject to the same academic standards. Transfer between full-time and part-time status is possible at any time.

Since the needs of part-time students vary, a prescribed sequence of courses is not possible. Consequently students should consult a computer engineering faculty advisor in person or by telephone.

TRANSFER STUDENTS

Articulation agreements are in place with Brooklyn College, C.W. Post, and St. John's University. Qualified students from two-year preengineering programs, such as those at liberal arts and commu-

nity colleges, may fulfill the requirements for the B.S. degree in computer engineering in two additional years. Since preengineering programs vary, a prescribed program is not possible; consequently, students should consult with an undergraduate advisor.

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

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

Transfer students must arrive and present their records for evaluation at least one week before the regular registration period of their first semester at Polytechnic.

THE BS/MS ACCELERATED HONORS PROGRAM

Full time students may apply for the BS/MS Accelerated Honors Program which leads to the simultaneous award of a Bachelor's and a Master's Degree. Depending on the student's preparation and objectives, completion of the two degrees may come as early as the end of three and three-quarter years of study, or as late as five years. But each program is individually designed in cooperation with a Departmental BS/MS Accelerated Honors Program Advisor to allow for varied transfer and AP credits; coop program participation; professional summer jobs and other goals consistent with an honors program.

Possible BS/MS combinations include: BS CompE (Electrical Engineering Concentration) plus MSEE; or BS CompE plus MSCS.

Admission to the program is normally made at the end of the Freshman year, based on superior admissions qualifications, and outstanding achievement during the student's first year at Polytech-

nic. Later admission may be considered. Each student who applies is individually interviewed. Students must complete 16-20 credits each semester; *maintain* 3.5 overall and technical averages, particularly in key courses; and display a record essentially free of course repetitions and withdrawals.

The required courses for the two degrees include all courses required for the individual BS and MS degrees, except that about 4 credits for Senior Project are optional. Nine credits of Master's Thesis are usually required, and a special 11 week full-time Summer honors research project at the end of the second or third year is urged, if offered. Partial summer scholarships may be offered.

Acceleration may be achieved through Credit by Examination; summer course work; research participation; extra course loads; careful course sequencing; and advance Placement Credit in such courses as MA101/102 (AP Calculus BC, grade of at least 4, preferably 5); and CS200 (AP Computer Science A, grade 5; or AP Computer Science AB, grade 4 or 5). Descriptive brochures illustrate some of the possibilities are available to prospective participants

SENIOR HONOR STUDENTS

A full-time student whose performance during the first three years is outstanding will be named as a Senior Honor Student and is permitted to replace some of the required senior technical courses with other courses, usually more advanced, which are directed toward the student's professional goals.

GUIDANCE FOR BS CompE STUDENTS

Your instructors will help you during hours posted on their doors, or by appointment. Extensive help is available for students taking Project or Thesis.

Computer Engineering advisors will be glad to advise on courses and program adjustments resulting from academic needs or personal problems. The Dean of Students is also helpful with academic problems, and supervises fraternities and dormitories.

The Office of Special Services sponsors a peer tutoring program as well as the Learning Center which provides drop-in tutoring in mathematics and physics. Operation Action is a six-week program to help students identify and remove roadblocks to their academic success. They also have a Stop-Procrastinating Workshop. "Lunch and Learn" helps with job interviews. Personalized career counseling is available. No charge is made.

The Freshman Seminar SL 101, introduces you to Polytechnic and its curricula.

The Placement Service helps with permanent, summer, and Cooperative Program jobs. Financial Aid provides and reviews scholarship and loan information on a continuing basis.

Many courses provide extra hours or special programs on a regular basis. These include English for foreign and other students needing additional help; HU008, HU009, HU103, HU120; (MA100, MA110); and EE101/102 and CS200 tutorials. Labs have open periods for making up required experiments or for informal experimentation.

Students from upper classes can be particularly helpful. You are urged to join the student branch of the Association for Computing Machinery (ACM) and/or the Institute for Electrical and Electronics Engineering (IEEE), and to drop in to their lab. Many ethnic clubs help students adjust to our computer engineering program.

PROGRAM STANDARDS, PROBATION, AND INC GRADE

The Academic standards required for all undergraduate computer engineering students are similar to those required for EE undergraduates. For details see the section entitled "Departmental Standards, Probation," paragraph 9 in the Electrical Engineering section of this Catalog. In particular, students must have a 2.00 grade-point-average in the technical courses of the junior and senior year.

INFORMATION

Undergraduate advising handouts, available to all students, contain further details on honors, probation, approved electives, projects, elective concentrations, course offerings and other matters of interest. Curriculum and prerequisite changes, new courses, special sections, and other last minute announcements are posted on the bulletin boards outside the electrical engineering and computer science undergraduate offices in Brooklyn and on the Long Island campus. All students are responsible for keeping informed.

UNDERGRADUATE COURSES

Descriptions of the undergraduate electrical engineering and computer science courses which are part of the B.S. CompE curricula can be found in the course description sections for programs in Electrical Engineering and of Computer Science.

FACULTY

Faculty associated with the Computer Engineering program are drawn from the Department of Electrical Engineering and the Department of Computer Science. Those with primary affiliation with the CompE program include the following:

ELECTRICAL ENGINEERING

Frank A. Cassara, Professor of Electrical Engineering
B.S., Rutgers—The State University; M.S., Ph.D., Polytechnic Institute of Brooklyn
Electronic circuits, communication systems

H.Jonathan Chao, Associate Professor of Electrical Engineering
B.S., M.S., National Chiao Tung University (Hsinchu, Taiwan); Ph.D., Ohio State University; *Design of VLSI chips for telecommunications*

Douglas A. Davids, Associate Professor of Electrophysics
B.S., M.S., Newark College of Engineering; Ph.D., Johns Hopkins University
Microwave acoustics, quantum electronics

Farshad Khorrami, Assistant Professor of Electrical Engineering
BSEE, B.S. (Math), M.S. (Math), Ph.D. (EE), Ohio State University
Robotics, control systems

Seung P. Kim, Assistant Professor of Electrical Engineering
B.S., Seoul National University; MSEE, Korea Advanced Institute of Science and Technology; M.S. (Computer Engineering), University of Pittsburgh; Ph.D. (EE), Pennsylvania State University
VLSI, signal processing

Yao Wang, Assistant Professor of Electrical Engineering
B.S., M.S., Tsinghua University (Beijing); Ph.D., University of California at Santa Barbara
Image coding, pattern recognition

COMPUTER SCIENCE

James T. LaTourrette, Professor of Electrical Engineering and Computer Science
B.S., California Institute of Technology; A.M., Ph.D., Harvard University
Quantum electronics, computer software

Joel B. Snyder, Senior Industry Professor of Electrical Engineering and Computer Science
B.E.E., M.E.E., Polytechnic Institute of Brooklyn; P.E., (New York, Massachusetts)
Microprocessor systems, data acquisition and transmission, signal processing

Susan Hummel, Assistant Professor of Computer Science; B.S., McGill University; Ph.D., New York University
Computer architecture, operating systems, parallel systems

Willard Korfhage, Assistant Professor of Computer Science
B.S., Princeton; M.S., Ph.D., University of California at Los Angeles
Distributed system and computer networks

Edward Kin-Ming Wong, Associate Professor of Computer Science and Electrical Engineering
B.E. (EE), SUNY, Stony Brook; Sc.M. (EE), Brown University; Ph.D. (EE), Purdue University
Artificial Intelligence, robotics

Zhiwei Xu, Assistant Professor of Computer Science
B.S., University of Electronic Science & Technology, China; M.S., Purdue University; Ph.D., University of Southern California
Computer architecture, expert systems

COMPUTER SCIENCE

Computer science is the study of the theory and applications of computers. The field of study covers the design and analysis of algorithms for information processing, principles of programming languages and compilers, operating systems, software engineering, artificial intelligence, computer organization and architecture, computational mathematics, parallel processing and application areas including database systems, computer graphics, computer music, and image analysis and understanding.

The computer science program is administered by the Department of Computer Science of the School of Electrical Engineering and Computer Science. Its faculty directs the degree programs in computer science and information systems engineering.

UNDERGRADUATE PROGRAM

This program has been accredited by the Computer Science Accreditation Commission (CSAC) of the Computing Sciences Accreditation Board (CSAB), a specialized accrediting body recognized by the Council on Post-secondary Accreditation (COPA) and the U.S. Department of Education.

The program in computer science offers a curriculum that prepares students for a professional career as computer scientists, or graduate studies in computer science leading to research or academic careers. The undergraduate program in computer science at Polytechnic is based on the principle that a well-rounded graduate should have a rigorous education in the fundamentals of computer science including significant exposure to the design and operation of computers, solid training in related mathematics and scientific disciplines, and a broad general education including the development of communication skills.

OVERVIEW OF THE UNDERGRADUATE CURRICULUM

This description of the curriculum is designed to give students an overview of the structure of the curriculum and to help them understand the reasons behind the design of the curriculum. Undergraduates in computer science at Polytechnic University have the advantage of being in a department with a strong graduate division. This means that the undergraduate students study in a rich intellectual environment where many of their instructors are engaged in state-of-the-art research. This significantly contributes to the quality of education and provides highly motivated undergraduates with the opportunity to engage in advanced projects with first-rate researchers.

Computer Science Component (42 credits)

One of the distinctive features of the computer science component is the balance of emphasis on subjects related to the design of computers and theoretical computer science. For example, students study switching and digital systems, computer organization and architecture, as well as data structures, software development, database systems, operating systems, microprocessors, advanced algorithms, and the principles of programming languages. The Department believes that this balance is important in preparing graduates for a professional or research career. The program culminates in a major design project, publicly presented.

Computer Science Concentration (13 credits)

The Technical Concentration required for the Bachelor of Science in Computer Science is composed of three Technical Concentration Electives plus the 4 credits of Concentration Project; the total

is usually 13 credits. The Concentration is selected with advisor approval to develop a specialization which will stimulate learning, develop depth, prepare for continuing education, and attract prospective employers. See the departmental advisor for information about the design and choices of a concentration.

Mathematics Component (20 credits)

Mathematics is essential to the CS curriculum. It forms the basis for understanding computer architecture and organization, principles of programming languages, algorithms, compilers, and operating systems. The mathematics sequence is designed to enhance the integration of mathematics with the computer science component. If students did not have a chance to learn high school mathematics well (as determined by the Polytechnic placement examination in mathematics), they will be given three extra hours a week of freshman mathematics, with no extra tuition charge. The physics sequence begins in the second term of the freshman year to take advantage of the preparation in mathematics.

Basic Science Component (13 credits)

Basic courses in physics and chemistry provide a well-rounded education in science. Computer scientists find that their training in basic science plays an important role in their career, by allowing them to understand the theoretical principles of new devices.

General Education and Communication Skills Component (34 credits)

Courses in the humanities and social sciences are an important part of the curriculum. Career advancement is not only based on technical skills and knowledge. It is equally based on the ability to

communicate effectively and apply the wisdom that results from a serious study and appreciation of the humanities and social sciences. In addition to basic humanities and social sciences courses, the Department requires students to take LA 139 (Engineering Ethics), LA 143 (Computers, Culture, and Society), HU 110 (Report Writing), and HU 116 (Computer Documentation), and 18 credits of humanities/social science electives.

For further details and descriptions see the section of this catalog entitled "Humanities and Social Sciences requirements for Engineering and Computer Science Majors," and handouts prepared each semester.

***Opportunities to Explore--
The Technical Elective Component
(12 credits)***

It is important for students to have the opportunity to explore other subject areas or to delve into areas in more depth. This is the purpose of having 18 credits of electives. Of these 18 credits, 6 credits must be selected from either computer science or mathematics courses. Students may elect to minor in another discipline if they so choose. Advanced students may also take some of the graduate computer science courses.

HONORS PROGRAM

Full-time students may apply for the BS/MS Accelerated Honors Program which leads to the simultaneous award of a Bachelor's and a Master's Degree. Depending on the student's preparation and objectives, completion of the two degrees may come as early as the end of three and three-quarter calendar years of study, or as late as five years. But each program is individually designed in cooperation with a departmental BS/MS Accelerated Honors Program Advisor to allow for varied transfer and AP credits; co-op program participation; professional summer jobs; and other goals consistent with an honors program.

Possible BS/MS combinations include: BSEE plus MSCS; BSCS plus MSCS; BSCompE plus MSCS.

Admission to the program is normally made at the end of the freshman year, based on superior admissions qualifications, and outstanding achievement during the student's first year at Polytechnic. Later admission may be considered. Each student who applies is individually interviewed. Students must complete 16 to 20 credits each semester; maintain 3.5 overall and technical averages, particularly in key courses; and display a record essentially free of course repetitions and withdrawals.

The required courses for the two degrees include all courses required for the individual BS and MS degrees, and all curriculum footnotes apply. Required credits are the sum of the credits for the two degrees, except that about 4 to 7 technical or free elective credits are excused. Nine credits of Master's Thesis are usually required, and a special 9-week full-time Summer honors research project at the end of the second or third year is urged, if offered. Partial Summer scholarships may be offered.

Acceleration may be achieved through Credit by Examination; summer course work; research participation; extra course loads; careful course sequencing; and advanced placement credit in such courses as MA 101/102 (AP Calculus BC, grade of at least 4, preferably 5); and CS 200 (AP Computer Science A, grade of 5; or AP Computer Science AB, grade of 4 or 5).

TRANSFER STUDENTS

Transfer students are accepted into the computer science BS program on the same basis described in the catalog under admissions. In addition, the Department requires that at least 18 credits in computer science and the 13 credits of the Concentration/Project be taken at Polytechnic.

Graduates of technology programs may be able to fulfill the requirements for the bachelor's degree in computer science in two to three-and-one-half years, depending on the scope and level of their previous education. Consult an undergraduate advisor for details.

Transfer credits granted for courses taken at other schools may vary based on reevaluation of content and level as evaluated on the data of admissions to Polytechnic. Thus, students completing

the same program, but in different years, may receive different amounts of transfer credit. Consult a computer science undergraduate advisor for current information. Computer science courses will be evaluated by the Computer Science Department. Transfer students must arrive and present their records for evaluation at least one week before the regular registration period for their first semester.

SENIOR HONOR STUDENTS

A full-time student whose performance in the first three years is outstanding will be named as a senior honor student and, in consultation with an advisor, is permitted to replace some of the required senior technical courses by other courses, usually more advanced, which are directed toward the student's professional goals.

DEPARTMENTAL STANDARDS, PROBATIONS, AND INC GRADE

Engineers and computer scientists are professionals who are expected to achieve work of acceptable quality and quantity within a specified time. Similarly, Polytechnic students need to assure timely academic progress. It is this ability, the ability to work and to achieve, which is most desired by prospective employers. If students have any questions, they should feel free to discuss them with an advisor--preferably in a timely fashion so that good solutions can be found to any problems that may arise.

To remain in good standing, Computer Science majors must earn term-by-term (year-by-year for part-time students), and cumulatively, minimum C (2.00) technical grade-point averages (GPA) in two distinct categories: (1) The Freshman/Sophomore Technical Grade-Point Average in freshman and sophomore courses prefixed CS, MA, and PH; and (2) the Junior/Senior Technical GPA in required junior and senior courses, plus all CS electives. These requirements are in addition to the University requirements for a minimum 2.00 grade-point average in all courses. Students not achieving these goals will be restricted in progressing to more advanced courses.

The following conditions apply to all CS students:

1. Students must meet all requirements for the courses they take, including those in this document; in documents entitled "Prerequisites, Corequisites, and Repeated Courses for EE/-CompE/CS Undergraduates"; "Acceptable Electives"; documents related to HU/SS requirements; in letters from departments and the Dean of Students; and other advising documents (usually revised three times a year)—available at CS/-CompE/EE undergraduate advising offices; and in the latest edition of the Polytechnic University Catalog;

2. For the following courses, students must earn a grade of C- or better when first taken, C if repeated once, before the student may proceed to any course for which these are prerequisite:

CS 200; CS 201; CS 236; HU 008 or 009 (if required; grade of S); HU 101 (or 103); HU 200 (or IS 141); and HU 110.

3. With advisor permission, students may repeat a course in which they earned a substandard grade.
4. Students with less than a C (2.00) semester average, or less than a C average in a closely related course sequence, may be asked to repeat courses in which grades were less than a C.

5. Transfer credits may be removed if students earn less than a C- in a subsequent course.

6. No CS student placed in HU 008 or HU 103 will be disqualified after getting an unsatisfactory grade in HU 008 or HU 103, unless the total number of times these courses are taken is more than four, and provided that: (a) the Department of Humanities certifies that the student has made a real effort to improve, as shown by attendance, participation, and work submitted; and (b) grades in other courses are satisfactory.

7. Students who take a course without having fulfilled all course prerequisites, or who are in violation of any probation requirements, face deregistration (without tuition refund) and possible disqualification.

8. Students are not permitted to accumulate more than five course withdrawals (W) in credit-bearing courses.

9. When, for valid reasons, such as illness or other critical emergency, a student is unable to complete the course work within the usual time, the instructor may give a grade of INC. The grade of INC is used sparingly, and not merely because students have planned poorly or overloaded themselves. The INC grade signifies that upon successful completion of the work, a passing grade will be issued.

Students failing to meet any of the above requirements are placed on probation as a warning that they are not progressing acceptably toward their degree. Repeated failure to meet probation requirements may lead to disqualification from the undergraduate CS program and courses. Students on probation may be required to decrease their course load, repeat courses passed with a grade less than C, or undertake other remedial programs.

The following students are not permitted to preregister (in April-May or November-December) for the following semester, but are obliged to consult their advisor between the time grades are posted and the regular registration day prior to the start of classes, so that any necessary reevaluations can be made: 1) students on departmental or continued final probation; 2) students who are on any kind of departmental probation and who have an overall cumulative GPA less than 2.00; or 3) students on Dean's Final Probation. Please note also that students placed on probation by the Dean of Students must get written permission from the Dean to register, and are usually restricted to only 15 credits for the semester.

Curriculum for the Bachelor of Science Degree in Computer Science (for Freshman entering 1990)

FRESHMAN YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.
First Semester				
CM 101	Gen. Chem. I	2	½	2½
CM 111	Gen. Chem. Lab I	0	1	½
CS 200	Prog. in Pascal	4	c	3
HU 101	Writing/Hum. I (or HU103)	3	0	3
MA 101	Calculus I (or MA100)	4	0	4
SS 104	Contemporary World History (optional)	3	0	3
CP 101	Co-op Seminar (optional)	1	0	0
PE 10x	Sports and Teams (optional)	0	2	0
SL 101	Freshman Seminar	1	1	<u>0</u>
				16
Second Semester				
CS 201	Data Structures/ Algorithms	4	c	3
HU 119	Public Speaking (or HU120)	1½	1½	2
HU 200	Writing & Hum. II	3	0	3
MA 102	Calculus II (or MA110)	4	0	4
PH 104	Intro. to Physics	3	0	3
CP 102	Co-op Seminar II (optional)	1	0	0
PE 10x	Sports and Teams	0	2	<u>0</u>
				15

SOPHOMORE YEAR

First Semester				
CS 205	Assembly/Machine Language	4	c	3
HU 110	Basic Report Writing I	3	0	3
HU/SS	Concentration elective	3	0	3
MA 103	Calculus III	3	0	3
PH 105	Introduction to Physics II	3½	0	3½
PH 115	Intro. to Physics Lab I	0	1½	½
PE 10x	Sports and Teams (optional)	0	2	0
				16
Second Semester				
CS 212	Prog./Software Development	3	d	3
CS 236	Switch Theory/Logic Design	3	0	3
HU 116	Computer Documentation	3	0	3
LA 139	Engineering Ethics	2	0	2
MA	Elective	3	0	3
PH 106	Intro. to Physics II	2	½	2½
PH 116	Intro. to Physics Lab II	0	1	½
PE 10x	Sports and Teams (optional)	0	2	0
				17

JUNIOR YEAR

First Semester				
CS 202	Advanced Algorithms	3	0	3
CS 206	Compiler Design	3	d	3
CS 312	Prog. Languages	3	0	3
CS 337	Comp. Architecture	3	d	3
HU/SS	Concent. Elective	3	0	3
MA 223	Intro. to Probability	3	0	3
				18
Second Semester				
CS 275	Theory of Computation	3	0	3
CS 306	Software Engineering	3	d	3
CS 316	Microprocessors	3	d	3
LA 143	Computers, Culture, Society	3	0	3
MA 224	Intro. to Math Statistics	3	0	3
	Technical Concentration			3
				18

SENIOR YEAR

First Semester				
CS 308	Intro. to Database Systems	3	d	3
CS 395	Intro. to Concentration Project	½	1½	1
HU/SS	Concentration Elective	3	0	3
CS	Elective			3
	Technical Concentration			3
	Technical Elective			3
				16
Second Semester				
CS 238	Operating Systems	3	d	3
	HU/SS Concent Elect.	3	0	3
CS	Elective			3
	Concentration Project			3
	Free Elective			3
	Technical Concentration			3
				18

Total credits required for graduation: 134

Courses marked "c" require work on various computer systems. Courses marked "d" include major Design/Computer projects.

The **FOUR HU/SS CONCENTRATION ELECTIVES**: Each student must take either **TWO** two-course concentrations (each composed of one introductory and one advanced course in the same discipline), or **ONE** three-course concentration (one introductory and two advanced in the same area). Consult the **DEGREE REQUIREMENTS** section of this catalog for details.

Note for PE 10x Physical Education—Sports and Teams (All teams): Physical Education is not required, but all students are invited to participate in such activities a sports, weightlifting, karate (Brooklyn only), intramural teams, and extramural teams—as many semesters, and as many times per semester as they please.

Note for SL101 Student Survival (Freshman I): A course on the Polytechnic experience, study suggestions, clubs and sports, curricular options, and other topics. Required for students who enter Polytechnic with fewer than six transfer or advanced standing credits, and recommended for all students during their first semester.

Note for Free Electives (Senior II): A Free Elective is a course given by any department, provided it does not duplicate material studied in other courses. It must advance the student's education and have advisor approval. Not permitted are such courses as CS100, 101, 211, or any CS 500 course; EE 370, 374; LA 120, 121, 125, 130, 131; ME 101, 111, 115, 116, 117.

Note for CS Concentration I, II, III (Junior II & Senior I): A Computer Science concentration is composed of three technical electives, plus CS 395, Introduction to Concentration Project (1 cr) and Concentration Project (3 cr), chosen in consultation with a concentration advisor. The concentration must involve advanced courses which are coherently related, and the project must include a related professional design. Concentration groupings are published and can be found in the departmental office; other combinations may be discussed.

Note for Technical Electives (Senior): Technical electives are chosen from courses marked CS, EE, EL, CM, LS, MA, PH, or other engineering departments. Each course must have an advanced content, not overlap other courses, usually have a strong analytic or design component, contribute to the student's professional education, and have the approval of an advisor. Students are urged to consider a CS Laboratory as a technical elective.

GRADUATE PROGRAMS

The Department of Computer Science offers master's and doctor's degree programs in computer science, and a master's degree program in information systems engineering. See the section of this catalog on Information Systems Engineering for a description of this program.

The computer science master's program is intended to develop competence in basic areas such as information structures, programming languages, computer design and organization, compilers and translators, operating systems, artificial intelligence, interactive computer graphics, information retrieval, database management, switching theory, theory of computation, numerical analysis and software engineering.

The computer science master's degree program is specifically structured to enable the graduate to keep abreast of developments in the chosen discipline and to interact with other disciplines. Students may extend their studies into related areas such as operations research, mathematics, electrical engineering, management, statistics and economics, in accordance with individual interests.

Outstanding students are advised to apply for financial aid in the form of teaching fellowships or partial tuition remission.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE

Entrance Requirements -- For entrance to the Master of Science degree programs, an undergraduate degree in computer science, mathematics, science or engineering, with a superior undergraduate record from an accredited institution, is required. Applicants having degrees in other fields will be considered for admission on an individual basis. Generally, entering students are expected to have a knowledge of mathematics through calculus. Additional entrance requirements for the two MS degree programs are as follows:

1. At least one year of university-level science;
2. A working knowledge of a higher-level programming language such as PL/I, Pascal, LISP, C, etc.;
3. A basic understanding of computer fundamentals such as computer organization and operation, data structures, assembly language programming, elements of logic and automata, computer architecture.

It is anticipated that entering students with BS degrees in computer science as well as students with degrees in technical areas from accredited institutions and strong minors in computer science will satisfy the entrance requirements for the MS degree programs.

Students having superior academic credentials, but lacking sufficient background, are admitted on conditional status pending satisfactory completion of additional preparatory courses as specified from undergraduate computer science courses and/or from the series of six graduate orientation courses, CS 530, CS 540, CS 550, CS 560, CS 580, and CS 590. Successful completion of the preparatory courses with a B or better average is a necessary condition for transfer to regular status.

The demonstrated ability to communicate in written and spoken English is an essential ingredient for success in pursuing graduate studies in computer science and information systems engineering and is required for regular status. Foreign students and others for whom English is a second language may be required to undertake preparatory work to improve their language skills before admission into the graduate program.

Admission with advanced standing is possible in accordance with Polytechnic regulations published elsewhere in this catalog. A maximum of nine units may be applied to the MS degree for previous graduate work at an acceptable institution.

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

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

Master of Science - (Computer Science)

	Units
1. Core Requirements (B average required):	15
CS 603 <i>Design and Analysis of Algorithms I</i> CS 613 <i>Computer Architecture I</i> CS 623 <i>Operating Systems I</i> CS 637 <i>Programming Languages</i> CS 641 <i>Compiler Design and Construction I</i>	
2. One of the following three courses:	3
CS 675 <i>Theory of Computation</i> MA 821 <i>Numerical Analysis</i> MA 705 <i>Linear and Modern Algebra I</i>	
3. Two one-year course sequences from the list:	6-12
CS 603, CS 604 <i>Design and Analysis of Algorithms I, II</i> CS 606, CS 607 <i>Software Engineering I, II</i> CS 613, CS 614 <i>Computer Architecture I, II</i> CS 623, CS 624 <i>Operating Systems I, II</i> CS 641, CS 642 <i>Compiler Design and Construction I, II</i> CS 661, CS 662 <i>Artificial Intelligence I, II or</i> CS 665 <i>Expert Systems and Knowledge Engineering</i> CS 671, CS 672 <i>Switching and Automata I, II</i>	
4. Approved elective courses of which maximum of 6 units may be a thesis	6-12

Thesis - Exceptional students may elect to write a master's thesis, for which no more than 6 units may be earned toward the degree. Such students should find an appropriate advisor who has agreed to monitor the thesis research.

Such research need not be original, but should adequately demonstrate the student's proficiency in the subject material. A defense of the master's thesis with at least three professors in attendance is required.

Master of Science (Information Systems Engineering)

See separate section of catalog on Information Systems engineering for this program.

REQUIREMENTS FOR THE DOCTOR'S DEGREE

Graduate students who have exhibited a high degree of scholastic proficiency and given evidence of ability for independent scholarly work may consider extending their goals toward the degree of doctor of philosophy. The requirements for admission to the program include the following:

1. A BS degree in science, engineering or management from an accredited school and a superior academic record.
2. An MS degree or one year of graduate work in an analytically-based area, and a superior academic record.
3. Sufficiently high GRE scores.

Upon 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 Department of Computer Science.

1. A minimum of 90 units of graduate work beyond the BS degree, including 24 units of dissertation.
2. Qualitative rather than quantitative considerations will determine the final approval of the program of graduate study; however, the following should be included:
 - a. The basic MS requirement in computer science;
 - b. A major concentration in a computer science area;
 - c. Supporting courses in noncomputer areas, for breadth;
 - d. A minor concentration in an area other than computer science (a minimum of four courses).

Requirements b, c and d must be approved by the Department of Computer Science.

3. Qualifying examinations consisting of four written examinations, generally covering topics corresponding to the MS requirements.
4. Presentation of an in-depth seminar talk on the subject of the disserta-

tion, at such time as the thesis advisor deems appropriate.

5. Preparation and defense of a scholarly dissertation which embodies an original research contribution.

UNDERGRADUATE COURSES

Students are advised to consult the Schedule of Classes for changes in prerequisites in effect after publication of this catalog.

General prerequisite: Students may not register for any junior- or senior-level courses until all freshmen requirements are completed.

CS 100 Introduction to Computer Programming 2:0:2

Introduction to computers to develop fundamental understanding of their use. Early use of computer permits immediate solutions to simple engineering problems. Development of more complex programming techniques for use in subsequent engineering and computer courses. FORTRAN language used. (This course cannot be used to satisfy any degree requirements in computer science or in electrical engineering.)

CS 200 Programming in Pascal 3:0:3

Introduction to discrete mathematics including: tools, techniques, methodologies, and algorithmic language. Computers and programming; running a program under UNIX; the algorithmic language; pseudocode; problem solving and program structure. Constants, variables, data types, assignments, arithmetic expressions, input and output. Top-down design and procedures. Selection and loops. Functions. Enumerated and subrange data types. Arrays, records, sets. Recursion, searching, and sorting. *Prerequisite: None. Corequisites: MA 101 or 100. A C- grade is required if this course is used as a prerequisite.*

CS 201 Data Structures and Algorithms 3:0:3

Introduction to data structures. Program specification and design. Abstract data

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types, examples of stacks and queues. Sequential and linked implementation of stack and queues. Dynamic storage allocation. Topics of discrete mathematics including: selected elements from a set, searching methods, sequential and binary, binary and general trees. Hashing. Sorting algorithms. *Prerequisites:* CS 200 (C- required); preferably MA 101 or 100. *Co-requisites:* preferably MA 102 or 110. C- grade required by BSCS and BSCoPE majors.

CS 202 Advanced Algorithms 3:0:3

Introduction to the design and analysis of algorithms. Searching. Topics in discrete mathematics including: simple graphs, diagraphs, and path problems. Binary search trees, versus balanced trees, (AVL-trees, 2-3 trees). Hashing. Mathematical background: analysis of algorithms, big O notation, establishing and solving simple recurrence equations. Sorting algorithms and their analysis (quicksort, mergesort, heapsort, radix sort). Lower bound. Priority queues. Graphs: DFS, BFS, connected components, topological sort, single source shortest path (Dijkstra), all source shortest path (Floyd), transitive closure (Warshall), minimum spanning tree (Prim). Design paradigms: divide and conquer, dynamic programming, greedy algorithms. NP-completeness. *Prerequisites:* CS 201 (C- grade required by BSCS majors).

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

Internal representation of numeric and character data. Machine organization and machine language programming. Assembly language, assemblers. Assembly language programming: branching, arrays, lists, arithmetic and bit manipulation, macros, stacks, subroutines, parameter passing, recursion. Linking and loading, position-independent and re-entrant code. Traps and interrupts. *Prerequisite:* CS 201 (C- required for BSCS and BSCoPE majors).

CS 206 Compilers 3:0:3

Grammars, lexical analysis, parsing theory and algorithms, intermediate languages, storage assignment, stack machines and run-time organization. A

large programming project is required. *Prerequisites:* CS 201 (C- required), CS 205 (C- required), CS 236 (C- required). *Suggested co-requisites:* CS 202 (required of BSCS majors) and CS 337.

CS 211 COBOL Programming 3:0:3

Computing using ANSI-COBOL for simple and complex business problems. Structured programming used throughout. Creating, using and updating sequential, indexed and relative data files on magnetic tapes and disks. Report writer and table handling modules in COBOL. Batch processing and time sharing processing. (This course cannot be used to satisfy any degree requirements in computer science or in electrical engineering.)

CS 212 C, UNIX, and Software Development 3:0:3

Programming in C in the UNIX environment. Methodology of program design. Programming style, tools, environment, documentation. Programming project. *Prerequisites:* CS 200 (C- required); CS 201 (C- required).

CS 236 Switching Theory and Logic Design 3:0:3

Introduction to concepts of switching theory and digital systems. Topics in discrete mathematics including: logic and propositions, properties of sets, and Boolean algebra. Number representations, arithmetic operations, coding, combinational circuits, logical design, sequential machines, state diagrams/tables, clock mode and pulse mode systems, state reduction, machine synthesis. *Prerequisites:* CS 200 (or CS 100 for non-CS majors)(C- required in CS 200 for BSCS and BSCoPE majors). CS 201 and 205 recommended. *Co/Prerequisites:* PH 105/115 (or knowledge of Kirchhoff's laws). C- grade is required if this course is to be used as a prerequisite.

CS 238 Operating Systems 3:0:3

Overview of user interface. Process structure, creation and context switching; system calls; process cooperation. Memory management; virtual memory. I/O management; interrupt handling. File structures; directories, fault-tolerance. Design project involving construction of

multi-tasking executive required. *Prerequisites:* CS 205 (C- required), CS 337 (C- required), CS 212 or knowledge of C language or special permission of the instructor.

CS 240 Computer Music 3:0:3

Digital audio fundamentals: sound measurement, A/D and D/A conversion, frequency spectra, Fourier series and transforms, DFT and FFT algorithms, convolution, filtering. Music tuning systems, microtuning, music encoding. Computer music programming, computational requirements. Additive, subtractive, and nonlinear synthesis techniques. Introduction to speech synthesis. Reverberation, localization, and psychoacoustical effects. Stochastic algorithms for computer music composition. Digital music synthesizers, MIDI microcomputer interface programming. *Prerequisites:* CS 201, MA 103, interest in music.

CS 275 Theory of Computation 3:0:3

The concept of algorithms, foundational programming languages, topics in discrete mathematics, computable functions, Godel numbering and Church's thesis, unsolvable problems, context-free grammars for formal languages, parsing, finite automata. *Prerequisite:* CS 201 (C- required); CS 236 (C- required). CS 202 required for BSCS majors.

CS 296 Computer Laboratory I 2:3:2

A series of required experiments provides an introduction to small computers: digital and analog circuit techniques, small computer assembly and programming, minicomputer and microcomputer organization and operations. Lab fee required. *Prerequisites:* CS 205, CS 236, EE 109 or EE 111 or EE 370 or EE 377, EE 195 or EE 374 or EE 377 lab. *Corequisites:* CS 337.

CS 297 Computer Laboratory II
1:6:3

An introduction to the use of small computers as systems components: interrupt programming concepts, analog signal interfacing and real time, closed-loop systems. Independent learning and hands-on experience with different small computers are provided by projects involving such subjects as computer graphics, light intensity control and motor speed control. *Prerequisites:* CS 296, or CS 337, CS 205, for EE majors all technical courses of the junior year.

CS 306 Software Design and Engineering
3:0:3

Introduces the techniques used to specify, design, test, and document medium and large software systems. Design techniques include structured programming, defensive programming, program design language (PDL), and program complexity models. Path testing, exhaustive test models, and construction of test data. Software reliability models. Introduction to software tools and management techniques. Student term projects involve group software development. *Prerequisites:* CS 201 (C- required), CS 212 (C- required); MA 223 and CS 202 are recommended.

CS 308 Introduction to Database Systems
3:0:3

The effective management and utilization of data. Objective of DBMS, data independence, integrity, security. Organization and access techniques, architecture, data definition and manipulation languages. Data models; hierarchical, network and relational structures. Practical applications of state-of-the-art techniques, foundations and other language styles. *Prerequisite:* CS 201 (C- required), CS 212 or CS 312.

CS 312 Principles of Programming Languages
3:0:3

Principles and program styles associated with current conventional programming languages. Topics include language evaluation criteria and historical influences on language design; lexical analysis,

syntax analysis; semantic considerations; control structures; data types; subprograms; process and data abstractions; procedural, functional, and other language styles. *Prerequisite:* CS 200 (C- required), CS 201 (C- required).

CS 316 Microprocessors
3:0:3

Block diagram description of the architecture of a typical microprocessor. Registers and ALU of the CPU. Interfacing components, bus structure, I/O techniques, priority interrupt schemes. Program techniques. *Prerequisite:* CS 201 (C- required), CS 205 (C- required), CS 337 (C- required). CS 202 (required by BSCS majors, effective Fall 1991).

CS 337 Computer Architecture and Organization
3:0:3

Computer architecture: machine language instruction set design. Computer organization: logical modules, registers, memories, I/O devices. Arithmetic and logical operations, fixed and floating point systems. Introduction to a hardware description language. Design and analysis of a complete digital computer employing hardwired and microprogrammed control. Stack machines. Hierarchical memory organizations. Instruction lookahead and overlapping. Pipelining. Parallel computer systems. *Prerequisite:* CS 205 (C- required for BSCS and BSCompE majors), CS 236 (C- required).

CS 391-4 Special Studies in Computer Science

Advanced courses in computer science given to selected students. These courses are vehicles for presenting novel material, trying new educational methods and courses, and taking advantage of the special competencies of visiting staff. *Prerequisite:* Permission of the computer science advisor, or as posted on bulletin board.

CS 395 Introduction to Concentration Project
1:1½:1

Group lectures and individual discussions to prepare students for professional achievement in their senior project. This is the first phase of a project (or projects) which requires the design, construction, testing, and documentation of a piece of equipment, software package,

or systems applications. *Prerequisites:* HU 110 (C- required), HU 119 or HU 120, completion of all technical and lab courses through the junior year. *Co/Prerequisite:* First term senior laboratory (usually CS 297 - BSCompE majors only), HU 116 (BSCS majors only).

CS 398 Senior Concentration Project in Computer Science
1:6d:3

Term project. Several students work as a group with a staff member and graduate students on a topic of interest. Written report and presentation required. *Prerequisites:* CS 395, HU 110 (C- required), HU 119 or HU 120, HU 116 (BSCS majors only). *Co/Prerequisites:* All courses specified by the project advisor.

CS 480 Structure and Implementation of Computer Programs
3:0:3

Programming in the SCHEME dialect of Lisp. First-class objects. A metalinguistic evaluator for SCHEME. Environments. Applicative-order evaluation. Functional programming. Storage management and garbage collection. *Prerequisites:* CS 205 (C- required), CS 212 (C- required). *Co-requisites:* CS 238.

ORIENTATION COURSES

The graduate courses listed in this section were formulated to accommodate the needs of students who wish to pursue graduate studies in computer science, but who lack sufficient undergraduate preparation. No credit will be allowed for any of these courses toward graduate degrees in computer science, information systems engineering or other degree programs administered by the Department of Computer Science. Submission of substantial computer programming assignments is required in all these courses except CS 560.

ENGINEERING

CS 530 Introduction to Computer Science 2½:0:3

Computers and programming; use of terminals; problem solving and program structure; control statements and procedures; data types. Functions. Arrays, records, set and files. Recursion, searching and sorting. Pointers and dynamic data structures. *Prerequisite: graduate status.*

CS 540 Data Structures and Algorithms 2½:0:3

Review of structured data types. Procedural and data abstraction. Stacks, queues. Sequential and linked representations. Recursion. Computational complexity. Trees. Graphs. Searching and sorting. *Prerequisite: CS 530.*

CS 550 Assembly Language and Systems Programming 2½:0:3

Internal representation of numeric and character data. Machine organization and machine language programming. Assembly language, assemblers. Assembly language programming: branching, arrays, lists, arithmetic and bit manipulation, macros, stacks, subroutines, parameter passing, recursion. Linking and loading, position-independent and re-entrant code. Traps and interrupts. *Prerequisite: CS 530*

CS 560 Switching Theory and Logic Design 2½:0:3

Automata and switching theory, Boolean algebra, truth tables. Combinatorial circuits, logical design, gate realizations. Sequential machines, state diagrams/tables, state equivalence, machine synthesis.

CS 580 Computer Architecture and Organization 2½:0:3

Computer architecture: machine language instruction set design. Computer organization: logical modules, registers, memories, I/O devices. Arithmetic and logical operations, fixed and floating point systems. Introduction to a hardware description language. Design and analysis of a complete digital computer em

playing hardware and microprogrammed control. Stack machines. Hierarchical memory organizations. Instruction look-ahead and overlapping. Pipelining. Parallel computer systems. *Prerequisite: CS 205 (C- required for BSCS and BS-CompE majors), CS 236 (C- required). Prerequisites: CS 550 and CS 560.*

CS 590 Introduction to Operating Systems 2½:0:3

Overview of user interface. Process structure, creation and context switching; system calls; process cooperation. Memory management; virtual memory. I/O management; interrupt handling. File structures; directories, fault-tolerance. Design project involving construction of multi-tasking executive required. *Prerequisites: CS 540, CS 550, and CS 580.*

GRADUATE COURSES

Graduate courses in computer science are offered on each campus on a regular basis, annually, or in two- or three-year cycles. The Computer Science Graduate Mailing, sent out to students prior to each registration, contains the latest information on course offerings for the semester, including Selected Topics.

CS 531 Introduction to Digital Computing 2½:0:3

First course in computing concentrating on analysis of problems for computer solution. Organization of computers. Structure and properties of algorithms and programs, flow charting. Debugging and verification, documentation, data representation, numerical error analysis. FORTRAN IV language used. (No credit will be allowed toward graduate degrees in computer science, information systems engineering or other degree programs administered by the Department of Computer Science.). *Prerequisite: graduate status.*

CS 603 Design and Analysis of Algorithms I 2½:0:3

Data structures: priority queues, binary search trees, height-balanced trees, heaps, hash tables. Searching and sorting

techniques: heapsort, quicksort, sorting in linear time, medians and order statistics. Design and analysis techniques: dynamic programming, greedy algorithms. Graph algorithms: elementary graph algorithms (breadth-first search, depth-first search, topological sort, connected components, strongly connected components), minimum spanning tree, shortest path. *Prerequisite: CS 540.*

CS 604 Design & Analysis of Algorithms II 2½:0:3

Advanced design and analysis techniques: amortized analysis of algorithms. Advanced data-structures: binomial heaps, Fibonacci heaps, data structures for disjoint sets, analysis of union by rank with path compression. Graph algorithms: elementary graph algorithms, maximum flow, matching algorithms. Randomized algorithms. Theory of NP-completeness and approach to finding (approximate) solutions to NP-complete problems. Linear and integer programming techniques. Combinatorial optimization. *Prerequisite: CS 603.*

CS 606 Software Engineering I 2½:0:3

Software development, modeling tools. Techniques: design estimation, testing, reliability, management. Design and analysis: top-down, modular structured. HIPO diagrams, cause-effect graphs. Probabilistic models: complexity, number of errors, exhaustive, regression. Management: costs, productivity, controls. *Prerequisites: MA 223 and one of the following: CS 603, CS 623, CS 641.*

CS 607 Software Engineering II 2½:0:3

A continuation of the materials begun in CS 606 with emphasis on software development tools and the management of software projects including prediction, estimation, and control of software costs and program productivity. Students will be organized into project groups and will plan and design a software system using manual and computerized development tools. Class presentations, exams and term project. *Prerequisite: CS 606.*

CS 608 Principles of Database Systems 2½:0:3

Database management system overview. Data independence and abstraction. Physical database, organization, and access methods. Data models, entity relationships, network, hierarchical, and relational structures. Relational model design theory, functional multivalued dependencies, normalization. Concurrent operation in centralized and distributed database systems. *Prerequisite: CS 308.*

CS 609 Information Analysis and System Design I 2½:0:3

Introduction to the system life cycles of a computer information system. System life cycle management. Basic analytical tools, determining system economics. Logical system design. Introduction to physical system design. *Prerequisite: CS 530.*

CS 610 Information Analysis and System Design II 2½:0:3

Basic design tools and objectives. Hardware/software selection and evaluation. Software design and software engineering. Database development. Program development. System development. Post-implementation analysis. *Prerequisite: CS 609.*

CS 613 Computer Architecture I 2½:0:3

CPU organization: control and arithmetic logic; bus interfaces and timing. Horizontal and vertical microprogrammed organizations. Instruction sets and data formats; interprocess synchronization; hardware/firmware/software trade-offs. Hardware organizations for support of virtual memory, high-level programming languages and operating system features. Knowledge of an assembly language is required. *Prerequisite: CS 580.*

CS 614 Computer Architecture II 2½:0:3

Further development of topics in machine organization and architecture. Memory hierarchies, virtual memory and cache memories. Pipelining. SIMD organizations; interconnection topologies. Systolic arrays; data flow organizations;

performance evaluation considerations. *Prerequisite: CS 613.*

CS 616 Microprocessors 2½:0:3

Architectures, instruction sets, memory management support, and multiuser operating system support of several families of microprocessors. Emphasis is on current 32 bit microprocessors. Background material needed to understand the operating system support and memory management techniques is presented. The following systems are examined with respect to the issues presented: the Intel 8086/386/486, the Motorola 6800/68000/68020/030/040, and the IBM 801/America/RS6000. The RS6000 exposes microprocessor design issues for the future, including RISC concepts, superscalar design, instruction rescheduling, precise interrupts, memory-CPU bandwidth balancing, cache design. *Prerequisite: CS 613*

CS 618 Fault-Tolerant Computers 2½:0:3

Introduces a variety of hardware and software techniques for designing and modeling fault-tolerant computers. Topics include: coding techniques (Hamming, SECDED, SECDED, etc.); majority voting schemes (TMR); software redundancy (N-Version programming); software recovery schemes. Introduces probabilistic methods for reliability modeling. Examples from space fault-tolerant systems, LAN networks, commercial non-stop systems (TANDEM and STRATUS). The HARP, ARIES, and SHURE fault-tolerant modeling tools will be used. *Prerequisite: CS 560.*

CS 623 Operating Systems I 2½:0:3

Operating systems for uniprocessors: processes, mutual exclusion, job scheduling, memory, storage hierarchy, file systems, and analytical modeling of computer systems. *Prerequisite: CS 590.*

CS 624 Operating Systems II 2½:0:3

Operating systems for parallel and distributed computers: concurrent programming, process synchronization, deadlocks, distributed computing, networks, distributed concurrency control, and

analytical modeling of computer systems. *Prerequisite: CS 623.*

CS 627 Performance Evaluation of Computer Systems 2½:0:3

Modeling and performance analysis of computer systems. Introduction to queuing network models and elements of queuing analysis. Exact and approximate analytical techniques, simulation and operation analysis. Examples in modeling multiprogramming operating systems, interactive systems, and flow control in computer networks. *Prerequisite: EL 531 or MA 223 and instructor's permission.*

CS 630 Input and Output Systems 2½:0:3

The theory, technique and technology of interaction between electronic digital information systems and the external environment from a systems perspective. Models of text, speeches, and images useful for systems studies. The processes and devices to convert between text, speech, and image representations of information and electronic digital information systems. *Prerequisite: CS 603.*

CS 637 Programming Languages 2:0:3

The structures, notations, and semantics of conventional programming languages. Introduction to analysis and design of user-oriented application languages. Advanced concepts of input and output. *Prerequisites: CS 540 and CS 550.*

CS 641 Compiler Design & Construction I 2½:0:3

Organization of compiler, symbol table organization, lexical analysis, syntax analysis, object code generation, introduction to code optimization techniques. Internal representation of parsed source program, Polish notation, triples, trees. Translation of arithmetic expressions and programming constructs. *Prerequisites: CS 540, CS 550, CS 560.*

CS 642 Compiler Design & Construction II 2½:0:3

Further considerations of code optimization techniques. Formal languages and grammars. Introduction to translator systems. *Prerequisite: CS 641.*

ENGINEERING

CS 653 Interactive Computer Graphics 2½:0:3

Problems and objectives of interactive computer graphics. Interactive display devices and input devices. Transformations, construction of display file, and graphics languages. Windowing, perspective projection, hidden-line problems and shading. Curved surface generation. *Prerequisite: CS 603 and CS 613 or permission of instructor.*

CS 661 Artificial Intelligence I 2½:0:3

Automation of intellectual processes. Nature of machine intelligence and its limitations. Descriptions of cognitive processes. Heuristic vs. algorithmic methods of problem solutions and question-answering systems. Game-playing programs. Formula manipulation, symbolic integration, automation of programming. General problem solvers. Introduction to pattern recognition.

CS 662 Artificial Intelligence II 2½:0:3

Further study of automation of intellectual processes. Automatic theorem proving. Expert systems. Simulation of verbal learning behavior. Learning machines, adaptive systems, robots, decision-making problems. Adequacy of existing theoretical treatments. *Prerequisite: CS 661.*

CS 663 Pattern Recognition Principles 2½:0:3

This course covers the basic principles and techniques used in the two approaches to pattern recognition: statistical/decision theoretic and syntactic/structural. Topics include Bayes decision theory, linear classifiers, parameter estimation and supervised learning, nonparametric techniques, feature selection, clustering, string grammars and languages, parsing, and stochastic languages. *Prerequisites: MA 223 and basic matrix algebra.*

CS 664 Computer Vision and Scene Analysis 2½:0:3

An important goal of artificial intelligence is to equip computers with the capability of interpreting visual inputs.

Computer vision and/or scene analysis is an area in AI that deals with the construction of explicit, meaningful descriptions of physical objects from images. It includes as parts many techniques from image processing, pattern recognition, geometric modeling and cognitive processing. This course introduces students to the many techniques, applications and current research in computer vision and/or scene analysis. *Prerequisite: CS 540 or equivalent or permission of instructor.*

CS 665 Expert Systems and Knowledge Engineering 2½:0:3

The purpose of an expert system is to disseminate the knowledge acquired by experts in their area to users using artificial intelligence techniques. The knowledge is formalized using various knowledge representation schema. This course will introduce students to various types of knowledge and their representation. The inference procedures, architecture and control used in expert systems will be discussed. An introduction to the rule-based programming language OPS5 will be given and a prototype expert system term project will be built based on it. *Prerequisite: CS 661 or permission of instructor.*

CS 667 Neural Network Computing 2½:0:3

An introduction to neural network models and their applications. Discussion of organization and learning in neural network models including: Perceptrons, Adalines, backpropagation networks, recurrent networks, adaptive resonance theory and the neocognitron. Implementations in general and special purpose hardware, analog and digital. Application in various areas with comparisons to non-neural approaches. Decision systems, nonlinear control, speech processing and vision. *Prerequisite: CS 540. Some familiarity with matrix notation and partial derivatives is recommended.*

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. Fi-

nite-state sequential machines, state-transition diagrams, machine and state equivalence, incompletely specified machines, state reduction, machine realizations. *Prerequisite: CS 560.*

CS 672 Switching and Automata II 2½:0:3

Further development of theory of finite-state machines. State assignments, partitions with substitution property and partition pairs, machine identification and testing. *Prerequisite: CS 671.*

CS 673 Formal Languages and Automata Theory 2½:0:3

Introduction to generative grammars, characteristics of regular, context-free, context-sensitive and type-zero grammars. Relationships between languages and machines. Finite-state machines, push-down automata, Turing machines. The Halting Problem, solvable and unsolvable linguistic questions. Offered subject to sufficient demand. *Prerequisite: mathematical maturity.*

CS 675 Theory of Computation 2½:0:3

Computability and decidability. Computable and primitive recursive functions. The Halting Problem. Recursively enumerable sets. Turing machines. One of the following topics will be covered: Grammars, languages, and automata; degrees of undecidability; abstract complexity; propositional calculus and quantification theory. *Prerequisite: mathematical maturity.*

CS 676 Mathematical Techniques for Information 2½:0:3

Basic results from queuing theory, data structures and graphs and network flows. Poisson processes, M/M/1, M/G/1 queues. Queuing networks. Linked lists, sorting, searching, dynamic storage management. Graphs and network flows, spanning trees; algorithmic complexity, linear programming, network flows, min-cut max-flow. *Prerequisites: regular graduate status, EL 531, and MA 103.*

CS 681 Information, Privacy, and Security 2½:0:3

Introduction to security and privacy issues associated with information systems. Cost/risk tradeoffs. Technical, physical, and administrative methods of providing security. Control of access through technical and physical means. Identification and authentication. Encryption, including the Data Encryption Standard (DES) and public key systems. Management of encryption systems, including key protection and distribution. Privacy legislation and technical means of providing privacy. *Prerequisite: graduate status.*

CS 682 Network Management and Security 2½:0:3

Human aspects of network management; performance measures; classical and vendor network management systems; unified systems; OSI network management; fault and performance; configuration control; security; encryption. *Prerequisite: EL 635.*

CS 901-912 Selected Topics in Computer Science each 2½:0:3

Topics of current interest in computer science. Recent offerings include software economics, parallel processing program methodology, object-oriented programming and distributed systems. Specific topics announced in advance. (See computer science graduate mailing for detailed description of each particular offering). *Prerequisite: specified when offered.*

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 advisor. An examination or term report is required. *Prerequisite: regular status and permission of director of the Computer Science Department.*

CS 996 Advanced Project in Computer Science 2½:0:3

This course permits the student to perform research in computer science somewhat less in scope than a master's thesis. The acceptance of a student by a faculty advisor is required before registration. An oral examination on the project report is required. *Prerequisite: regular status.*

CS 997 Thesis for Degree of Master of Science each 3 units

Exceptional students may elect to write a master's thesis for which no more than six units may be earned toward the degree. Such research should adequately demonstrate the student's proficiency in the subject material. Oral thesis defense with at least three professors in attendance plus a formal, bound thesis volume are required. Thesis registration must be continuous. *Prerequisite: regular status and satisfactory grades in prescribed courses.*

CS 999 Dissertation for Degree of Doctor of Philosophy each 3 units

Original investigation of computer science problem. Must demonstrate creativity and include features of originality and utility worthy of publication in a recognized journal. Candidate must successfully defend dissertation orally. Registration of 24 units required (continuous dissertation registration required). *Prerequisite: passing of qualifying examination and approval of the Computer Science Department.*

FACULTY

Henry Ruston, Professor of Electrical Engineering and Computer Science and Acting Head of the Computer Science Department

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

Ivan T. Frisch, Professor of Electrical Engineering and Computer Science; Provost

B.S. (Physics), Queens College; B.S. (EE), M.S. (EE), Ph.D. (EE), Columbia University
Information systems, computer networks and network control

Donald Hockney, Professor of Computer Science and Director of the Center for Applied Large-Scale Computing (CALC) and Vice Provost of Academic Computing

B.A., McMaster University; Ph.D., Cornell University
Logic, data base systems, network design

James T. LaTourrette, Professor of Electrical Engineering and Computer Science

B.S. (Physics), California Institute of Technology; M.A. (Physics), Ph.D. (Physics), Harvard University
Computer languages and algorithms, computer software

Paul F. Pickel, Professor of Mathematics and Computer Science

B.A. (Chemistry), Ph.D. (Math), Rice University
Mathematical programming, computer graphics, artificial intelligence

Stanley Preisner, Professor of Mathematics and Computer Science

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

ENGINEERING

Martin L. Shooman, Professor of Electrical Engineering and Computer Science S.B., S.M., Massachusetts Institute of Technology; D.E.E., Polytechnic Institute of Brooklyn
Software engineering, system reliability and safety

Richard Van Slyke, Professor of Electrical Engineering and Computer Science B.S. (Physics), Stanford University; Ph.D. (Operations Research), University of California (Berkeley)
Computer communications, telecommunications

Gad M. Landau, Associate Professor of Computer Science B.Sc. (Math, CS), M.S., Ph.D., Tel-Aviv University (Israel)
Algorithms

Edward K. Wong, Associate Professor of Computer Science B.E. (EE), SUNY, Stonybrook; Sc.M. (EE), Brown University; Ph.D. (EE), Purdue University
Computer vision, pattern recognition, image processing

Boris Aronov, Assistant Professor of Computer Science B.A. (Math, CS), Queens College, CUNY; M.S., Ph.D. (CS), New York University
Computational geometry, combinatorial geometry, geometric algorithms

Phyllis G. Frankl, Assistant Professor of Computer Science B.A. (Math, Physics), Brandeis University; M.A., (Math), Columbia University; M.S., Ph.D. (CS), New York University
Software engineering, theory of computation

Susan Flynn Hummel, Assistant Professor of Computer Science B.A. (Math), McGill University; Ph.D. (CS) New York University
Computer architecture, operating systems, parallel systems

Willard Korfthage, Assistant Professor of Computer Science B.S.E. (EE/CS), Princeton University; M.S., Ph.D. (CS), University of California at Los Angeles
Distributed systems, computer communications, operating systems, monitoring and visualization

Jeanette P. Schmidt, Assistant Professor of Computer Science B.Sc. (Math, CS), Hebrew University of Jerusalem; M.S. (CS), Ph.D. (CS), Weizmann Institute of Science, Rehovot, Israel
Algorithms, analysis of randomized algorithms

Vassilis J. Tsotras, Assistant Professor of Electrical Engineering and Computer Science B.A. (EE/CS), National Technical University of Athens (Greece); M.Sc. (EE), M.Phil. (EE), Ph.D. (EE), Columbia University

Joel Wein, Assistant Professor of Computer Science B.A. (Applied Mathematics), Harvard University; Ph.D. (Applied Mathematics), Massachusetts Institute of Technology
Parallel and distributed computation, theoretical computer science, combinatorial optimization, network optimization

(Bill) Zhiwei Xu, Assistant Professor of Computer Science B.S. (CS) University of Electronic Science and Technology (China); M.S. (CompE), Purdue University; Ph.D. (CompE), University of Southern California
Computer architecture, parallel processing

Linda Anne Grieco, Coordinator of Advising B.A. (Math), Hofstra University; M.S. (CS), Polytechnic Institute of New York; Ph.D. (Math), Rutgers University
Programming and computer software

Haldun Hadimioglu, Visiting Assistant Professor of Computer Science B.S. (EE), M.S. (EE), Middle East Technical University (Turkey), Ph.D. (CS) Polytechnic University
Concurrent computer systems, computer architecture and design, parallel computation, distributed operating systems

Mohammed Ghriba, Instructor in Computer Science Dipl. d'Ingénieur (CS) de l'Université des Sciences et de Technologie d'Alger (Algérie); M.S. (CS), Polytechnic University
Software engineering, theory of computation, communications software

Colleen Molter, Instructor in Computer Science B.S., M.S. (EE), Polytechnic University
Computer architecture, fault tolerant computing

INDUSTRY PROFESSORS

Joel B. Snyder, Senior Industry Professor of Electrical Engineering and Computer Science B.E.E., M.S. (EE), Polytechnic Institute of Brooklyn; P.E. (New York and Massachusetts)
Microprocessor systems, data acquisition and transmission, signal processing

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

Barry Jones, Industry Assistant Professor of Electrical Engineering and Computer Science B.S. (EE), Cooper Union; M.S. (EE), Marist College
Electromechanical systems, real-time computer systems

ADJUNCT FACULTY

Maurice Karnaugh, Distinguished Adjunct Professor
B.S. (Physics), City College of New York; M.S., Ph.D., Yale University

David R. Doucette, Adjunct Professor
B.S., M.S., Ph.D., Polytechnic Institute of Brooklyn

Barry V. Gordon, Adjunct Professor
B.E.E., M.E.E., New York University

Edward Lancevich, Adjunct Professor
B.E.E., City College of New York, CUNY; M.S. (EE), Columbia University; Ph.D. (EE), Polytechnic Institute of New York

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B.A., Ph.D. (Philosophy), Yale University

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B.A. (Math), Rutgers University; M.A. (Applied math), University of Maryland; Ph.D. (Applied math), New York University

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B.S., University of California (Irvine); M.S., Ph.D., Rutgers University

Bruce A. Martin, Adjunct Assistant Professor
B.S. (Applied Math), Polytechnic Institute of Brooklyn

Lillian S. Ruston, Adjunct Assistant Professor
S.B. (EE), Massachusetts Institute of Technology; M.S.(EE), Ph.D.(EE), Polytechnic University

Philip S. Brown, Lecturer
B.S., City College of New York; M.S., Engineer, Polytechnic Institute of New York

Mohammed Feknous, Lecturer
Ingeniorat en Electronique (E.E.), Ecole Nationale Polytechnique d'Alger; M.S. (E.E.), University of Missouri-Rolla

John Kaufman, Lecturer
B.A. (CS), New York University; M.S. (CS), Polytechnic University

Oleg Olovyanikov, Lecturer
B.S. (EE), M.S. (CS), Polytechnic University

Thomas O'Rourke, Lecturer
B.S., M.S. (EE), Polytechnic University

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

EMERITUS FACULTY

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

ELECTRICAL ENGINEERING

THE SCHOOL OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

The School of Electrical Engineering and Computer Science was formed in 1990 to coordinate the academic and research programs of the Electrical Engineering Department and the Computer Science Department. These activities trace their beginnings to Polytechnic's first electrical engineering program in 1886. The earliest emphasis on electrical power generation, distribution, and lighting expanded to radio communications in the early 20th century; microwaves, radar, and television in the 1940's; and digital computers in the 1950's.

In addition to the recognized excellence in teaching, textbook writing, and research achievements of its faculty and students, the School has a long tradition of close ties with engineering practice in industry and government. Leaders from industry serve on advisory boards for the School's programs, and it has served the life-long learning needs of working engineers since part-time graduate programs were initiated in 1926.

As an administrative unit, the School fosters interdepartmental cooperation in the many areas where EE and CS have common interests, including the BS program in Computer Engineering, and graduate student research in the Centers for Advanced Technology in Telecommunications (CATT), Applied Large-Scale Computing (CALC), and Imaging Sciences (IIS). The School's faculty and graduate students also participate in the electrophysics research associated with the Weber Research Institute (WRI), founded as the Microwave Research Institute in the 1940's by Dr. Ernst Weber, who later became head of the EE department, and then president of Polytechnic.

The centers and the degree programs in electrophysics, system engineering, computer engineering, computer science, and information systems engineering are described in more detail elsewhere in this Catalog.

THE DEPARTMENT OF ELECTRICAL ENGINEERING

The Department of Electrical Engineering administers a variety of degree programs summarized in the table which follows. From its beginnings in the 1880's the department has enjoyed national and international reputation based on the accomplishments of its alumni, on the research achievements of students and faculty, and on the textbooks written by faculty and alumni. This reputation has been confirmed periodically by surveys of members of the profession; the latest, the 1989 Gourman Report shows Polytechnic EE programs as best in the New York City area and highly-ranked nationally, 12th for B.S. and 13th for M.S. The most recent American Society for Engineering Education list has the PhD (EE) 10th nationally, out of over 200 Electrical Engineering degree programs in the United States.

This section of the Catalog describes the programs and courses in electrical engineering. All of these programs are offered by The Department of Electrical Engineering within the School of Electrical Engineering and Computer Science. For more information about the School and the Departments consult the Academic Departments section found in Part I of this Catalog. The program listings for computer engineering, computer science, electrophysics, information system engineering, and system engineering may also be of interest. The graduate programs in electrophysics and in system engineering are described in

the appropriate Catalog sections; however, the courses for these two programs (except for thesis) are located in the electrical engineering section. Programs and courses in computer science, and the graduate program in information systems engineering and computer engineering, are described in other sections of the Catalog. The departmental faculty also participates in the graduate programs in energy, imaging sciences, and telecommunications management, described elsewhere in the Catalog.

Degree Programs Administered by the Department of Electrical Engineering

UNDERGRADUATE

Electrical Engineering

- *Bachelor of Science*

Computer Engineering

- *Bachelor of Science*

(Administered jointly with Department of Computer Science)

GRADUATE

Electrical Engineering

- *Master of Science*
- *Electrical Engineer*
- *Doctor of Philosophy*

Electrophysics

- *Master of Science*
- *Doctor of Philosophy*

Systems Engineering

- *Master of Science*
- *System Engineer*

Information Systems Engineering

- *Master of Science*

THE ELECTRICAL ENGINEERING PROFESSION

Electrical engineering is a rapidly growing profession which has evolved from its early beginnings in electric power generation and distribution through the development of radio to television and computers. More recently, it has contributed to man's pleasure, safety and health with automatic systems and devices used daily in medical and health care, high-speed transportation, and satellite communication.

While undergraduate and graduate programs in electrical engineering are designed primarily to develop talents in these areas, graduates eventually apply their training to such diversified fields as bioengineering, city planning, astronautics, radio astronomy, system engineering, management, and patent law. As students mature and realize their abilities, their professional lives may center on engineering, government, sales or education.

The electrical engineering faculty at Polytechnic covers a wide range of fields. Principal areas of teaching and research are micro-electronic devices and systems; computer engineering and computer science; telecommunications; speech and image processing; electro-optics and electro-acoustics; microwave engineering; power systems and energy conversion; plasma science and engineering; system and control engineering; quantum electronics; and materials science.

UNDERGRADUATE PROGRAM

The program for the degree of bachelor of science in electrical engineering gives students broad-based preparation for a career in electrical engineering in any of its specializations, and readies them for immediate employment in industry, business, and government, or for further graduate education. The program (both campuses), is accredited by the Accreditation Board for Engineering and Technology (ABET).

Curriculum of Study for the Bachelor of Science Degree in Electrical Engineering (for Freshman entering in 1989 or later)

FRESHMAN YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.

First Semester

CS 200	Prog. Methodology (Pascal)*	4	c	3
MA 101	Calculus I (or MA 100)*	5	0	4
CM 101	Gen. Chemistry I	2½	0	2½
CM 111	Gen. Chem. Lab I	0	1½	½
HU 101*	Writing & Human (or HU103)*	3	0	3
SS 104*	Cont. World History	3	0	3
SL 101	Freshman Seminar	2	0	0
PE 10x	Sports and Teams (optional)	0	2	0
CP 101	Co-op Education I (Optional)	1	0	0
		16		

Second Semester

CS 201	Data Structures and Algorithms	4	c	3
MA 102	Calculus II (or MA 110)*	5	0	4
CM 103	Chem. for Engineers	1½	0	1½
CM 113	Chem. for Eng. Lab	0	1½	½
HU 200*	Writing & Hum. II*	3	0	3
HU 119*	Public Speaking (or HU120)	1½	1½	2
PH 104	Intro. Physics I* (Mechanics)	5	6	3
PE 10x	Sports and Teams (optional)	0	2	0
		17		

SOPHOMORE YEAR

First Semester

EE 101	Elect. Circuits I*	4	0	3
EE 193	Sophomore EE Lab I	½	1½	1
CS 205	Assembly & Mechanics. Language	3	c	3
MA 104	Appl. Diff. Eqns.	3	0	3
PH 105	Intro. Physics II*	5	0	3½
PH 115	Physics Lab. I	0	1½	½
HU 110*	Report Writing*	3	0	3
PE 10x	Sports and Teams (optional)	0	2	0
		17		

Second Semester

EE 102	Elect. Circuits II*	4	0	3
EE 194	Sophomore EE Lab II	½	1½c	1
MA 103	Calculus III	3	0	3
CS 236	Switching Theory & Logic Design*	3	0	3
PH 106	Intro. Physics III (Waves, Optics, Sound)	4	0	2½
PH 116	Physics Lab II	0	1½	½
PH 234	Introduction to Modern Physics	2	0	2
LA 139*	Eng. Ethics	2	0	2
PE 10x	Sports and Teams (optional)	0	2	0
		17		

JUNIOR YEAR

First Semester

HU/SS*	Concent. (Non-Skill)	3	0	3
EE 103	Signals & Transforms	4	0	4
EE 109	Solid State Devices and Circuits I	4	0	4
EE 165	Fields and Waves I	3	0	3
CS 337*	Computer Arch. & Organization	3	d	3
EE 195	Junior EE Lab I	1	3	2
PE 10x	Sports and Teams (optional)	0	2	0
		19		

Second Semester

HU/SS*	Concent. (Non-Skill)	3	0	3
EE 110	Solid State Devices & Circuits II	3	d	3
EE 166	Fields & Waves II	3	0	3
EE 104*	Feedback Systems	3	d	3
MA 223	Intro. to Probability	3	0	3
CS 296	Computer Lab I	2	3d	2
PE 10x	Sports and Teams (optional)	0	2	0
		17		

SENIOR YEAR

First Semester

HU/SS*	Concent. (Non-Skill)	3	0	3
	• Technical Elective EE/CSxxx	3	0	3
EE 180*	Electric Machinery I (or EE167)	3	0	3
EE 113	Solid State Devices & Circuits III	3	d	3
EE 140	Communication Syst.	3	0	3
EE 196*	Senior EE Lab I (or CS297)	1	3d	2
EE 395*	Intro. to Project	½	1½d	1
PE 10x	Sports and Teams (optional)	0	2	0
		18		

ENGINEERING

Second Semester

HU/SS*	Elective (Free or Concen.)	3	0	3
•	Technical Elective EE/Csxxx	3	0	3
•	Technical Elective EE/Csxxx	3	0	3
•	Technical Elective: Free	3	0	3
•	Senior EE Lab/ Project (or EE196)	1	6d	3
PE 10x	Sports and Teams (optional)	0	2	0 15
Total Credits for Graduation:				136

- See FOOTNOTES for important restrictions
 - C- required, C if repeated
 - Courses marked "c" use computers
 - Courses marked "d" include design
- FOOTNOTES FOR BSCompE and BSEE CURRICULA

GENERAL FOOTNOTES which apply throughout the curricula:

Important documents requiring frequent updating are published separately (about three times a year). Included are "Advising Notes", "Prerequisites, Corequisites, and Repeated Courses for EE and CompE Undergraduates", HU/SS Concentration Information, "Acceptable Electives for BSEE and BSCompE Students", and other documents available at advising offices. This updated information is a formal part of this document.

- Courses marked with an asterisk (*) in the Curriculum Tables require a grade of C- or better when first taken. C if repeated once, before the student may to proceed any course for which they are prerequisite. These courses are important preparatory courses for the advanced curricula:

CompE: CS200, 201, 205, 236, & 337; EE101 & 102; HU101 (or 103); HU200 (or IS141); HU110; MA101 (or 100), MA102 (or 110); PH104 & 105.

EE: CS200 & 236; EE101 & 102; HU101 (or 103); HU200 (or IS141); HU110; MA101 (or 100); MA102 (or 110); PH104 & 105.

FOOTNOTES for HUMANITIES and SOCIAL SCIENCES COURSES

The total HU/SS credits listed in the standard curriculum are:

28 for the BSCompE & BSEE — 12 elective & 16 required: HU101(3), HU200(3), HU110(3), HU119(2), SS-104(3), LA139(2).

These courses are of two types: Two Communications (*often called "Skills"*) — Writing and Speech; and Nine Cultural (*often called "Non-Skills"*).

HUMANITIES: World Literature; Philosophy and Technology; Music and the Fine Arts; Modern Languages.

SOCIAL SCIENCES: World History; History of Science and Technology; Economics; Psychology; and Anthropology/Sociology.

The Skills and Non-Skills credits are listed as follows:

HU101 (or 103) and HU200 *Writing & the Humanities I, II*; total 6 credits — 3 Skills and 3 Non-Skills credits.
HU110 emphasizes report writing and documentation. Each is 3 credits — 3 Skills and 0 Non-Skills.
HU119 (or 120) teaches speech: 2 credits — 2 Skills and 0 Non-Skills.
SS104 concerns world history: 3 credits — 0 Skills and 3 Non-Skills.
LA139 concerns professional ethics: 2 credits — 0 Skills and 2 Non-Skills.
LA143 concerns computers and society — 0 Skills and 3 Non-Skills.

Electives in HU/SS must be selected to form a concentration. Consult the DEGREE REQUIREMENTS section of the catalog, subsection "Humanities & Social Science Requirements for Engineering & Computer Science Majors".

FOOTNOTES for TECHNICAL COURSES (CS, EE, EL, & other engineering courses)

- Note for CS337 (Junior Fall; EE majors only):

In place of CS337 students may take an approved non-EE/CS elective in engineering science. Examples are ME112 Dynamics (with prerequisites

PH104 and EE165, not ME111); or ME201 Thermodynamics (with prerequisites MA104 and PH105).

- Note for EE104 (Junior Spring; EE majors only):

Students planning to take their senior electives in Power Engineering should delay EE104 until Senior Fall and take EE180 in Junior Spring.

- Note for EE180 (Senior Fall EE majors only):

Students may take EE180 Electric Machinery, EE167 Quantum and Solid-State Electronics, or any other course related to electrical materials, electromagnetics, or optics, with advisor approval. (If students have completed ME119, they may disregard this change, or may take EE-180, 167, or the other courses specified above, and use ME119 as a technical elective.)

- Note for EE196 Senior Electrical Engineering Lab I (EE majors only):

Students taking CS297 in place of EE 196 as a 3-credit elective must defer EE196 to Senior Spring, since CS297 is offered only in the Fall. EE196 may be replaced by either IS 297, EE202 or EE214 to satisfy degree requirements (without registering for EE395). If EE202 or 214 is coregistered with EE395, the pair constitutes a Senior Project; but some other lab/project course (such as CS297) is required to complete the required 2-credit and the 4-credit senior labs and projects.

- Note for Free Electives (Senior Spring; CompE, EE's occasionally):

A Free Elective is a course given by any department, provided it does not duplicate material studied in other courses. It must advance the student's education, and have advisor approval. Not permitted are such courses as CS100, 101, 211, 5x0; EE370, 374; LA120, 121, 125, 130, 131; ME101, 111, 115, 116, 117; MG 202, 502; MT 305.

- **Note for CompE Concentration I, II, III** (Junior Spring and Senior Fall, Spring CompE):

A **Computer Engineering Concentration** is composed of three technical electives, plus CS395 Introduction to Concentration Project (1 cr.) and Concentration Project (3 cr.) — chosen in consultation with a Concentration advisor. The Concentration must involve advanced courses which are coherently related, and the project must include a related professional design. Concentration groupings are published in this document under "Concentrations for the BSCompE" in the Computer Engineering Section of the Catalog; other combinations may be discussed with the CompE advisor.

- **Note for Technical Electives** (Senior; CompE/EE):

Technical electives are chosen from courses marked CS, EE, EL, CM, LS, MA, PH, or other engineering departments. Each course must have an advanced content, not overlap other courses, usually have a strong analytic or design component, contribute to the student's professional education, and have the approval of an advisor. Students are urged to consider a second Senior Laboratory/Project as a Technical Elective. Graduate courses may be chosen if the student's GPA in related courses is a B, and overall GPA is 2.7. An updated list of some allowed out-of-department courses, "Acceptable Electives for BSEE and BSCompE Student", is published by the CS/EE Undergraduate Advising Offices each semester. ROTC cadets may receive 3 technical elective credits if they complete MS301 and 303 for credit at Polytechnic.

In the CompE Program, one technical elective with a strong design component is required.

- **Note for CS297, EE395, and Concentration Project (CompE) and Senior Lab/Project:**

All students are required to complete a 4-credit Senior Project, composed of the one-credit course CS395 or EE395, and a three-credit laboratory/project course:

CS297 (EE majors only), 398; EE202, 204, 206, 208, 210, 212, 214, 216, 397, 399, or EL970. Not all courses are appropriate for all majors; some are offered on one campus; not all are offered every year. The three-credit course tends to emphasize the technical work; the 1-credit course emphasizes professional preparation, reports, oral presentation, and additional studies. These courses are all described in the section of the Catalog titled "Undergraduate Courses" in both the Electrical Engineering and Computer Science sections.

A Senior Project is an individual or small-group activity performed under the supervision of a staff member who will serve as the advisor. Professional planning, analysis, and achievement are required. Written and oral presentation before a group will help to prepare each student for professional competence. To understand what the Senior Project is all about, and the purpose of CS395/EE395, read the description of CS395/EE395 in the section titled "Undergraduate Courses."

CompE majors are required to choose the project in their particular area of Concentration. EE students may select any project for which they have the Pre/Corequisites.

For more details on senior projects, see the extensive discussion in the document titled "Senior Projects for EE/CompE Majors."

ELECTIVES, CONCENTRATIONS, AND PROJECTS

Students majoring in electrical engineering take 16 credits of advanced technical electives, including senior project, to prepare for the career of their choice. Courses are selected from electrical engineering; computer science; physical and life sciences; mathematics; management and operations research; and the other engineering disciplines. Many students take electives to sample fields not covered in required courses, or to take an advanced course in a subject already studied. Other students with firm professional goals prefer to concentrate

their elective courses in a chosen area. Students who plan to take a sequence of related electives can defer one or two of the required junior year courses to a later semester.

Possible concentrations include, but are not limited to:

- *Advanced Electronic Design and VLSI*
- *Bioengineering with Life Sciences; Pre-Medicine*
- *Communication and Information Systems*
- *Computer Architecture and Operating Systems*
- *Computer Hardware Design and Organization*
- *Computer Software Design and Artificial Intelligence*
- *Control and Robotics*
- *Data Structures, Machine Languages, and Compilers*
- *Electric Power Engineering*
- *Electromagnetic Fields and Waves*
- *Lasers, Fiber Optics, and Microwave Devices*
- *Linear Systems and Networks*
- *Materials Engineering and Semiconductor Fabrication*
- *Physics and Chemistry*

All students undertake a 4-credit professional senior design laboratory or project guided by a staff member. See description of EE395, Introduction to Project. Recent senior project topics include:

- *Modes of a Laser with Intracavity Frequency Doubler*
- *In-Building Propagation of UHF Signals*
- *Neural-Type Optimization*
- *Continuous Phase-Modulation Digital Signaling*
- *Compact, Low-Field, High-Harmonic Gyrotron*
- *Pulsed Hollow-Cathode Lasers*
- *Flashover in Crossed Electric and Magnetic Fields*
- *Small-Scale Model of Coilgun*
- *Power Electronics*
- *Picosecond Optoelectronics for Ultrashort Pulses*
- *Numerical Methods for Optical Microscopy*
- *Morphological Analysis and Coding of Images*
- *Radar and Sonar Signal Processing*

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- *Telecommunication Management Workstation*
- *Expert System for Computer Music*
- *Hardware Design of a DSP Processor*
- *Digital Simulation of an Analog System*
- *Computer-Aided Instruction for Digital Signal Processing*
- *Local Area Networks (LAN)*
- *The Processing of Images from Incomplete Data*
- *Wireless Information Networks*

Graduate courses (non-daggered) may be taken as electives by senior students whose junior-year grade-point average in technical courses exceeds 2.7, provided students have a B average in related and prerequisite courses. Daggered graduate courses in electrical engineering may usually be taken as senior electives by any undergraduate.

Five-year programs leading to two bachelor's degrees are possible—for example, electrical engineering and physics. Five-year programs leading to a bachelor's and a master's degree are also possible for qualified students—for example, BS in electrical engineering and MS in computer science.

All selections are discussed with and approved by an EE advisor.

COMPUTER-AIDED DESIGN

In the classroom, design principles are discussed. Sometimes the device is built in the laboratory to test it, but more often the engineer makes a mathematical simulation of very high accuracy using a computer. Circuits for the touch-tone telephone were designed this way, for example.

The computer-aided design (CAD) facilities and programs available to students included SPICE for transistor circuit design; communication filter and network design; power system load flow; logic-circuit testing and simulation; integrated-circuit chip layout; control-system design; image processing; optimal expansion of power systems; microwave element design; printed-circuit-board layout; and others as needed for courses or designed by students working on a project.

PART-TIME UNDERGRADUATE PROGRAM

Some of the courses required in the undergraduate electrical engineering program can be completed in the evening by attending classes Monday through Thursday from 5:55 p.m. to 10 p.m. (10:40 p.m. summer), on a part-time basis. Such undergraduate evening courses are offered at both the Brooklyn and Farmingdale campuses, but evening students may have to take day courses to complete the degree.

Polytechnic University is unique in offering identical programs and diplomas to full-time and part-time students. Day and evening sections of courses have identical content. Full-time and part-time students attend the same classes, and are subject to the same academic standards. Transfer between full-time and part-time status is possible at any time.

Since the needs of part-time students vary, a prescribed sequence of courses is not possible. Consequently, students should consult a department advisor in person or by telephone.

TRANSFER STUDENTS

Qualified students from two-year pre-engineering programs, such as those at liberal arts and community colleges, may fulfill the requirements for the B.S. degree in electrical engineering in two additional years. Since pre-engineering programs vary, a prescribed program is not possible; consequently, students should consult with an undergraduate advisor. Articulation agreements are in place with Brooklyn College, C.W. Post, and St. John's University.

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

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

Transfer students must arrive and present their records for evaluation at

least one week before the regular registration period of their first semester at Polytechnic.

THE BS/MS ACCELERATED HONORS PROGRAM

Full time students may apply for the BS/MS Accelerated Honors Program which leads to the simultaneous award of a Bachelor's and a Master's Degree. Depending on the student's preparation and objectives, completion of the two degrees may come as early as the end of three and three-quarter years of study, or as late as five years. But each program is individually designed in cooperation with a Departmental BS/MS Accelerated Honors Program Advisor to allow for varied transfer and AP credits; co-op program participation; professional summer jobs and other goals consistent with an honors program.

Possible BS/MS combinations include: BSEE plus MSEE; MS (Electrophysics); MS (Systems Engineering); or MSCS.

Admission to the program is normally made at the end of the Freshman year, based on superior admissions qualifications, and outstanding achievement during the student's first year at Polytechnic. Later admission may be considered. Each student who applies is individually interviewed. Students must complete 16-20 credits each semester; maintain 3.5 overall and technical averages, particularly in key courses; and display a record essentially free of course repetitions and withdrawals.

The required courses for the two degrees include all courses required for the individual BS and MS degrees, and all curriculum footnotes apply. Required credits are the sum of the credits for the two degrees, except that about 4 to 7 technical or free elective credits are excused. Nine credits of Master's Thesis are usually required, and a special 11-week full-time Summer honors research project at the end of the second or third year is urged, if offered. Partial Summer scholarships may be offered.

Acceleration may be achieved through Credit by Examination; summer course work; research participation; extra course loads; careful course sequencing; and Advanced Placement Credit in such courses as MA101/102 (AP Calculus BC, grade of at least 4, preferably 5); and CS200 (AP Computer

Science A, grade 5; or AP Computer Science AB, grade of 4 or 5).

Descriptive brochures illustrate some of the possibilities that are available to prospective participants.

SENIOR HONOR STUDENTS

A full-time student whose performance during the first three years is outstanding will be named as a Senior Honor Student and is permitted to replace some of the required senior technical courses with other courses, usually more advanced, which are directed toward the student's professional goals.

GUIDANCE FOR BSEE STUDENTS

Your instructors will help you during hours posted on their doors, or by appointment. Extensive help is available for students taking Project or Thesis. Electrical Engineering advisors will be glad to advise on courses and program adjustments resulting from academic needs or personal problems. The Dean of Students is particularly helpful with personal problems and supervises fraternities and dormitories. The Office of Special Services sponsors a peer tutoring program. The Learning Center provides drop-in tutoring in mathematics and physics. Operation Action is a six-week program to help students identify and remove roadblocks to their academic success. They also have a Stop-Procrastinating Workshop. "Lunch and Learn" helps with job interviews. Personalized career counseling is available. No charge is made. The freshman seminar SL 101, Student Survival, introduces you to Polytechnic and its curricula. The Placement Service helps with permanent, summer, and Cooperative-Program jobs. Financial Aid provides and reviews scholarship and loan information on a continuing basis. Many courses provide extra hours or special programs on a regular basis. These include English for foreign and other students needing additional help: HU008, HU009, HU103, HU120; Mathematics (MA100, MA110); and EE101/102 and CS200 tutorials. Labs have open periods for making up required experiments or for informal experimentation. Students from upper classes can be particularly helpful. You are urged to join the student branch of the Institute for Electrical and Electron-

ics Engineering (IEEE), and to drop in to their lab. Many ethnic clubs help students adjust to our electrical engineering program.

DEPARTMENTAL STANDARDS, PROBATION: CompE AND EE

Engineers and computer scientists are professionals who are expected to achieve work of acceptable quality and quantity within a specified time. Similarly, Polytechnic students need to assure timely academic progress. It is this ability, the ability to work and to achieve, which is most desired by prospective employers.

If students have questions, they should feel free to discuss them with an advisor — preferably in a timely fashion so that good solutions can be found to any problems which may arise.

To remain in good standing, Computer Engineering and Electrical Engineering majors must earn term-by-term (year-by-year for part-time students), and cumulatively, minimum C (2.00) technical grade-point averages (GPA) in two distinct categories: (1) the *Freshman/Sophomore Technical Grade-Point Average* in freshman and sophomore courses prefixed CS, EE, MA, and PH; and (2) the *Junior/Senior Technical GPA* in required junior and senior courses, plus all electives prefixed CS, EE, and EL, and (in the case of CompE majors) all Concentration electives. (In the calculation of these two averages, the exclusion of the first grade earned in a course applies only for the first four such courses and only when the new grade is earned within one calendar year of the date of the official final examination when the course was first taken.) Moreover, no EE student will be allowed to register for any EE courses in the junior year of the BSEE curriculum and no CompE student will be allowed to register for any CS or EE courses in the junior year of the BSCompE curricula whose cumulative technical GPA is less than 1.85. Also, no EE student will be allowed to register for any EE courses in the senior year of the BSEE curriculum and no CompE student will be allowed to register for any CS or EE courses in the senior year of the BSCompE curricula whose cumulative technical GPA is less than 1.95. In addition, no BSEE or BSCompE degree will be awarded to any

student whose Junior/Senior Technical GPA is less than 2.00. (In the computation of the Junior/Senior Technical GPA for this purpose, CS337 will be treated as a technical elective for EE students and one technical elective with the lowest grade is excluded when all electives taken by the student have only EE, EL, and CS prefixes.) These requirements are in addition to the University requirement for a minimum 2.00 grade-point average in all courses.

The following additional conditions apply to all CompE and EE students:

1. Students must meet all requirements for the courses they take, including those in this document, "Prerequisites, Corequisites, and Repeated Courses for EE/CompE Undergraduates", "Acceptable Electives for BSEE and BSCompE Students", documents related to HU/SS requirements; and other advising documents (usually revised three times a year) — available at CompE/EE undergraduate advising offices; and in letters from their department and the Dean of Students.
2. In the following courses, students must earn a grade of C- or better when first taken, C if repeated once, before the student may proceed to any course for which these are prerequisite:

CompE: CS200, CS201, CS205, CS236, CS337; EE101, EE102; HU101 (or 103), HU200 (or 104), HU110; MA101 (or 100), MA102 (or 110); PH104, PH105.

EE: CS200, CS236; EE101, EE102; HU101 (or 103), HU200 (or 104), HU110; MA101 (or 100), MA102 (or 110); PH104, PH105.
3. With advisor permission, students may repeat a course in which they earned a substandard grade, but must earn at least C (C- is not acceptable), or be disqualified from taking any further EE or CS courses. Permission to attempt a course a third time is almost never granted.
4. Students with less than a C (2.00) semester average, or less than a C average in a closely related course sequence, may be asked to repeat

courses in which grades were less than C. Students required to take HU008 (or 009) are required to earn an S before taking HU103 (or 101).

5. Transfer credits may be removed if students earn less than C- in a subsequent course.
6. No CompE/EE students placed in HU008 or HU103 will be disqualified after getting an unsatisfactory grade in HU008 or HU103, unless the total number of times that final exams are taken in these courses is more than four, and provided that: (a) The Department of Humanities certifies that the student has made a real effort to improve, as shown by attendance, participation, and work submitted; and (b) grades in other courses are satisfactory.
7. Students who take a course without having fulfilled all course prerequisites, or who are in violation of any probation requirements, face deregistration (without tuition refund) and possible disqualification.
8. Students are not permitted to accumulate more than five course withdrawals (W) in credit-bearing courses.
9. When for valid reasons, such as illness or other critical emergency, a student is unable to complete the course work within the usual time, the instructor may give a grade of I. The grade of I is used sparingly, and not merely because students have planned poorly or overloaded themselves. The I grade signifies that upon successful completion of the work, a passing grade will be issued. Incomplete (I) grades earned by EE/CompE majors in any course must be removed before the next semester. Students with any I grades are not permitted to participate in any registration unless they get written permission from D.Hunt (EE, CompE); N.Posner (EE, Freshman/Sophomore CompE); J. Snyder (Junior/Senior CompE); B.Feknos (Junior/Senior CompE) in Brooklyn; in Farmingdale, J.Bongiorno (EE, CompE); F.Cassara (Freshman/Sophomore CompE); J.LaTourrette (Junior/Senior CompE); L.Grieco

(CompE). See further discussion of Incomplete grades below.

10. The number and distribution of credits required for graduation that are in effect at the time a student enters Polytechnic generally remains in effect for eight calendar years, or proportionally less for transfer students. However, as the curriculum is modified, the Department will make every effort so that course modifications do not increase the number of required credits, as long as the students remain in good standing.
11. Students may choose graduate courses as electives provided they have earned B grades in related courses, a GPA of 2.7, and advisor approval.

Students failing to meet any of the above requirements are placed on probation as a warning that they are not progressing acceptably toward their degree. Repeated failure to meet probation requirements may lead to disqualification from undergraduate CompE/EE programs and courses. Students on probation may be required to decrease their course load, repeat courses passed with a grade less than C, or undertake other remedial programs.

The following students are not permitted to preregister (in April-May or November-December) for the following semester, but are obliged to consult their advisor between the time grades are posted and the regular registration day prior to the start of classes, so that any necessary reevaluations can be made: 1) students on departmental continued or final probation; 2) students who are on any kind of departmental probation and who have an overall cumulative GPA less than 2.00; or, 3) students on Dean's Final Probation. Please note also that students placed on probation by the Dean of Students must get written permission from the Dean to register, and are usually restricted to only 15 credits for the semester.

Exceptions to the above standards may be made only by an official undergraduate CompE/EE advisor, in writing.

GRADUATE PROGRAMS

The Department of Electrical Engineering offers graduate programs leading to the degrees of master of science, engineer, and doctor of philosophy in the areas listed in the table at the beginning of this section. The programs leading to degrees in electrical engineering are described in the following paragraphs. Other sections of this Catalog describe the programs in electrophysics, system engineering, computer science, and information systems engineering.

The requirements for graduate degrees in electrical engineering are quite general. Each student may follow a program in any one of a variety of fields, including those described in the following paragraphs. For up-to-date information, please refer to the EE Department *Graduate Student Manual*, which is revised annually and is available from the EE Graduate Office.

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

Information Science — Information science deals with various communications systems, such as television, voice and data transmission, radar telemetry and space communication, facsimile and display systems, plus the modern problems associated with data analysis and communication between man and machine and between machine and machine.

Signal Processing — Signal processing deals with the generic problem of extracting the useful/desired information (signal) from the received data in the presence of uncertainties such as noise and other distortions. The techniques are applicable to any information processing situation and they involve analysis and design of signals, channels, and receiving systems as well as task-oriented signal processing algorithms.

Systems and Control — System engineers are concerned with modeling and predicting the behavior of large systems from a knowledge of the component parts. Examples include air-traffic control systems, health-care delivery systems, and systems to monitor and control pollution of the environment. Control engineers are concerned with all aspects of automatic regulation of system

performance. Together with the system engineer, they are trained in the fields of automation and system theory. Typical examples of control systems are automatic guidance systems for aircraft and space vehicles, electric motor control, and chemical process control.

Electronics and Networks — The discipline of electronics and networks involves the design, construction, and theoretical treatment of circuits used in modern electronic equipment, particularly those involving semiconductor devices and integrated 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 periodic media. Such studies include microwave waveguides and antennas, optical fibers and integrated optics, diffraction and scattering effects, surface and bulk acoustic wave propagation, and transduction. Applications include radar, microwave and optical communications, and surface acoustic wave technology.

Plasma and Atmospheric Physics — This area is involved with breakdown and ionization of gases and the interaction of the resultant plasma with electromagnetic waves. Such studies have application to the propagation of high power radio waves in the atmosphere and the ionosphere.

Power Systems and Energy Conversion — Studies in power and energy include not only the traditionally important generation, conversion, and distribution of electrical power but also such modern topics as ion plasmas and fuel cells for the generation of electrical energy and the realization of electromagnetic propulsion for space rockets.

Quantum Electronics and Materials Science — Quantum electronics and materials science deal with the interaction of electromagnetic fields and waves with matter. The theoretical basis of this area requires a quantum treatment but many aspects can be understood without specific use of quantum methods of analysis. Topics of interest include lasers, electro-optics, optical communication devices, and electric, magnetic and thermal properties of materials.

REQUIREMENTS FOR THE MASTER OF SCIENCE 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. A student who also desires to obtain a Polytechnic B.S. degree in electrical engineering must do so first, before beginning studies for a master's degree in the Department of Electrical Engineering.

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 undergraduate and introductory level graduate electrical engineering courses. Such graduate courses count toward the master's degree. A student with a B.S. degree in a field other than electrical engineering may also want to consider the departmental master's degree programs in electrophysics or in system engineering.

To satisfy the requirement for the M.S. in electrical engineering degree, the student must complete a total of 36 units of courses, as described below. An overall grade point average of B in all graduate courses is required by the University. In addition, a B average is required in specific groups of courses, as indicated below.

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 613 *Computer Architecture I*

9 Units

2. Two one-year sequences which may include courses in group (1). Both sequences must be in EL or CS courses and at least one must be an EL sequence.

6-12 Units

3. Approved electives, which may include a thesis (9 units) and one reading course (3 units maximum).

21-15 Units

Total: 36 Units

At least 18 of the 36 units offered for the M.S. degree in electrical engineering must be in EL prefixed courses, and at least 24 units must be in EL or CS prefixed courses.

An overall B average is required in the combination of five to seven courses offered to satisfy categories (1) and (2) in the above table.

The core courses cover fundamental material and should be taken as early as possible.

A complete program of study, including the choice of one year sequences, is arranged with a departmental advisor. The EE Department *Graduate Student Manual* should first be consulted for detailed rules and procedures, such as student status, recommended one-year sequences, recommended electives, current areas of research, repetition of courses, and disqualification for low grades. The manual also contains announcements of changes in degree requirements, if any, adopted by the faculty after the publication of this Catalog.

Out-of-department courses (i.e., courses not carrying either of the departmental prefixes EL or CS): A maximum of 12 units of approved courses may be taken as electives.

Thesis: An exceptional student may elect to write a master's thesis for which 9 units toward the degree may be earned. Such a student should find an appropriate advisor who has agreed to monitor the thesis research. The research should adequately demonstrate the student's proficiency in the subject material. Oral defense of the master's thesis with at least three professors in attendance is required.

Transfer credits: The 9 units of transfer credits which may be allowed in accord with Polytechnic regulations can be applied toward the one-year sequence

requirements and toward the electives. Transfer credits may not be used to satisfy the core course requirements.

Validation credit: Validation credits may be allowed in accord with Polytechnic regulations. In order to obtain credit, permission to take the validation examination must first be obtained by application to the EE Graduate Committee.

Repetition of courses: A student may register no more than three times for the same course including registration for which a W was earned. A course will not be allowed for degree credit if it was taken in violation of this rule.

REQUIREMENTS FOR THE ENGINEERS DEGREE

The degree of engineer in electrical engineering is offered in recognition of the need of systems and component designers for advanced training beyond the master's degree. This degree program involves additional graduate courses and a substantial design project. A guidance committee, usually drawn from the full-time faculty of the department, advises the student and grants final approval when the departmental requirements have been satisfied. The guidance committee usually consists of three members, the chairman and at least one other member should be from the Department of Electrical Engineering. Participation is encouraged by a committee member or members from the adjunct faculty or from other departments. The committee is appointed after the student is admitted to the program.

The complete program for each student is detailed following consultation between the student and the guidance committee. The minimum requirements of the program are 72 units past the bachelor's degree apportioned as follows:

1. A master's degree in electrical engineering, for which the student receives

36 Units
2. An engineer project which demonstrates mature design, engineering economics trade-offs, etc., for which the student receives

6-12 Units
3. Approved electives

30-24 Units

72 Units

The engineer project may be suggested by either the student or the guidance committee and is officially approved on the student's submission of an acceptable written proposal which details the problem, background and approach, gives the budget for estimated project expenses, and states the desired number of units (6,9 or 12) to be earned. Upon completion of the engineer project, the student will submit bound copies of the project report and will defend the work at an oral examination. More detailed information regarding the project and defense may be found in the *EE Graduate Student Manual*. In certain exceptional cases involving students with well-documented records of original significant analysis and design achievements, the guidance committee may waive the requirements that the analysis and design work be performed in residence. However, bound reports and an oral defense will still be required. In such cases, six units of project will be credited toward the degree. The student shall choose elective courses with the advice and consent of the guidance committee to achieve a concentrated and well-integrated background in the chosen area. Courses outside the electrical engineering area are generally acceptable provided they build toward the student's goal. Typical areas of concentration are power, safety and reliability, electronics, systems and controls, communications, computers and electro-optics.

REQUIREMENTS FOR THE DOCTOR'S OF PHILOSOPHY DEGREE

General — Graduate students who have exhibited a high degree of scholastic proficiency and have given evidence of ability for conducting independent research may consider extending their goals towards the doctorate. The degree of Ph.D. is awarded to a student who completes the program of studies and research described below, and prepares and defends a dissertation representing an original and significant contribution worthy of publication in a recognized scientific or engineering journal. For a more complete description of the topics summarized here, please refer to the latest *EE Graduate Student Manual*.

Admission to Programs — Entrance into the doctoral program of study and research is contingent on the candidate's

passing the departmental qualifying examination and forming a guidance committee (both described below). A student entering with a bachelor's degree will normally take the qualifying examinations after one year of study. Entering students holding master's degrees may take these examinations as soon as they are prepared, but full-time students are expected to submit to examinations within the calendar year.

Students entering the doctoral program at the baccalaureate level must meet the entrance requirement listed above for the master's program. Students entering at the master's level for the Ph.D. program in electrical engineering are normally expected to have a master's degree in electrical engineering.

Qualifying Examinations — The Ph.D. qualifying examinations are offered once each year. These examinations are divided into three sections (a) a basic section—a written examination requiring broad knowledge and problem-solving ability at the undergraduate level; (b) an advanced section — a written examination requiring preparation at the first-year graduate level in several subject areas related to the student's principal area of interest; (c) a concentration section — an oral examination concentrating mainly on the student's declared area of interest. Principal areas of concentration are: communications, signal processing, automatic control, electronics, electromagnetics, and network optimization, and power. The basic section must be completed first and is generally offered in June. Students interested in the related area of electrophysics should refer to the corresponding Ph.D. program described under that title.

Details regarding allowed subject areas, recommended background courses, sample examination questions, and the precise format for the coming year are available in the latest *Graduate Student Manual*.

Guidance Committee — Upon passing the qualifying examination, the graduate student must find a faculty member in the student's area of major interest who will become the thesis advisor. In consultation with the thesis advisor, the student suggests an advisor for a minor outside of electrical engineering and a guidance committee of three or four faculty members, with the thesis advisor usually acting as chairman. At least one other guidance committee

member must be in the students' area of major research interest; this member may be from outside of the Polytechnic. The Minor advisor may, but need not, be a member of the guidance committee. The student must submit the names of these guidance committee members to the EE Graduate Committee for approval.

The thesis advisor approves the program of study in the student's major, and the minor advisor approves the program of courses in the minor. When the requirements for minor or major are completed, the student should have the appropriate advisor certify this in writing to the Office of Research and Graduate Affairs, with copies to the EE Graduate Office.

The guidance committee conducts the area examination and thesis defense, and approves the final thesis.

Course Requirements — Polytechnic requires that each candidate for the doctorate complete a minimum of 90 units of academic work beyond the bachelor's degree, including a minimum of 24 units of dissertation research. Candidates in EE must take a minimum of 51 units in formal courses (as distinct from "independent study" units such as reading, project, or thesis) as part of the general requirement of 90 units. Ph.D. students are required to take a minimum of 12 units of courses in a minor area outside of electrical engineering. The minor must be taken in an area that is both distinct from and yet consonant with the student's major area of study. Approval of the minor program is described in the preceding paragraph. The major program of study is developed by the student in consultation with the thesis advisor. The major program should constitute a coherent study in depth of the most advanced knowledge in the student's area of concentration. Attendance at graduate seminars is expected when they are offered in the student's principal area of interest (see course description EL 891).

Area Examination — The area examination consists of a presentation or review of the general background in the problem area of the student's dissertation. The purpose of the examination is to demonstrate that the student understands the fundamental prior research in the field of the thesis work. The examination should be taken early in the Ph.D. program, after no more than 12 units of

dissertation have been taken, and should not be a review of partial thesis results. The examination may be in the form of an open seminar attended by other interested faculty and students. The guidance committee evaluates the student's performance and determines whether the depth of knowledge and understanding necessary to carry out research in the chosen area has been demonstrated.

Postponement of the area examination beyond registration for 12 units of thesis requires the approval of the EE Graduate Committee.

Submission of the Thesis and Final Examination — On completion of the doctoral dissertation the candidate will submit to an oral defense of the thesis. The examination is conducted by the guidance committee but is open to all members of the faculty and to such other persons as may be invited. Copies of the dissertation will be made available to prospective examiners a reasonable time in advance. The guidance committee chairman will notify the Office of Research and Graduate Studies of the candidate's readiness so that the examination date may be scheduled. The student is advised to consult the Office of Research and Graduate Studies regarding submission of the final manuscript, reproduction and binding.

UNDERGRADUATE COURSES

Students are advised to consult departmental handouts and the Schedule of Classes for changes of courses, course content, and prerequisites in effect after the publication of this Catalog.

General prerequisites: students may not register for any junior- or senior-level courses until all freshman requirements are completed. Knowledge of computer programming at the level of CS 200 is assumed in all EE courses.

BASIC COURSES

EE 101 Electric Circuits I 4:0:3

Passive and active circuit elements. Node and loop analysis, source transformations, linearity and superposition, voltage and current division, Thevenin's and Norton's theorems. Source-free and

forced responses of RL, RC and RLC circuits. *Prerequisites:* MA 101 (or 100), MA 102 (or 110), PH 104, and CS 200 (all with grade C- or better); *Co-Prerequisites:* MA 104 and PH 105/115; preferably EE 193. C- or better is required in EE 101.

EE 102 Electric Circuits II 4:0:3

Continuation of EE 101. Sinusoidal steady-state response. Phasors. Theorems, including maximum power, root-mean-square values, and average power. Complex frequency. Resonance. Fourier series. Mutual inductance. Three-phase systems. *Prerequisites:* EE 101 (grade C- or better), PH 105 (grade C- or better), PH 115, MA 104; *Co-prerequisite:* preferably PH 106, EE 194. C- or better is required in EE 102.

EE 103 Signals & Transforms 4:0:4

Fourier series. Analog and digital systems, integro-differential equations and recursion equations with initial conditions, solutions by Laplace and z-transforms. Linear Time Invariant (LTI) systems and their input-output relations, impulse response, continuous and discrete-time convolution, causality, and stability of linear systems. Fourier transforms and frequency response of LTI systems. Discrete-time signals, systems, and their z-transforms. Digital simulator for analog systems. Stability tests for rational LTI systems. Bode plots. *Prerequisites:* EE 102 (C- grade or better), and MA 104, MA 103; suggested EE 109.

CONTROL AND INSTRUMENTATION

EE 104 Feedback System Principles 3:0:3

Introduction to analysis and design of continuous, linear feedback control systems. Modeling of physical systems, Signal Flow Graphs and Mason's Gain Formula, sensitivity and steady-state error, Routh-Hurwitz and Nyquist stability tests. The use of root locus and frequency response techniques to analyze system performance and design compensation to meet performance specifications. Realistic design problems. *Prerequisite:* EE 103, PH 104 with C- or better (C if repeated).

ENGINEERING

EE 107 Control System Design 3:0:3

Topics on the design of linear feedback control systems, selected from the following: lag-lead compensators; pole-placement controllers; state-variable feedback and observers; linear quadratic optimal control, stochastic systems, sampled-data and computer-controlled systems; and phase-plane and describing-function techniques for non-linear systems. (See departmental bulletin board for detailed descriptions of each offering and of any additional prerequisites). *Prerequisite: EE 104.*

ELECTRONIC CIRCUIT ANALYSIS AND DESIGN

EE 109 Solid State Devices and Circuits I 4:0:4

Semiconductor fundamentals. Physics of junction diodes. Diode circuits and applications: rectifiers, voltage regulators, clipper circuits. Physics and device models for Bipolar Junction Transistors (BJT) and Field Effect Transistor (JFET and MOSFET), including Ebers-Moll equations, large-signal analysis, operating modes, and switching times. Single-stage midband amplifier analysis: Q-point selection, stabilization, small-signal models, and circuit analysis. Fabrication of integrated circuits. *Prerequisites: EE 102 and PH 105, both with grade C- or better; PH 234. Corequisites: preferably EE 165, EE 195. (Alternate prerequisite: EE 101, grade A- or better; PH 104, grade B or better; PH 105, grade B or better; and PH 234, grade B or better. Corequisite: EE 102.)*

EE 110 Solid State Devices and Circuits II 3:d:3

Small-signal analysis and design of transistor amplifiers at low, midband, and high frequencies. Computer-aided analysis and design. Operational amplifier building blocks: differential amplifiers, current sources, level shifters, output stages. Op-Amp examples. Applications of feedback to electronic circuits. *Prerequisites: EE 109; Co/Prerequisites: preferably EE 165, EE 195, EE 103 (Bode Plots)*

EE 113 Solid-State Devices and Circuits III 3:d:3

Transient response of piecewise linear single energy storage element networks, diode wave-shaping networks, analysis and design of digital logic integrated circuits, voltage sweep circuits, monostable, astable, and bistable multivibrators. *Prerequisite: EE 110, EE 195. Corequisite: recommended EE 196 (or 202), or CS 296.*

EE 115 Advanced Electronics 3:0:3

Special topics in electronic circuits and instrumentation, second order modeling. Advanced transistor and integrated circuit design active and passive memories. Application of bistate devices. Nonlinear devices including topics such as digital circuits, blocking oscillators, ferroelectric and ferro-magnetic circuits. *Prerequisite: EE 113*

EE 116 Communication Electronics 3:0:3

Design and analysis of small-signal and large-signal tuned amplifiers, sine-wave oscillators, mixers, AM modulators and demodulators, FM modulators and demodulators, phase locked loops. *Prerequisite: EE 110. Co/Prerequisite: recommended EE 113.*

EE 119 Semiconductor Technology* 3:0:3

Principal techniques involved in processing and fabrication of semiconductor devices and integrated circuits including material preparation, junction forming, circuit integration and packaging. *Prerequisite: EE 109, or MT 410. Also listed under MT 375.*

EL 545-546 Microwave Integrated and Semiconductor Circuits I, II*

See graduate course listings.

COMMUNICATIONS AND INFORMATION TRANSMISSION

EE 140 Principles of Communication Systems 3:0:3

Principles and techniques for modern communications systems. Analog and digital signals, sampling, quantization, signal representation. Analog and digital modulation, pulse code modulation, time and frequency multiplexing. Noise in communication systems. *Prerequisites: EE 103, MA 223, and EE 109.*

EE 141 Signal Processing 3:0:3

Spectral representations of discrete-time signals and the Fast Fourier Transform. Random discrete-time and spectral analysis. Detection and estimation of signals in noise. Adaptive filtering and linear mean square estimation. Computer projects involving applications of signal processing. *Prerequisites: CS 200, MA 223, EE 103 and EE 140.*

ELECTROMAGNETIC FIELDS

EE 165 Electromagnetic Fields and Waves I 3:0:3

Electrostatic fields in vacuum. Gauss's law, potential, and capacitance. Magnetostatic fields in vacuum, Ampere's law, and inductance. Faraday's law and Maxwell's equations. Plane waves, transmission lines, and the propagation and reflection of waves. *Prerequisites: EE 102 and PH 105, each with grade C- or better; PH 106; MA 103; MA 104.*

EE 166 Electromagnetic Fields and Waves II 3:0:3

Conductors, dielectrics, magnetic materials, and boundary conditions. Plane waves in dielectrics. Transmission-line impedance transformation, and standing waves. Rectangular conducting wave guides. Radiation from dipoles and arrays. *Prerequisite: EE 165.*

EL 571-572† Engineering Electromagnetics I, II

See graduate course listings.

EL 573† Introduction to Microwave Engineering*

See graduate course listings.

ELECTRONIC MATERIALS SCIENCE**EE 167 Quantum and Solid State Electronics** 3:0:3

Review of experimental necessity for introduction of quantum states and wave-particle dualism elements of wave mechanics and quantum statistics. Application to electronic structure of atoms, periodic table, properties of electrons in metals, semiconductors, insulators. Laser systems. *Prerequisite:* PH 234 and EE 109. *Corequisite:* EE 166.

EL 551-552†† Electro-Optics I, II

See graduate course listings.

EL 557† Introduction to Electric and Magnetic Properties of Solids

See graduate course listings.

ELECTRIC POWER**EE 180 Electrical Machinery I** 3:0:3

Description, theory, and analysis of steady-state performance for the four types of electrical machine: transformer, induction motor, synchronous machine, and DC machine. Equivalent circuits and vector diagrams derived and used as the primary tools for analysis. *Prerequisite:* EE 165. *Corequisite:* EE 166.

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 166, and preferably Pre/Co-requisite: EE 204.

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, and economic dispatch. *Prerequisite:* EE 102 (grade C- or better); EE 180.

EL 564† Electromechanical Power Conversion*

See graduate course listings.

EL 568-569† Electrive Drives I, II*

See graduate course listings.

EL 581† Introduction to Plasma Engineering*

See graduate course listings.

ELECTRICAL ENGINEERING LABORATORY

Students enrolled in electrical engineering laboratory courses are charged a laboratory fee which includes the cost of a laboratory kit consisting of electronic parts and components. Transfer students who enroll in junior and senior level laboratory courses may be required to purchase components of preceding courses for which they have transfer credits.

EE 193 Sophomore Electrical Engineering Laboratory I ½:1½:1

Introduction to electrical measurements. Lab fee required. *Co/Prerequisite:* EE 101, PH 105/115, MA 102 or 110, MA 104, preferably HU 110. Withdrawal from EE 101 requires withdrawal from EE 193.

EE 194 Sophomore Electrical Engineering Laboratory II ½:1½:1

Electrical circuits laboratory. Lab fee required. *Prerequisites:* EE 101 (Grade C- or better) and EE 193, MA 104, PH 105/115. *Co/Prerequisite:* EE 102, HU 110, preferably PH 106/116. Withdrawal from EE 102 requires withdrawal from EE 194.

EE 195 Junior Electrical Engineering Laboratory II 1:3:2

Circuits and electronics laboratory. Lab fee required. *Prerequisites:* EE 194, EE 102 (Grade C- or better); *Co/Prerequisite:* EE 109, HU 110.

EE 196 Senior Electrical Engineering Laboratory I 1:3d:2

Experiments in electronics, control, and electromagnetic waves. Lab fee required. *Prerequisite:* EE 195, EE 110; *Co/Prerequisite:* EE 104, EE 166.

EE 202 Senior Electronics Laboratory/Project 1:6d:3

Formal Laboratory Experiments related to analog, digital, and communications electronics — including a two-stage amplifier design with SPICE simulation, FM modulators, multivibrator and timing circuits, active filters, large-signal tuned amplifiers, sine-wave oscillators, and phase-locked loops. The symbol "d" signifies that an extensive design achievement is required. Reports and oral presentations: for students using this course as their Senior Project (coregistered with CS or EE 395), a professional written final report, corresponding to standards published by the Department, must be filed in the Department office for a passing grade. Formal oral presentation before a group of students and staff required. *Prerequisites:* EE 113, CS 296, HU 110 (C- required); HU 119 (or 120); all junior courses. *Corequisite:* CS 395 (CompE majors) or EE 395 (EE majors). CS/EE 395 is not required as a Pre/Corequisite if EE 202 is used as a senior elective or a substitute for EE 196, rather than as a Senior Project. Advisor: EE 202 instructor. Farmingdale and Brooklyn; Spring. Lab fee required.

EE 204 Senior Machinery Laboratory/Project 1:6d:3

Structured laboratory experiments, 4 hours/week, on the basic power machines: the transformer, the d-c machine, the induction motor, and the synchronous machine. Squads consist of two people; each experiment is allotted three weeks; and each person submits a formal report for each experiment. Reports and oral presentations: for the design project, the student registers for CS or EE 395. Each

squad selects an experimental project from a list provided by the instructor. Two additional hours per week are needed for the project. The symbol "d" signifies that an extensive design achievement is required. For students using this course as their Senior Project (coregistered with CS or EE 395), a professional written final report, corresponding to standards published by the Department, must be filed in the department office for a passing grade. Formal oral presentation before a group of students and staff required. *Prerequisites:* EE 180, HU 110 (C- required); HU 119 (or 120); all junior courses. *Occasionally, EE 180 may be used as a corequisite by a senior having good grades, and written permission of the course director. Corequisite:* CS 395 (CompE majors) or EE 395 (EE majors). *CS/EE 395 is not required as a Pre/Corequisite if EE 204 is used as a senior elective, rather than as a Senior Project.* Advisor: EE 204 instructor. Brooklyn; Fall and/or Spring. Farmingdale students are invited to attend one day a week to take EE 204 as a technical elective, two days to take both EE 204 and CS/EE 395 as a Senior Project. Lab fee is required. Withdrawal from EE 180 requires withdrawal from EE 204.

EE 206 Senior Semiconductor Laboratory/Project 1:6d:3

Experiments and projects on the fabrication of PMOS transistors, starting with a blank silicon wafer, mask generation, lithography, oxidation, diffusion, metalization, and encapsulation. Test and analysis of completed packages. The symbol "d" signifies that an extensive design achievement is required. Reports and oral presentations. For students using this course as their Senior Project (coregistered with CS or EE 395, a professional written final report, corresponding to standards published by the Department, must be filed in the Department office for a passing grade. Formal oral presentation before a group of students and staff required. *Prerequisite:* EE 119, HU 110 (C- required), HU 119 (or 120); all junior courses. *Corequisite:* CS 395 (CS, CompE majors). *CS/EE 395 is not required as a Corequisite if EE 206 is used as a senior elective, rather than as a Senior Project.* Advisor: EE 206 instructor. Farmingdale; Spring. Brooklyn students are invited to attend one day a week. Lab fee required.

EE 208 Senior Special Topics Laboratory/Project 1:6d:3

Experiments and projects related to current research laboratories. Emphasis on written and oral project reports. Lab fee required. *Prerequisites:* HU 110 (minimum grade C-), HU 119 or HU 120; EE 395, CS 395; all junior courses. *Other Pre/Corequisites:* as required by instructor.

EE 210 Summer Honors Laboratory/Project 1:6d:3

An individual or small-group intensive 11-week research-oriented project, often related to current research. Offered in the Summer following the junior year, under the supervision of a staff member. The symbol "d" signifies that an extensive design achievement is required. Reports and oral presentations. For students using this course as their Senior Project (postregistered in CS or EE 395 in the following Fall), a professional written final report, corresponding to standards published by the Department, must be filed in the Department office for a passing grade. Formal oral presentation before a group of students and staff required. *Prerequisite:* Completion of all technical courses of the junior year, technical average 3.3 or greater; competitive selection by Steering Committee and Staff Sponsor; HU 110 (C- required), HU 119 (or 120). *Postrequisite:* If this course is being used as a Senior Project, the student registers for CS 395 (CS or CompE majors) or EE 395 (EE majors) in the following Fall to complete additional studies, oral presentations, and the final professional report. Advisor: same as Summer. Brooklyn and Farmingdale; Summer only. No lab fee.

EE 212 Senior VLSI Laboratory/Project 1:6d:3

Senior VLSI (Very-Large Scale Integrated Circuit) project. The symbol "d" signifies that an extensive design achievement is required. *Students will not be admitted to this laboratory unless they have completed EE/CS 395 in the preceding semester under the guidance of the EE 212 instructor.* Depending on the availability of equipment, students will design a chip having hundreds of transistors, using a commercial VLSI-CAD system. If time permits, the chip will be

fabricated. The student will then test the chip design in the laboratory, and consider appropriate modifications. Reports and oral presentations: for students using this course as their Senior Project (along with CS or EE 395), a professional written final report, corresponding to standards published by the Department, must be filed in the Department office for a passing grade. Formal oral presentation before a group of students and staff required. *Prerequisites:* CS 395 (CS or CompE majors) or EE 395 (EE majors) taken Senior Fall in Brooklyn; CS 205, CS 337, CS 296, CS 297; EE 113; all junior courses; at least one lab and three technical courses of the senior year; HU 110 (C- required); HU 119 (or 120); HU 116 (BSCS majors only). *CS 316 and either EE 167 or EE 119 are helpful related courses. Occasionally, CS 296, CS 297, and EE 113 may be excused for outstanding students, with written preapproval by a senior EE/CompE/CS advisor.* Advisor: EE 212 instructor. Brooklyn and Farmingdale; Spring. Lab fee required.

EE 214 Senior Robotics/Control Laboratory Project 1:6d:3

Theoretical principles germane to feedback control and robotics. Small-scale analog and/or digital control applications. Data acquisition and control through a computer. Experiments such as:

- Stabilization of an inverted pendulum (non-linear) on a cart, by accelerating the cart back and forth using various feedback-control algorithms.
- Control of a two-degree-of-freedom non-linear robot manipulator, using various algorithms.
- Pulse-width modulation technique for the control of d-c motors.
- Adaptive control algorithms and their application to a specific second-order system.

The symbol "d" signifies that an extensive design achievement is required. Reports and oral presentations. For students using this course as their Senior Project (coregistered with CS or EE 395), a professional written final report, corresponding to standards published by the Department, must be filed in the Department office for a passing grade. Formal oral presentation before a group of students and staff required. *Prerequisites:* EE 103 and EE 104 or similar

preparation in control; recommended EE 113 (or EE 370 for B+ students; EE 195 (or EE 374 for B+ students); HU 110 (minimum grade C-); HU 119, (or 120); HU 116 (BSCS majors only); all junior courses. CS 297 recommended. Corequisite: CS 395 (CS or CompE majors) or EE 395 (EE majors). Open to BSEE and BSCompE majors and to others with permission of a senior EE, CompE, or ME advisor. Advisor: EE 214 instructor. Brooklyn; Spring. Farmingdale students are invited to attend, one day a week. Lab fee required.

EE 216 Image Processing Laboratory/Project 1:6cd:3

Senior Projects in digital image processing using PC's equipped with special imaging hardware. Design of good test images which can demonstrate the pros and cons of this implemented algorithms expected. The symbol "d" signifies that an extensive design achievement is required. Reports and oral presentations: for students using this course as their Senior Project (coregistered with CS or EE 395), a professional written final report, corresponding to standards published by the Department, must be filed in the Department office for a passing grade. Formal oral presentation before a group of students and staff required. Prerequisites: EE 103; MA 153 (or knowledge of matrices and eigenvalues); MA 223, CS 212 or C programming skill essential; EL 512 Image Processing I; HU 110 (minimum grade C-); HU 119 (or 120); HU 116 (BSCS majors only); all junior courses. Corequisite: CS 395 (CS or CompE majors) or EE 395 (EE majors). CS/EE 395 is not required as a corequisite if EE 216 is used as a senior elective, rather than as a Senior Project. Advisor: EE 216 instructor. Brooklyn; Spring. Farmingdale students are invited to attend, one day a week. Lab fee required.

EL 970† Microwave Engineering Laboratory/Project

See graduate course listings.

INTERDEPARTMENTAL COURSES

EE 370 Principles of Electrical Engineering 3:0:3

Electrical signals and circuit elements. Network analysis. Transient and sinusoidal steady-state analysis of first and second order circuits. Diode and transistor circuits. Digital and logic circuits. (Cannot be used to satisfy any electrical engineering degree requirements.) Prerequisite: MA 102 (or 110), PH 105; Co/Prerequisite: MA 104.

EE 374 Instrumentation Laboratory 0:3:1

Experiments designed to supplement EE 370. Familiarization with electrical measurements, equipment, and modern electronic components. (Cannot be used to satisfy any electrical engineering degree requirements.) Lab fee required. Prerequisite: PH 115; Co/Prerequisite: EE 370.

PROJECTS AND SPECIAL LISTINGS

EE 391-394 Special Studies in Electrical Engineering credit to be arranged

Advanced course in electrical engineering given to selected students. Course is vehicle for presenting novel material, trying new educational methods, taking advantage of special competence of visiting staff. Prerequisite: Permission of electrical engineering advisor.

EE 395 Introduction to Senior EE Lab/Project [for EE majors] ½:1½d:1

Required for the BSCS, BSCompE, BSEE, and must be paired with a Senior Project course for the credit to count toward the degree. The symbol "d" signifies that CS/EE 395 is the first step to a significant design achievement. Group lectures and individual discussions to prepare students for professional achievement in their Senior Project. This is the first phase of the project (or projects) which requires the design, construction, testing, and documentation of one or more pieces of equipment or software packages. Choosing a topic,

selecting an advisor (for those students taking EE 399/398/397/396), planning the work, consulting the library and references, reviewing previous approaches, probing for information and advice, estimating time and cost, ordering parts and/or software, and selecting a work-site. Planning and preliminary written and oral reports. Evaluation of progress with advisor. Departmental guidelines for the professional written report and final oral presentation before an audience, using audio-visual aids. Working in a group: leadership and sharing; responsibility and irresponsibility. ATTENDANCE AT WEEKLY SEMINAR IS REQUIRED. No lab fee. Prerequisite: HU 110 (Grade C- or better); HU 119 (or HU 120); completion of all technical (including lab) courses through the junior year. Co/Prerequisites: First-term senior laboratory (EE and CompE majors only); HU 116 (BSCS majors only); and one or more electives in the area of expected concentration or specialization, as specified in the course descriptions below. This course is Prerequisite to EE 208, 212, 399, 398, 397, 396; It is Corequisite to EE 202, 204, 206, 214, 216; ELxxx. It is Postrequisite to EE 210. EE 395 is usually not required if these courses are taken as technical electives rather than as Senior Projects. (Senior BSCS and CompE majors take CS 395).

EE 397 Bachelor's Thesis in Electrical Engineering 3 credits

Individual solution of electrical engineering problem involving adequate statements of problem, choice of methods of attack, proper solution of problem. Presentation of results in oral reports and a formal bound report. An extensive design achievement is required. EE 399, not this course is usually taken by undergraduates. For students using this course as their Senior Project (along with CS or EE 395), a professional written final report, corresponding to standards published by the Department, must be filed in the Department office for a passing grade. Formal oral presentation before a group of students and staff required. Brooklyn and Farmingdale; Fall and Spring; rarely Summer. Lab fee required. Prerequisite: Senior status and approval of Senior Faculty Department Advisor.

EE 398 Project in Electrical Engineering *credit to be arranged*

Solution of electrical engineering problem or detailed study of advanced area of electrical engineering under supervision of advisor. Written report must be filed in the departmental office for a passing grade. An extensive design achievement is required. EE 399, not this course, is usually taken by undergraduates. For students using this course as their Senior Project (along with CS or EE 395), a professional written final report, corresponding to standards published by the Department, must be filed in the Department office for a passing grade. Formal oral presentation before a group of students and staff required. Brooklyn and Farmingdale; Fall and Spring; rarely Summer. Lab fee required. *Prerequisite:* Senior status and approval of Senior Faculty Department Advisor.

EE 399 Senior Concentration Project in Electrical Engineering *1:6d:3*

Second phase of design project: construction, testing, and documentation of a device or a computer software package. Supervised by the staff advisor selected in the prerequisite course, EE 395. Emphasis on depth of analysis; quality of system performance; consideration of alternative methods; and evaluation of such social factors as safety, reliability, utility, cost, and need for further development. The symbol "d" signifies that an extensive design achievement is required. For EE majors only. A professional written final report, corresponding to standards published by the Department, must be filed in the Department office for a passing grade. Formal oral presentations before a group of students and staff required. *Prerequisites:* EE 395 (EE majors only) with a minimum grade of C; HU 110 (minimum grade C-); HU 119 (or 120); all junior courses; at least one lab and three technical courses of the senior year; written approval of the Senior Faculty Department Advisor. *Co/Prerequisite:* All courses specified by the project advisor or the Department. *Note:* Rather than taking EE 399, most EE and CompE undergraduates will take EE 395 plus such Senior Project courses as EE 202, EE 204, EE 206, EE 208, EE 210, EE 212, EE 214, EE 216, and suitable graduate laboratories provided prerequi-

sites are met. Brooklyn and Farmingdale; Fall and Spring. Lab fee required.

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 advisor's approval.

LINEAR SYSTEMS AND NETWORKS

EL 610 Linear System *2½:0:3*

Basic system concepts. Equations describing continuous and discrete-time linear systems. Time domain analysis, state variables, transition matrix, impulse response. Transform methods. Time-variable systems. Controllability, observability, and stability. *Prerequisite:* Graduate status and EE 103.

Also listed under ME 670

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 sub-spaces, elementary divisors, canonic forms and minimax theorems for eigenvalues of hermitian pencils. *Prerequisite:*

sites: Graduate status and MA 103, MA 104. Also listed under MA 837

EL 615 Network Theory of Lumped and Distributed Structures* *2½:0:3*

Network principles derived from physical constraints are emphasized. Immittance and scattering formalisms, general energy and reciprocity theorems, properties of distributed parameter and nonreciprocal networks, broadband theory and the synthesis of transmission line broadband quarter-wave transformers. *Prerequisite:* Graduate status, and EE 101 and EE 102.

EL 617 System Reliability* *2½:0:3*

Structural reliability, redundancy, bounds on reliability of complex systems. Repairable systems: Markov models, maintainability and availability. Optimization of spare parts inventories, inspection intervals and replacement times. Failure models: accumulated shocks and stress-strength-time. Marginal failures, dependent failures. *Prerequisite:* EL 531 or MA 561 or equivalent. Also listed under IE 685

EL 618 Component Reliability* *2½:0:3*

Failure models for industrial components: exponential Weibull lognormal, gamma, Gumbel, and other distributions. Failures and hazard rates, graphical probability plots and maximum-likelihood parameter estimation and testing. Sampling plans based on life tests and accelerated life tests. Serial and parallel analysis on component reliability. *Prerequisite:* EL 531 or MA 561 or equivalent.

SIGNAL PROCESSING

EL 512 Image Processing I *2½:0:3*

Introduction of basic concepts and techniques in digital image processing: image acquisition and display using digital devices, properties of human visual perception, sampling and quantization, sampling rate conversion, two-dimensional transforms, linear and nonlinear filtering, morphological operations, contrast enhancement, noise removal, image deblurring, image registration and geometric transformation, edge detec-

tion. Students will learn to perform some basic image processing operations using computers equipped with special imaging hardware, such as video cameras and frame grabbers. *Prerequisites:* EE 103; MA 223; MA 153 or knowledge of basic matrix algebra; CS 212 or C-Programming skill; Senior or graduate student status. Instructor approval required for senior students.

EL 611 Signals, Systems, and Transforms 2½:0:3

Continuous and discrete linear systems, system function. Fourier transforms, periodic functions, Z transforms, discrete Fourier series, fast Fourier transforms. Analog and digital filters, finite order system functions. Digital processing of analog signals. Sampling theorems. *Prerequisite:* Graduate status and EE 103.

EL 612 Image Processing II 2½:0:3

Advanced topics in digital image processing, such as image compression, image recovery, medical imaging, advanced television systems, etc. (See department mailing for detailed description of each particular offering.) Both basic principles and recent research developments will be introduced. In addition to the lecture material, each student is required to finish a term project implementing in software or hardware an existing or new image processing algorithm. *Prerequisites:* EL 512; EL 531; EL 610; C-Programming skill; Graduate student status.

EL 711 Advanced Signals and Systems 2½:0:3

Approximation methods in digital simulation of analog signals. Sampling theorems. Maximum system response under constraints. Analytic properties of Laplace transforms, complex inversion factorization, windows, extrapolation, maximum entropy. Two-dimensional and Hankel transforms. Diffraction. Fourier optics. Ambiguity functions and pulse compression. Spectral estimation. *Prerequisite:* EL 611.

EL 713 Digital Signal Processing I 2½:0:3

Time and transform domain description of discrete-time signals and filters. Z transforms, difference equations, discrete Fourier analysis and the FFT. Properties and design of recursive and non-recursive filters. Effects of finite precision arithmetic and round-off errors. Hardware realizations of digital filters. Introduction to spectral analysis. *Prerequisites:* EL 611.

EL 714 Digital Signal Processing II 2½:0:3

Two-dimensional signals and systems: Fourier representations and multi-dimensional sampling. 2-d discrete Fourier transform and convolution. Difference equations, Z transforms and multi-dimensional stability. Design and implementation of non-recursive and recursive digital filters. Multiparameter statistical estimation theory: the principle of maximum likelihood. Signal parameter estimation in additive noise and performance degradation due to parameter uncertainty. The Kalman filter: Steady state theory and frequency domain analysis. Kalman filters for smoothing, correlated signal in noise and colored noise. *Prerequisites:* EL 631 and EL 713.

EL 715 Array Signal Processing 2½:0:3

General sonar and radar array processing concepts. Array performance considerations. Narrowband and broadband signal processors. Classical and high resolution techniques for direction finding. Eigenstructure based techniques and spatial smoothing techniques. Performance analysis of eigen-structure-based techniques. Asymptotic distribution of eigenparameters associated with smoothed sample covariance matrices in uncorrelated and coherent scenes. Wiener solution and adaptive algorithms. Least Mean Square (LMS), Accelerated Gradient Search and Gradient algorithms with constraints. Direct implementation by inversion of the sample covariance matrix and transient response considerations. *Prerequisite:* EL 611, EL 631.

EL 911-919 Selected Topics in Systems 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.

The following were formerly listed under Imaging Sciences and Engineering:

IM 606 Imaging Laboratory 0:5:3

This laboratory is designed to give students physical contact with imaging techniques. Image formation is explored from matrix ray tracing to Fourier transform optics and holography. Polarized light in anisotropic materials and electro-optic effects are investigated, and one experiment in a major imaging technology (silver halide photography, electrophotography) is included. *Prerequisite:* EL 551 or equivalent.

IM 742 Introduction to Remote Sensing ½:0:3

Remote sensing is one of the important technological spin-offs of space exploration. This course presents an overview of the basic physics, the techniques, and the practical applications of remote sensing.

CONTROL SYSTEMS

EL 522† Sensor Based Robotics 2½:0:3

Robot mechanisms, robot arm kinematics (direct and inverse kinematics), robot arm dynamics (Euler-Lagrange, Newton-Euler, and Hamiltonian Formulations), trajectory planning, sensing, end-effector mechanisms, force and moment analysis, introduction to control of robot manipulators. *Prerequisite:* Concurrent with EE 104. Also listed under ME 661

EL 621 System Theory and Feedback Control I 2½:0:3

Design of single-input-output systems in the frequency domain. Stability of interconnected systems from component transfer functions. Parameterization of

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stabilizing controllers. Introduction to optimization (Wiener-Hopf design). *Prerequisite: Graduate status and EE 104.*

EL 622 Nonlinear and Sampled-Data Control Systems 2½:0:3

Introduction to nonlinear systems. Phase plane analysis, nonlinearities, linearization, limit cycles and averaging. Stability techniques: describing function, Lyapunov functions, Popov locus and circle criterion. Analysis and design of sampled-data systems by z-transforms and state variable methods.

Prerequisites: EL 610 and EE 104 or equivalent.

EL 721 System Theory and Feedback II 2½:0:3

A continuation of EL 621 for multi-input-output systems. Matrix fractions, optimal and suboptimal design considerations for two-degree of freedom systems. *Prerequisites: EL 621 and EL 613.*

EL 723 System Optimization Method 2½:0:3

Formulation of system optimization problems. Elements of functional analysis applied to system optimization. Local and global system optimization with and without constraints. Variational methods, calculus of variations, and linear, nonlinear and dynamic programming iterative methods. Examples and applications. *Prerequisite: EL 610 or EL 613.*

EL 724 H^∞ Frequency Domain Methods in Control 2½:0:3

Systems and operators, stabilizability, parameterization of stabilizing controllers, H^∞ weighted sensitivity minimization for rational plants, H^2 controller and H^∞ controller design. *Prerequisites: EL 621 and EL 725. Also listed under ME 870*

EL 725 State Space Design for Linear Control Systems 2½:0:3

Topics to be covered include: canonical forms; control system design objectives; feedback system design by pole placement; linear observers; the separation principle; linear quadratic optimum

control; random processes; Kalman filters as optimum observers; the separation theorem; robust control; the servo compensator problem. *Prerequisite: EL 610. Also listed under ME 671*

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 822 Application of Nonlinear Control to Robotics 2½:0:3

Differential geometric approaches for control of nonlinear systems and applications to robot manipulators. Introduction to Lie algebra and Lie bracket. Multi-variable inverses for nonlinear systems, external feedback linearization, zero dynamics. Application of nonlinear control to robotics: inverse dynamics, feedforward control, PD and PID controllers, variable-structure control, adaptive control techniques (STR and MRAC), and force control. *Prerequisite: EL 725 (EL 522 is recommended but not essential). Also listed under ME 860*

EL 823 Optimal Control Theory* 2½:0:3

Optimal control problem for deterministic systems with various constraints. Solution for both continuous and discrete-time systems using the maximum principle and dynamic programming. Hamilton-Jacobi theory as applied to the synthesis problem. *Prerequisite: EL 723 and EL 610. Also listed under MA 844 and ME 771*

EL 825 Large Scale Systems and Decentralized Control 2½:0:3

Introduction to analysis and synthesis of large scale systems. System order reduction algorithms, interconnected system stability, series expansion and singular perturbation. Decentralized control: decentralized fixed modes, LQR, frequency shaped cost functionals, and overlapping decompositions. *Prerequisites: EL 725 or instructor permission. Also listed under ME 873*

EL 826 Adaptive Control 2½:0:3

Controllable and observable system models (ARMA models), parameter estimation (least squares, projection algorithm, lattice filters), one and multi-step ahead prediction control, minimum variance, pole placement, LQG control, model reference adaptive control. *Prerequisite: EL 725 or equivalent. Also listed under ME 871*

EL 827 Stochastic Control 2½:0:3

Introduction to stochastic control, stochastic processes, covariance and spectral density, stochastic state models, spectral factorization of continuous or discrete time processes, parametric optimization, introduction to prediction and filtering theory: Wiener and Kalman filters. *Prerequisite: EL 610 and EL 631. Also listed under ME 872*

EL 921-929 Selected Topics in Control Engineering each 2½:0:3

Topics of current interest to feedback and control system engineers. (See department mailing for detailed description of each particular offering). *Prerequisite: Specified when offered.*

INFORMATION SCIENCE

EL 531 Probability 2½:0:3

Events, probability, repeated trials. Random variables distributions moments, characteristic functions. Functions of random variables. Sequences of random variables. Limit theorems. Engineering applications of statistics. *Prerequisite: Graduate status and MA 223.*

EL 535 Elements of Communications Networks 2½:0:3

An introductory course in telecommunications networks. Review of calculus, and probability theory in the context of telecommunications. Modulation of sinusoidal waves. Amplification and regeneration. Characterization of telecommunications traffic in terms of spectrum, capacity, response, and duty cycle. Voice communications systems, switches, PBXs, and transmission options. Circuit switching. Facsimile, image, and video communications. ISDN and other integrated services approaches. *Prerequisite:*

site: Graduate status. This course cannot be applied towards degrees offered by the EE Dept.

EL 631 Engineering Applications of Stochastic Processes 2½:0:3

Correlation, power spectrum, coherence, with applications in linear systems. Nonstationary signals, normal processes, mean square estimation, spectral analysis. Topics in Markov processes. *Prerequisite: EL 531.*

EL 632 Principles of Analog Communications 2½:0:3

Performance analysis of AM and FM systems, FM bandwidth, Hilbert transform and its applications, noise models. Threshold effect in FM receivers and the application of phase locked loops to threshold extension. Sampling theorem, pulse modulation, A/D conversion pulse code modulation (PCM) and delta modulation, pulse design. *Prerequisite: EE 140 or equivalent and MA 223 or equivalent.*

EL 633 Detection and Estimation Theory 2½:0:3

Detection of signals in noise, matched filters, M-ary digital communications. Signal detection and feature extraction in noisy environment based on likelihood ratio tests. Game-theoretic formulation of classification problems. Bayesian and point estimators: Near-optimum detectors. Combined estimation and detection. Wiener theory and Kalman-Bucy filters. *Co/Prerequisite: EL 631.*

EL 635 Principles of Communication Networks 2½:0:3

An introductory course in data communications and computer communications networks. Many examples of networks, modeling. Basic principles of the design and performance analysis of networks. Data communication hardware: terminals, modems, multiplexers, concentrators, communications media. Nodal processor and host processor architecture. Software considerations and design. Protocols. Line control, polling and random access methods. Satellite and local area networks. *Prerequisite: Graduate status or EE 140.*

EL 733 Digital and Data Communications 2½:0:3

Detection of signals in noise. Signaling through bandlimited channels: intersymbol interference, equalizers. Principles of M-ary communication: signal space methods, optimum detection. Bandwidth efficiency of modulation schemes, combined coding and modulation. Spread spectrum systems: bandwidth expansion schemes performance in jamming and multi-user environments. *Prerequisites: EE 140 and EL 531.*

EL 735 Communication Networks I 2½:0:3

Analysis and modeling of centralized and distributed data communication networks. Modeling of user traffic, communications link and processors. Queueing analysis. Packet-switched network. Time delay analysis of networks. Capacity assignment. Concentration, multiplexing, polling, and buffer analysis. Multiple access for broadcast networks-satellites, ALOHA, ground radio, local area networks. New switching techniques. Integrated voice and data. *Prerequisites: EL 531 and EL 635.*

EL 736 Communication Networks II 2½:0:3

Principles of network design, network design algorithms, centralized network design, static and dynamic routing algorithms, concentrator and switching node location, network reliability analysis, application of minimum spanning tree and shortest path algorithms to problems in network design, linear and integer programming techniques, distributed network design, case studies. *Prerequisites: EL 635 and CS 603.*

EL 738 Algebraic Codes* 2½:0:3

General theory of linear codes. Groups, rings, fields, matrices and vector spaces. Coding and error correction methods. Encoding and decoding cyclic codes. Convolutional codes and other encoding schemes. Capabilities and limitations of error-correcting code. Emphasizes codes used in computers. *Prerequisite: Graduate status and a basic knowledge of probability and linear algebra.*

EL 739 Information Theory* 2½:0:3

Concepts of entropy and mutual information as mathematical measures for discrete information sources and discrete communications channels. Source encoding theorems and source coding techniques. Extension to sources with memory, channel capacity, and noisy channel coding theory. Extensions to continuous waveforms. *Prerequisite: EL 531.*

EL 833 Advanced Signal Processing* 2½:0:3

Radon-Nikodym derivatives. Hajek-Feldman theorem for Gaussian stochastic processes. Detection and parameter estimation of stochastic and deterministic signals imbedded in colored and nonstationary Gaussian noise. Nonparametric methods in detection and estimation. Diversity reception systems. *Prerequisite: EL 633.*

EL 931-939 Selected Topics in Information Science each 2½:0:3

Selected topics of current interest in information science. (See departmental mailing for detailed description of each particular offering). *Prerequisite: Specified when offered.*

ELECTRONIC DEVICES, CIRCUITS, AND SYSTEMS

EL 545† Microwave Integrated and Semiconductor Circuits-I 2½:0:3

Transmission line review; co-axial, two-wire, parallel plate transmission lines. Printed transmission lines: microstrip line, stripline and other printed lines; quasistatic analysis, introduction to spectral-domain analysis, Green's functions; characteristic impedance; attenuation, perturbation method. Coupled transmission lines, directional coupler, coupled line filters. Transmission line transitions: bends, junctions, cross-overs, qualitative equivalent models. *Prerequisite: EE 166.*

EL 546† Microwave Integrated and Semiconductor Circuits-II 2½:0:3

Review of semiconductor physics, introduction to microwave integrated circuits (MIC's) S-parameter analysis, flow graphs, stability criteria of amplifiers.

Oscillators and amplifiers, noise figure, noise measurement. PN junction diodes, varactors, Schottky-barrier, PIN, IMP-ATT and Gunn diodes; bipolar and field-effect transistors; device physics and applications to VCO, frequency multipliers, detectors, mixers, attenuators, phase shifters, switches. *Prerequisite: EL 545, EE 110.*

EL 641 Advanced Electronic Circuitry I 2½:0:3

Basic semiconductor physics. Small-signal, low-frequency models for bipolar junction transistors and biasing. Physics, models, and biasing for field-effect transistors. General treatment of nonlinear controlled sources. High-frequency models. Single- and multi-stage broadband small-signal amplifiers, operational amplifiers, discrete and analog integrated circuits. *Prerequisite: Graduate status and EE 109 and EE 110.*

EL 642 Advanced Electronic Circuitry II 2½:0:3

Tuned circuits and impedance transformers, narrow-band linear amplifiers. Tuned-circuit sine-wave oscillators, mixers, AM modulators and demodulators, and FM modulators and demodulators. *Prerequisite: EL 641.*

EL 643 Advanced Electronic Circuitry III 2½:0:3

Junction and field-effect transistors as switches. Basic digital logic gates and switching circuits. Integrated circuit logic schemes and "building blocks". Sweep circuits and synchronization. *Prerequisite: EL 641.*

EL 645 Integrated Circuit (VLSI) System Design 2½:0:3

Overview of digital electronic circuit functions on a single silicon chip. Systematic approach to design from circuit function to basic layout, subsystem layout, and mask layout using techniques based on computer-aided design. Computer testing of logic functions and simulation of circuit functions. *Prerequisites: Graduate status, CS 337 and EE 113.*

EL 646 Integrated Circuit (VLSI) Fabrication Techniques 2½:0:3

Study of process technology used to produce integrated circuits with emphasis on silicon technology: bipolar, MOS, and VLSI processes. Definition of process requirements in terms of the circuit structure, i.e., concentration profiles and topographical layout as defined by previously determined mask set. Analysis of the steps from crystal growth through diffusion, ion implantation, oxidation, photolithography, metalization, interconnection, and packaging to final tests. Study of impact and process on design rules. *Prerequisites: Graduate status and EE 112. Also listed under MT 709*

EL 647 Power Electronics

See course listings under Power Engineering.

EL 941-949 Selected Topics in Electronics each ½:0:3

Special topics of current interest to staff in the field of electronic devices, circuits, and systems. (See departmental mailing for detailed description of each particular offering.) *Prerequisite: Specified when offered.*

ELECTRO-OPTICS, QUANTUM ELECTRONICS AND MATERIALS SCIENCE

EL 551-552† Electro-Optics, I, II each 2½:0:3

Maxwell equations; Propagation of plane waves: polarization, reflection, refraction, interfaces, and multilayers; diffraction; Fourier optics; Gaussian beams; Laser resonators; Optical fibers and Guiding layers; Optical waveguide couplers, Propagation in anisotropic media; Modulators, Optical detection. *EL 551 prerequisite: EE 166 or equivalent. EL 552 prerequisite EL 551.*

EL 557† Introduction to Electric and Magnetic Properties of Solids 2½:0:3

Crystal structures and dynamics, lattice vibrations, the phonon thermal conductivity of solids. Energy-band theories, Brillouin zones, conductors, semiconductors, insulators, semiconductor junctions,

junction devices, light-emitting diodes, detectors for visible and infrared. *Prerequisite: EE 167.*

EL 651 Statistical Mechanics I 2½:0:3

Equilibrium distributions. Relationships to laws of thermodynamics. Quantum effects. Maxwell-Boltzmann, Fermi-Dirac, Bose-Einstein distributions. Applications to bulk properties of matter and to thermal radiation. Kinetic theory. Nonequilibrium phenomena using Boltzmann transport equation. *Prerequisite: Graduate status. Also listed under PH 663*

EL 652 Statistical Mechanics II 2½:0:3

Micro-, Macro-, and grand-canonical ensembles and principles of classical statistical mechanics. Condensation phenomena. Treatment of fluctuation and transport phenomena. Density matrix formalism of quantum statistical mechanics. Many-body problems. *Prerequisite: EL 651 or PH 663. Also listed under PH 664*

EL 653-654 Quantum Electronics I, II each 2½:0:3

Interaction of electromagnetic radiation with quantized matter systems; spontaneous emission, absorption and induced emission; Two-level systems; Relaxation processes; Homogeneous and inhomogeneous lines; Laser devices: Gaseous, solid state, and diode lasers; Laser dynamics: Q-switch, mode locked, and ultra short pulse generation; Non-linear optics: Harmonic generation, parametric interactions, Raman and Brillouin nonlinearities; Fundamental noise properties of laser oscillators. *EL 653 prerequisite: Graduate status. EE 167 or equivalent recommended. EL 654 prerequisite EL 653.*

EL 655-656 Quantum Mechanics I, II each 2½:0:3

Quantum mechanics with applications to atomic systems. The use of Schrodinger's equations. Angular momentum and spin. Problems and approximation methods. Semiclassical theory of field-matter interaction. *EL 655 prerequisite:*

Graduate status. EL 656 prerequisite: EL 655. Also listed under PH 667-668

EL 658 Fiber Optic Communications 2½:0:3

Preview of fiber optic communications, optical fibers, light sources, detectors, modulation techniques. Transmitter, receiver, and repeater technology. System applications. Integrated optics. *Prerequisite: Graduate status.*

EL 950 Laboratory in Electronic Materials and Electro-Optics* 0:5:3

Selected experiments in electrical properties of materials. Physical properties of semiconductors, Hall effect measurements, photoelectricity, superconductivity, magnetoresistance, masers and lasers, harmonic generation, frequency mixing and modulation in optics and quasi-optic region. Experiments of project type designed to prepare students for independent research in above areas. Lab fee required. *Prerequisite: Graduate status.*

EL 951-959 Selected Topics in Quantum Electronics, Material Science and Electro-Optics each 2½:0:3

Topics of current interest dealing with interaction of matter with electromagnetic fields. (See department mailing for detailed description of each particular offering.) *Prerequisite: Specified when offered.*

POWER ENGINEERING

EL 564† Electromechanical Power Conversion* 2½:0:3

Motion of elementary charged particles in electromagnetic fields. Transformation laws for the electromagnetic field intensities. Magnetoplasma-dynamical equations. Electrical and mechanical power densities, power density relations, and the design of the armature conductors in terms of power densities. Representation of fields in terms of traveling waves; synchronous and asynchronous interaction. Steady-state performance of synchronous converters. MHD power generation. *Prerequisite: EE 166*

EL 568† Electric Drives I: Characteristics and Controls 2½:0:3

Transient conditions in electric drives. Load torques, moments of inertia, masses and forces translated to a rotating shaft. Acceleration and deceleration time. Consideration in selecting motor power rating. Motor heating (cooling) under different kinds of duty. Load diagram construction. Speed control of electric drives. Four quadrant operation of dc and ac drives with static converter supply. Worked examples effectively illustrate the application of the mathematical derivations. *Prerequisite: EE 180.*

EL 569† Electric Drive II: Design* 2½:0:3

Torque-speed envelopes, electrical and mechanical ports. Modeling of the motor and speed control. Outline of direct approach to design. Mechanical and thermal stress limitations. Magnetic and electrical loading. Relations between flux and current densities. Determination of losses. Scaling laws. Flux plotting techniques. Procedures, computer programs, and applications. *Prerequisite: EL 568.*

EL 647 Power Electronics 2½:0:3

Principles of thyristor devices, GTOs, MOSFETs, dynamic characteristics of DC choppers, dependence of turnoff circuits on load characteristics, and switched-mode power supplies. Phase control, full wave circuits with inductive load, commutation. Power inverters. *Prerequisite: Graduate status and EE 103, and EE 110.*

EL 661 Introduction to Power System Engineering* 2½:0:3

Power system engineering analysis: three-phase circuit calculations, network representations and load flow calculations. Reliability analysis: generation reliability. Generation costing and economic dispatch. *Prerequisite: EE 183 or equivalent.*

EL 662 Introduction to Power System Planning* 2½:0:3

Power system economics: revenue requirements, load duration and reserve requirements. Load forecasting—econometric methods. Optimal

expansion planning and methodologies: Optimal generation expansion computer modeling. Decision analysis techniques. *Prerequisite: EL 661.*

EL 663 Electrical Transients in Power Systems 2½:0:3

Analysis of lumped-circuit, normal and abnormal transients in power equipment and systems. Short-circuit fault analysis and transient recovery of three-phase circuits. Analysis of traveling-wave surges on transmission lines, windings, and on integrated systems. *Prerequisite: EE 183 or equivalent.*

EL 664 Relay Fault Protection* 2½:0:3

Protective relay functions and classification. Electromechanical relay types, operating principles, and basic characteristics. Communication channels for relaying. Current and voltage transformers, transducers. Protection of busses, transformers, generators, motors, and other station equipment by the zone protection method. Distribution and transmission line relaying systems. Relay setting calculations. Primary and backup protection, application, and philosophy with applied relay engineering examples. *Prerequisite: EL 663.*

EL 665 Power System Stability I* 2½:0:3

Introduction to the study of power system dynamics: mathematical modeling of prime movers, power plants, synchronous machines, field exciters transmission lines, relay loads, and stabilizers. *Prerequisites: EE 104 and EE 183.*

EL 666 Power System Stability II* 2½:0:3

Study of electrical machine and system dynamics, system governing and generation control prime-mover, energy supply, system dynamics and control. *Prerequisite: EL 665.*

EL 961-969 Selected Topics in Power each 2½:0:3

Topics of current interest in electric power engineering. (See departmental mailing for detailed description of each

particular offering.) *Prerequisite: To be specified when offered.*

ELECTRODYNAMIC AND WAVE PHENOMENA

EL 571-572† Engineering Electromagnetics I, II each 2½:0:3

Engineering applications of electromagnetics. A device-hardware oriented course for graduate and advanced undergraduate students. Topics include: hollow conducting waveguides, dielectric guides; two-wire, coaxial and strip transmission lines; linear antennas, arrays, horn and dish antennas. Waveguide components: attenuators, phase shifters; waveguide-coaxial transitions, etc. Electromechanical transducers: loud speakers, microphones, relays. *EL 571 prerequisite: EE 166. EL 572 prerequisite: EL 571.*

EL 573† Introduction to Microwave Engineering 2½:0:3

Review of EM theory, transmission lines. S, Z, Y, ABCD parameters, network theory, network analyzer, signal flow graphs, CAD methods. Impedance matching, multisection and tapered impedance transformer, Bode-Fano criteria. Power divider, directional coupler, hybrid circuits. Microwave resonators: series, parallel resonant circuits, stubs, and cavities. Filter theory and design: microstrip and stripline designs, coupled line filters, Kuroda identities, Chebychev and maximally flat filters. *Prerequisite: EE 166.*

EL 581 Introduction to Plasma Engineering* 2½:0:3

Basic plasma concepts and applications; parameters describing the plasma; motion of charged particles in electromagnetic fields; effect of particle collisions on plasma transport: diffusion and mobilities. Plasmas as dielectric media; plasma dielectric response functions for collective plasma oscillations and for electromagnetic wave propagation in plasma. *Prerequisite: EE 166.*

EL 671 Fields and Waves 2½:0:3

The course lays the groundwork to the theory and understanding of electromagnetic fields, their sources and their prop-

agation in the form of waves. The treatment starts from basic physical concepts and develops the description of electromagnetic fields in terms of Maxwell's equations by using vector analysis and related techniques. *Prerequisites: Graduate status and EE 162.*

EL 672 Electrodynamics: Wave Propagation and Guidance 2½:0:3

The electrodynamics of waves guided by metallic and dielectric structures, resonators, radiation, and other relevant theoretical aspects of modern electromagnetic engineering are covered. The emphasis is on understanding wave phenomena and on studying the basic concepts and techniques that are useful when treating relevant problems over the entire electromagnetic spectrum. *Prerequisite: EL 671.*

EL 673 Electrodynamics: Fields and Materials 2½:0:3

Interaction of electromagnetic fields with material media from classical viewpoint. Macroscopic description of dielectric, magnetic and conducting materials, energy relations, dispersion, and attenuation in dielectrics and ionized media. Wave propagation in anisotropic crystals and ferrites, waves in inhomogeneous media. *Prerequisite: EL 671 or PH 623. Also listed under PH 625.*

EL 676 Fundamentals of Radar* 2½:0:3

Principles of range and direction find by means of radio echoes. Requirements and limitations of radar, the radar equation, and statistical nature of reception. Establishment of design criteria for radar receivers, indicators, modulators, and microwave components. Presentation of systems and techniques including MTI, Doppler radars and pulse compression. *Prerequisite: EL 611.*

EL 771-772 Radiation and Diffraction I, II* each 2½:0:3

First semester: An introductory level with asymptotic methods for radiation and diffraction. Saddle point approximations of radiation and diffraction integrals for harmonic and transient fields, wave packets; ray description of reflection and

refraction, diffracted rays (geometrical theory of diffraction). Second semester: rigorous methods. Eigen-function expansions; discrete and continuous spectra, Green's functions; alternative representations, asymptotic reduction of rigorous integral representations. *EL 771 prerequisite: EL 672. EL 772 prerequisite: EL 771.*

EL 773-774 Guided Waves and Beams I, II* each 2½:0:3

Theory and application of guided waves and beams in areas of electromagnetics (radar), microwave acoustics and integrated optics. Propagation characteristics of surface and leaky waves; effects of loss; mode coupling; characterization of discontinuities. Propagation in periodic structures. Beam fields; properties of laser beams; divergence, Fresnel, and Fraunhofer approximations; scattering and guiding of beams by planar structures; beam displacement and distortion; coupling to surface waves. *EL 773 prerequisite: EL 672. EL 774 prerequisite: EL 773.*

EL 775 Antenna Theory 2½:0:3

Concepts of antenna radiation patterns, radiation resistance equivalent network; gain; effective area; reciprocity. Electromagnetic fields due to prescribed sources. Huygens' principle. Fresnel and Fraunhofer regions. finite and infinite arrays. Mutual coupling. Aperture antennas. Traveling-wave antennas. Frequency independent antennas. *Prerequisite: EL 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 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.*

EL 783-784 Linear Wave Process in Plasmas I, II*
each 2½:0:3

Oscillatory and guided wave representation of fields in general linear systems. Self-consistent nonequilibrium field description of particle and wave dynamics in classical plasma-like systems. Kinetic versus fluid dynamic description of gaseous and solid-state plasmas. Dispersion relations, wave structure, and instabilities in isotropic and anisotropic plasmas. *EL 783 prerequisite: EL 581. EL 784 prerequisite: EL 783.*

EL 871 Advanced Ray Methods in Wave Propagation*
2½:0:3

Asymptotic theory of radiation and diffraction, with emphasis on inhomogeneous and dispersive media. WKB approximations and comparison methods, advanced saddle-point techniques and relation to ray optics. Space-time rays in inhomogeneous dispersive media, diffraction and transition phenomena for transients. *Prerequisite: EL 772.*

EL 873 Nonlinear Waves*
2½:0:3

Generic nonlinear wave equations. Whitcomb's Lagrangian formulation and averaging method. Quasi-particle techniques in nonlinear problems. Inverse scattering methods. Application of KdV, nonlinear parabolic, etc., equations in electrophysics. *Prerequisite: EL 671.*

EL 970 Microwave Engineering Laboratory/Project
1:4:3

Design, fabrication, testing of passive circuits (couplers, filters), active circuits

(amplifier, oscillator) and antennas using printed circuits. Design and simulation using microwave CAD tools (Supercompact, Touchtone, Puff, PCAAMT), HP-8510 automated Network Analyzer measurement, frequency and time-domain measurements, antenna pattern measurement, printed circuit layout and photoetching. *Prerequisite: EE166; Co-requisite: EL 545 or EL 571.*

EL 971-979 Selected Topics in Electromagnetic Theory
each 2½:0:3

Aspects of electromagnetic and acoustic wave propagation, diffraction and radiation of current interest, including wave interactions with materials and special mathematical and numerical techniques. (See departmental mailing for detailed description of each particular offering). *Prerequisite: Specified when offered.*

EL 981-989 Selected Topics in Plasmas
each 2½:0:3

Aspects of plasmas of current interest. Subjects drawn from plasma composition dynamics and interactions with electromagnetic fields. (See departmental mailing for detailed description of each particular offering). *Prerequisite: Specified when offered.*

DEPARTMENT PROJECTS, READINGS, THESIS, AND SEMINAR

EL 591-599† Selected Topics in Electrical Engineering
each 2½:0:3

Topics of current interest in electrical engineering offered for credit to both selected undergraduate and graduate students. (See departmental mailing for detailed description of each particular offering.) *Prerequisite: Specified when offered.*

EL 891 Graduate Seminar*
each 2½:0:3

Seminars in various areas of electrical engineering, electrophysics, system engineering, 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 specialization in electrical engineering, electrophysics, or system engineering and who have completed essentially all related course offerings. Readings conducted under guidance of a faculty member who is expert in the field, consisting in general of readings in advanced literature. Examination required. Not more than 3 units may be offered toward the master's degree. *Prerequisite: Degree status.*

EL 995-996 Advanced Projects I, II
each 0:5:3

Theoretical and experimental projects in various research areas in electrical engineering and electrophysics for the advanced graduate student. Projects assigned on basis of specialized interest and preparation of the student. A written report or oral examination is required at the discretion of the advisor. *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 advisor. Oral thesis defense and formal, bound thesis volume required. Registration of 9 units required (continuous thesis registration required). *Prerequisite: Degree status.*

EL 998 Projects for Engineer Degree in Electrical Engineering
each 3 units

Comprehensive planning and design of electrical engineering project under guidance of faculty advisor. Emphasis on current techniques. Oral examination and formal, bound report required. Scope of project is 6-12 units by prior agreement

with advisor (continuous project registration required). *Prerequisite:* Degree status.

EL 999 Dissertation for Degree of Doctor of Philosophy in Electrical Engineering *each 3 units*

Original investigation of electrical engineering problem. Must demonstrate creativity and include features of originality and utility worthy of publication in recognized journal. Candidate must successfully defend dissertation orally. Registration of 24 units required (continuous dissertation registration required). *Prerequisite:* Passing qualifying examination. Registration beyond twelfth unit requires passing of area examination.

FACULTY

Leonard G. Shaw, Professor of Electrical Engineering and Head of School of Electrical Engineering and Computer Science
B.S., University of Pennsylvania; M.S., Ph.D., Stanford University
Signal processing, reliability

Henry L. Bertoni, Professor of Electrophysics and Head of the Department of Electrical Engineering
B.S., Northwestern University; M.S., Ph.D., Polytechnic Institute of Brooklyn
Electromagnetics; acoustics

Donald Bolle, Professor of Electrical Engineering
B.Sc., Durham University (England); Ph.D., Purdue University
Guided wave propagation, nonreciprocal devices

Joseph J. Bongiorno, Jr., Professor of Electrical Engineering and Assistant Department Head, Long Island Center;
B.E.E., M.E.E., D.E.E., Polytechnic Institute of Brooklyn
Control systems

Leonard Bergstein, Professor of Electro-Optical Sciences
Ph.D., Polytechnic Institute of Brooklyn
Electro-optics

Robert R. Boorstyn, Professor of Electrical Engineering and Computer Science
B.E.E., CCNY; M.S., Ph.D., Polytechnic Institute of Brooklyn
Computer communication networks, telecommunications

Frank A. Cassara, Professor of Electrical Engineering
B.S., Rutgers—The State University; M.S., Ph.D., Polytechnic Institute of Brooklyn
Electronic circuits, communication systems

Edward S. Casedy, Professor of Electrical Engineering
B.S., Union College; S.M., Harvard University; Dr.Eng., The John's Hopkins University
Power, plasmas, energy economics

Bernard R. S. Cheo, Professor of Electrical Engineering
B.S., Taiwan College of Engineering (Taiwan); M.S., University of Notre Dame; Ph.D., University of California (Berkeley)
Electromagnetics, plasmas, power

Leopold B. Felsen, University Professor
B.E.E., M.E.E., D.E.E., Polytechnic Institute of Brooklyn
Propagation and diffraction, optics

Ivan T. Frisch, Director of the Center for Advanced Technology in Telecommunications, Acting Provost, and Professor of Electrical Engineering and Computer Science
B.S., Queens College; M.S., Ph.D., Columbia University
Information systems, computer networks and network control

Donald F. Hunt, Professor of Electrical Engineering
B.S., University of Pennsylvania
Networks and systems

Erich E. Kunhardt, Professor of Electrophysics and Physics
B.S., M.S., New York University; Ph.D., Polytechnic Institute of New York
Gaseous electronics, plasma dynamics, pulse power physics

Szu-Ping Kuo, Professor of Electrical Engineering and Electrophysics
B.S., M.S., National Chiao-Tung University (Taiwan); Ph.D., Polytechnic Institute of New York
Magnetohydrodynamics

Ludwik Kurz, Professor of Electrical Engineering
B.E.E., M.E.E., CCNY; Eng. Sc.D., New York University
Communications, pattern recognition, and image processing

Arthur E. Laemmel, Professor of Electrical Engineering and Computer Science
B.E.E., Polytechnic Institute of Brooklyn
Coding and computer circuits

James T. LaTourrette, Professor of Electrical Engineering and Computer Science
B.S., California Institute of Technology; A.M., Ph.D., Harvard University
Quantum electronics

Tony T. Lee, Professor of Electrical Engineering
B.S., National Cheng Kung University, Taiwan; M.S., Cleveland State University; Ph.D., Polytechnic Institute of New York
Telecommunication switching and performance analysis

Maurice C. Newstein, Professor of Electrophysics
A.B. Temple University; Ph.D., Massachusetts Institute of Technology
Quantum electronics

Henry Ruston, Professor of Electrical Engineering and Computer Science
B.S.E.(Math), B.S.E.(EE), University of Michigan; M.S.(EE), Columbia University; Ph.D.(EE), U. Mich.
Software engineering, programming, circuit theory

Philip E. Sarachik, Professor of Electrical Engineering
A.B., B.S., M.S., Ph.D., Columbia University
Optimal and adaptive systems

Martin L. Shooman, Professor of Electrical Engineering and Computer Science
S.B., S.M., Massachusetts Institute of Technology; D.E.E., Polytechnic Institute of Brooklyn
Software engineering, system reliability and safety

Leonard Strauss, Professor of Electrical Engineering
B.E.E., CCNY; M.S., Columbia University
Integrated circuits

Theodor Tamir, Professor of Electrical Engineering and Electrophysics
B.S., Dipl. Ing., M.S., Technion (Israel); Ph.D., Polytechnic Institute of Brooklyn
Electromagnetics, electro-optics

Richard Van Slyke, Professor of Electrical Engineering and Computer Science
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Computer communications, telecommunications

Wen-Chung Wang, Professor of Electrical Engineering and Electrophysics
B.S., Taiwan Engineering College (Taiwan); M.S., Ph.D., Northwestern University
Microwave acoustics

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B.E.E., CCNY; M.S., New York University
Networks, control systems

Zivan Zabbar, Professor of Electrical Engineering
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Power electronics, electric drives, power systems

Leo Birenbaum, Associate Professor of Electrical Engineering and Electrophysics
B.E.E. Cooper Union; M.E.E., M.S., Polytechnic Institute of Brooklyn
Bioeffects of microwaves, microwave measurements, electrical machinery

H. Jonathan Chao, Associate Professor of Electrical Engineering
B.S., M.S., National Chiao-Tung University (Hsinchu, Taiwan); Ph.D., Ohio State University
Design of VLSI chips for telecommunications

Douglas A. Davids, Associate Professor of Electrophysics
B.S., M.S., Newark College of Engineering; Ph.D., Johns Hopkins University
Microwave acoustics, quantum electronics

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B.E.E., M.E.E., Ph.D., Polytechnic Institute of Brooklyn
Digital filters, power systems

I-Tau Lu, Associate Professor of Electrical Engineering
B.S. National Chiao-tung University (Taiwan); M.S. National Taiwan University; Ph.D. Polytechnic Institute of New York
Electromagnetics, microwave circuits

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Dipl. EE, National Technical University of Athens (Greece); M.S., Polytechnic Institute of New York; Ph.D., Columbia University
Computer communication networks, performance evaluation of computer systems

Shivendra S. Panwar, Associate Professor of Electrical Engineering
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Communication networks

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B. Tech., Indian Institute of Technology (Bombay); Ph.D., University of Pennsylvania
Signal processing

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B.S., M.S., Ph.D., University of Maryland
Computational electromagnetics, experimental optoelectronics

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B. Tech., Indian Institute of Technology; M.S., Ph.D., University of Massachusetts
Electromagnetics, antennas

Giora Griffel, Assistant Professor of Electrical Engineering
B.S., Ph.D., Tel-Aviv University
Optoelectronic integrated circuits, semiconductor lasers

Farshad Khorrami, Assistant Professor of Electrical Engineering
BSEE, B.S. (Math), M.S. (Math), Ph.D. (EE), Ohio State University
Robotics, control systems

Seung P. Kim, Assistant Professor of Electrical Engineering
B.S., Seoul National University; M.S.E.E., Korea Advanced Institute of Science and Technology; M.S. (Computer Engineering), University of Pittsburgh; Ph.D. (EE), Pennsylvania State University
VLSI signal processing

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Diploma in Electrical Engineering, University of Thessaloniki, Greece; M.S., Ph.D., University of Maryland
Telecommunications scheduling and routing

Vassilis Tsotras, Assistant Professor of Electrical Engineering and Computer Science
B.S., National Technical University (Athens); M.S., Ph.D., Columbia University
Computer communication systems

Peter Voltz, Assistant Professor of Electrical Engineering
B.S., M.S., Ph.D., Polytechnic Institute of New York
Systems and control

Yao Wang, Assistant Professor of Electrical Engineering
B.S., M.S., Tsinghua University (Beijing); Ph.D., University of California at Santa Barbara
Image coding, pattern recognition

ASSOCIATED FACULTY

Joel B. Snyder, Senior Industry Professor of Electrical Engineering and Computer Science
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Microprocessor systems, data acquisition and transmission, signal processing

Shalom S. Bergstein, Industry Professor of Electrical Engineering
B.S., M.S., Ph.D., Polytechnic Institute of New York
Communications, fiber optics

Louis P. Herzberg, Industry Professor of Electrical Engineering
B.S., City College of New York; M.S., Ph.D., Polytechnic Institute of Brooklyn
VLSI and communication technology, signal processing

Barry Jones, Industry Professor of Electrical Engineering and Computer Science
B.S., Cooper Union, M.S., Marist College
Electromechanical systems, Real-time computer systems

ADJUNCT FACULTY

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B.Sc., University of Athens; M.S., University of Toronto; Ph.D., Polytechnic Institute of New York

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Phillip Grieve, Lecturer
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James Moulic, Lecturer
B.S., M.S., University of Illinois; Ph.D.E.E., Polytechnic Institute of New York

Wilbur Pritchard, Lecturer
B.S., City College of New York

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

James Wetterau, Lecturer
B.E.E., CCNY; M.S., Polytechnic Institute of New York; P.E., (New York)

EMERITUS FACULTY

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

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

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

Alexander Hessel, Professor Emeritus of Electrophysics
M.Sc., Hebrew University; D.E.E., Polytechnic Institute of Brooklyn
Antenna theory

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

Enrico Levi, Professor Emeritus of Electrophysics
B.S. (M.E.), B.S. (E.E.), Dipl. Ing., Technion (Israel); M.E.E., D.E.E., Polytechnic Institute of Brooklyn
Energy conversion

Frank J. Lupo, Professor of Electrical Engineering and Computer Science
B.E.E., M.E.E., New York University; Ph.D., Columbia University; P.E. (New Jersey)
Bioengineering, networks and systems

Nathan Marcuvitz, University Professor Emeritus
B.E.E., M.E.E., D.E.E., Polytechnic Institute of Brooklyn

Eli Absalom Mishkin, Professor Emeritus of Applied Physics
Ingenlevr, Sc.D., Technion (Israel)

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

Marvin Panzer, Associate Professor of Electrical Engineering
B.E.E., Cooper Union; M.E.E., D.E.E., Polytechnic Institute of Brooklyn

Istvan Palocz, Professor Emeritus of Electrical Engineering and Electrophysics
Dip. E.E., Docent, University of Technical Sciences (Budapest); Ph.D., Polytechnic Institute of Brooklyn
Wave propagation

Athanasios Papoulis, University Professor Emeritus
M.E., E.E., Athens Polytechnic Institute (Greece); M.S., M.A., Ph.D., University of Pennsylvania
Signal theory

Beulah Rudner, Assistant Professor of Electrical Engineering
B.A., Hunter College;
M.E.E., Polytechnic Institute of Brooklyn

Harry Schachter, Professor of Electrical Engineering
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Microwave acoustics and communication systems

Benjamin Senitzky, Professor of Electrophysics and Physics
B.E., Ph.D., Columbia University
Optical and semiconductor devices

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

Jerry Shmoys, Professor Emeritus of Electrical Engineering
B.E.E., Cooper Union;
Ph.D. New York University
Antennas, propagation

Leo M. Silber, Associate Professor of Electrophysics
B.S., University of Massachusetts;
M.S., Ph.D., Purdue University
Magnetic materials, plasmas

Edward J. Smith, Professor Emeritus of Electrical Engineering and Computer Science
B.E.E., Cooper Union; M.E.E., D.E.E., Polytechnic Institute of Brooklyn

Ernst Weber, Professor Emeritus and President Emeritus
Dr. Phil., University of Vienna (Austria); Dr. Techn., Technical University of Vienna (Austria)

Gerald Weiss, Professor Emeritus of Electrical Engineering
B.E. E., Cooper Union;
S.M., Harvard University; D.E.E., Polytechnic Institute of Brooklyn;
P.E. (New York)

ELECTROPHYSICS PROGRAM

Polytechnic offers a program of study leading to the degrees of master of science and doctor of philosophy in electrophysics. The program is intended to prepare students to work at the interface between electrical engineering and physics, where new engineering applications of various physical phenomena are developed. Emphasis is placed on wave propagation and wave interactions with matter, as applied to a wide range of topics. Students entering the program typically have an undergraduate background in electrical engineering or in physics, a strong interest in physical phenomena and/or applied mathematics, and a desire to participate in research.

The program is administered by the Department of Electrical Engineering.

The program of study consists of basic courses in wave propagation, electromagnetic theory, and mathematical techniques offered through the Department of Electrical Engineering. 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, and waves in the earth's atmosphere. The basic courses are offered yearly on both the Brooklyn and Long Island campuses. Specialized courses may be offered on one or the other campus, or in alternate years on the two campuses.

The electrophysics faculty at Polytechnic has made significant contributions to each of the areas cited above and maintains active theoretical and experimental programs in them. Because the electrophysics program is an outgrowth of these research activities, students in

the program are exposed to the most current technical developments in each area and can be guided in research at the forefront of the areas. The theoretical effort is supported by extensive computational facilities existing at Polytechnic. The experimental research is carried out in laboratories in Long Island and Brooklyn. At Long Island, experimental facilities include laboratories devoted to surface acoustic waves, magnetostatic wave devices, lasers, semiconductors, ion implantation, microwaves and millimeter waves, gas discharges and plasmas. The Brooklyn campus has laboratories devoted to electro-optics and ultrasonics.

REQUIREMENTS FOR THE MASTER'S DEGREE

The entrance requirements for the master of science in electrophysics are a bachelor's degree in engineering or science from an accredited institution, with a superior undergraduate record, including undergraduate courses in differential equations, electromagnetic theory, quantum and solid-state physics, and linear systems. Students with deficiencies in these areas may be admitted if they take appropriate introductory courses to remove these deficiencies. Outstanding students are advised to apply for financial aid in the form of research fellowships, teaching fellowships, or partial tuition remission.

To satisfy the requirements for the M.S. in electrophysics degree, the student must complete a total of 36 units of courses, as described below. An overall grade point average of B in all graduate courses is required by the University. In addition, a B average is required in specific groups of courses, as indicated below.

1. Course Courses

Three courses from among the following:

EL 551	<i>Electro-Optics I</i>
EL 581	<i>Introduction to Plasma Engineering</i>
EL 611	<i>Signals, Systems and Transforms</i>
EL 651	<i>Statistical Mechanics I</i>
EL 653	<i>Quantum Electronics I</i>
EL 671	<i>Fields and Waves</i>

9 Units

- Two one-year sequences, which may include the above courses. Both of these one-year sequences must be in electrical engineering or physics courses, and at least one must be an EL sequence.

6-12 Units

- Approved electives. 21-15 Units
Total: 36 Units

A complete course of study, including the choice of the one-year sequences, should be arranged in consultation with an advisor. 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 or CS prefixes, and 18 units of these must be in EL prefixed courses.

An overall B average is required in the combination of five to seven courses offered to satisfy categories (1) and (2) in the above table.

The *EE Department Graduate Student Manual* should be consulted for more detailed rules and procedures, including student status, recommended electives and one-year sequences, current areas of research, and disqualification for low grades.

REQUIREMENTS FOR THE DOCTOR'S DEGREE

Graduate students who have demonstrated a high degree of scholastic proficiency and have given evidence of ability to conduct independent research may consider extending their studies toward the doctorate.

Admission to Program—Admission to the program is based on qualifying examinations which a student usually takes after having completed one year of graduate studies. Successful completion of the master's requirements in electrophysics should provide adequate course preparation for the examinations.

Specific requirements for this degree parallel those for the Ph.D. in E.E. as described elsewhere in this Catalog and in the *EE Graduate Student Manual*. These include course requirements, guidance committee formation, area examination, submission of the bound thesis, etc.

Outstanding students are advised to apply for financial aid in the form of research fellowships, teaching fellowships, or partial tuition remission.

Qualifying Examinations—The format for the qualifying examinations is described in connection with the Ph.D. in electrical engineering. Principal areas of concentration for electrophysics candidates are: quantum electronics, solid-state electronics, electromagnetics, and electro-optics. Current information about examination topics should be obtained from the Electrical Engineering graduate office.

GRADUATE COURSES

EP 997 Thesis for Degree of Master of Science in Electrophysics *each 3 units*

Independent research project demonstrating professional maturity, performed under guidance of advisor. Oral thesis defense and formal bound thesis volume required. Registration of 9 units required (continuous thesis registration required). *Prerequisite: Degree status.*

EP 999 Dissertation for Degree of Doctor of Philosophy in Electrophysics *each 3 units*

Original investigation of electrophysics problem. Must demonstrate creativity and include features of originality and utility worthy of publication in a recognized journal. Candidate must successfully defend dissertation orally. Registration of 24 units required (continuous dissertation registration required). *Prerequisite: passing of qualifying examination. Registration beyond the 12th unit requires passing of area examination.*

PARTICIPATING FACULTY

Leonard Bergstein, Professor of
Electro-Optical Sciences

Henry L. Bertoni, Professor of
Electrophysics

Lawrence Carin, Assistant Professor of
Electrophysics

Nirod Das, Assistant Professor of
Electrical Engineering

Bernard R.S. Cheo, Professor of
Electrical Engineering

Leopold B. Felsen, University Professor

Giora Griffel, Assistant Professor of
Electrical Engineering

Erich E. Kunhardt, Ernst Weber
Professor of Electrophysics

Szu-Ping Kuo, Professor of Electrical
Engineering and Electrophysics

James T. LaTourrette, Professor of
Electrophysics

Maurice C. Newstein, Professor of
Electrophysics

Theodor Tamir, Professor of Electrical
Engineering and Electrophysics

Wen-Chung Wang, Professor of
Electrical Engineering and Electrophysics

Douglas A. Davids, Associate Professor
of Electrophysics

I-Tai Lu, Associate Professor of
Electrical Engineering

Leo Birenbaum, Associate Professor of
Electrical Engineering and Electrophysics

ENVIRONMENTAL SCIENCE AND ENGINEERING

The Department of Civil and Environmental Engineering offers graduate programs in environmental science and engineering leading to the following degrees:

- Master of Science in Civil Engineering
- Master of Science in Environmental Health Science
- Master of Science in Environmental Engineering
- Engineer in Civil Engineering
- Doctor of Philosophy in Civil Engineering
- Doctor of Philosophy in Environmental Health Science

Programs with environmental health science and environmental engineering designations are described below. Programs with civil engineering designations are described in the section of this catalog for Civil Engineering.

Programs in environmental science and engineering are suitable for students having undergraduate degrees in the physical, chemical or biological sciences, or any engineering field. Most courses in these programs are attended by both science and engineering students, and the course materials and faculty are highly interdisciplinary, corresponding to the practice of the environmental professions.

Graduates with degrees in this field are employed by governmental environmental regulatory and construction agencies; consulting firms that specialize in environmental engineering and planning; industrial firms whose factories or products have an impact on the air, water or land environments; and engineering, testing and control laboratories that are engaged in research and monitoring of environmental problems. These programs may also be attractive to science teachers who wish to broaden the scope of the courses they teach.

Requirements for the master's degree include prescribed courses and approved

elective courses. A project must be completed. A thesis may be substituted for project and elective courses.

The Ph.D. degree requires advanced study beyond the master's level and high level original work. A thesis must be written and defended.

Computer literacy is a requirement for all areas of specialization. In some cases, an undergraduate or graduate course may be included in the program to overcome deficiencies.

Students interested in graduate programs are advised to refer to the Graduate Manual (available from the office of the Department of Civil and Environmental Engineering) for further information on degree requirements and the latest revisions of curricula and courses.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE

Two programs in environmental science and engineering are offered, in addition to the M.S. in civil engineering. Students pursuing the M.S. in environmental health science or the M.S. in environmental engineering generally have undergraduate or graduate preparation in the sciences, although the programs leading to these degrees may also be taken by students with engineering preparation.

Courses in some areas of specialization are not offered on a regular basis. Students should consult with the department advisors to determine the expected scheduling of such courses.

M.S. PROGRAM IN ENVIRONMENTAL HEALTH SCIENCE

Departmental Requirement

	Units
CE 996 <i>Project for the Degree of Master of Science</i>	<u>3</u>
	3

Environmental Health Science Requirements

CE 737 <i>Environmental Chemistry & Microb. I</i>	3
CE 739 <i>Environmental Chemistry & Microb. II</i>	3
CE 742 <i>Water & Wastewater Treatment I</i>	3
CE 743 <i>Water & Wastewater Treatment II</i>	3
CE 751 <i>Environmental Health Engineering</i>	3
CE 752 <i>Air Pollution</i>	3
CE 770 <i>Solid Waste Management</i>	<u>3</u>
	21

Approved Electives

<i>At least 12 units of approved graduate courses</i>	<u>12</u>
<i>Minimum Total Units</i>	36

M.S. PROGRAM IN ENVIRONMENTAL ENGINEERING

Departmental Requirement

	Units
CE 996 <i>Project for the Degree of Master of Science</i>	<u>3</u>
	3

Environmental Engineering Graduate Course Requirements

CE 715	Open Channel Hydraulics	3
CE 722	Hydrology	3
CE 737	Environmental Chemistry & Microb. I	3
CE 739	Environmental Chemistry & Microb. II	3
CE 742	Water & Wastewater Treatment I	3
CE 743	Water & Wastewater Treatment II	3
CE 747	Analysis of Stream & Estuary Pollution	<u>3</u>
		21

Approved Graduate Electives

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

Required Additional Undergraduate Work for the MS in Environmental Engineering - Minimum background in science should include one year of chemistry and physics and, in mathematics should include basic courses in calculus and differential equations. In addition, a minimum of 15 credits of additional undergraduate makeup or prerequisite courses are required. Transfer credit for undergraduate and non-engineering graduate courses from other institutions will not normally be allowed. Individual programs will depend on previous preparation of student, and may be approved by a Department Committee. Students with a Bachelor's degree in engineering may have the requirements partially or fully waived.

REQUIREMENTS FOR THE DOCTOR OF PHILOSOPHY DEGREE

Students with exceptional scholastic ability may pursue a doctorate in environmental health science. For a doctorate in environmental health science, a master's degree in science is a prerequisite. Applicants with degrees in other fields may be admitted with deficiencies as evaluated by a departmental graduate advisor.

All doctoral students must complete a minimum of 90 units of work beyond the bachelor's degree. Minimum re-

quirements of formal course work (not including guided readings, seminars, projects and theses) are 48 beyond the bachelor's degree or 27 beyond the master's degree of which at least 18 must be completed at Polytechnic. Ph.D. students must select a major field and two minor fields in consultation with the advisors.

To qualify as Ph.D. candidates, students must pass written and oral qualifying examinations. Registration for a minimum of 30 units of dissertation research is required. Registration should be continuous, until the dissertation has been completed and accepted.

GRADUATE COURSES

GENERAL

CE 598-599 Special Topics in Civil Engineering 2½:0:3

Specialized current topics of interest of an interdisciplinary nature. Offered at irregular intervals. Advance announcements include course description and prerequisites.

CE 780 Analysis of Uncertainty in Civil Engineering 2½:0:3

Brief review of basic concepts including problem identification, definitions of statistical parameters and principles of probability. Applications utilizing techniques of frequency distribution, regression and correlation, time series analysis, significance testing, elementary decision theory, sensitivity and risk analysis, reliability assessments. All topics emphasize applications to civil engineering practice and research, and include problem solving in such areas as hydrology, structures geotechnical, transportation, and environmental engineering. Student specialty areas will be considered in selection of problems for study.

CE 781 Analysis of Public Works 2½:0:3

Methods for the identification, formulation, preliminary appraisal, and detailed analysis of individual projects and systems of civil engineering projects. Different approaches appropriate for gov-

ernment agencies, public utilities, industrial firms, and private entrepreneurs. Planning considers projects that satisfy single and multiple purposes and objectives, meet local and regional needs, and take advantage of opportunities for development. Financial and economic analyses, including sensitivity and risk analysis. Mathematical models for evaluation of alternatives and optimization. Impacts of projects: environmental, social, regional economic growth, legal and institutional, and public involvement. Also listed under MG 830.

CE 790 Fire Protection Engineering 2½:0:3

Overview of fire problems in the United States. Statistics, trends and fire experiences of interest to engineers. Chemistry and physics of fire phenomena, including ignition, flammability, heat transfer, products of combustion and modes of fire growth and extension. Properties and behavior of materials at elevated temperatures. Performance of structures exposed to fire and failure mode analysis. Laboratory and full-scale testing of construction materials, components, assemblies and structures. Building codes, fire codes and standards. Measures for fire protection: detection, alarm and communication systems and systems for fire suppression and smoke control.

CE 791 Infrastructure Systems Analysis 2½:0:3

Methodologies and procedures for macro-level analysis of engineered infrastructure systems. Introduction to computer-based techniques for optimization of design, operation and maintenance of infrastructure subsystems. Demographic, system loading and capacity analyses for water distribution, wastewater collection and disposal, solid wastes collection, street sweeping, snow removal and other municipal service systems. Infrastructure financing and capital budget process. Life cycle and benefit-cost analyses applied to infrastructure renewal. Prerequisite: CE 214 or equivalent.

ENGINEERING

CE 849 Environmental Geotechnology 2½:0:3

Chemical phase transfer. Acids and bases in soils. Chemical reactions in soils. Identification, clay mineralogy. Hydraulic conductivity, diffusion and unsaturated flow. Well hydraulics. Contaminant transport. Flow potentials. Seepage barriers. Bioremediation. *Prerequisites:* CE 223, CE 232.

ENVIRONMENTAL SCIENCE AND ENGINEERING

CE 598-599 Special Topics in Civil Engineering 2½:0:3

Specialized current topics of interest of an interdisciplinary nature. Offered at irregular intervals. Advance announcements include course description and prerequisites.

CE 737 Environmental Chemistry and Microbiology I 1:2:3

Introduction to the chemistry and microbiology of polluted and natural waters, including applications of principles developed.

CE 739 Environmental Chemistry and Microbiology H 1:2:3

Advanced topics in chemistry and microbiology of polluted and natural wastewater treatment.

CE 742 Water and Wastewater Treatment I 2½:0:3

Physical, chemical and biological principles involved in process design and treatment of water and wastewater. Topics include aeration, filtration, softening, chemical treatment, coagulation, flocculation, desalination, taste and odor control. *Co-Prerequisite:* CE 737.

CE 743 Water and Wastewater Treatment II 2½:0:3

Continuation of CE 742. Topics include sedimentation, adsorption, aerobic and anaerobic biological treatment, sludge treatment and disposal. *Co-Prerequisite:* CE 739.

CE 745 Water and Wastewater Treatment Laboratory 1:2:3

Laboratory processes in water and wastewater engineering, dealing with physical, chemical and biological methods and principles. Processes include disinfection, softening, sedimentation, oxygen transfer, coagulation, adsorption, filtration, aerobic and anaerobic biological treatment systems. Warburg analysis of waste. *Co-Prerequisite:* CE 743.

CE 746 Industrial Waste Treatment 2½:0:3

Sources of industrial wastewaters and their treatability by physical, chemical and biological processes. Problems and solutions involved in combining municipal and industrial waste treatment. Status of government regulations imposed on industries in prevention of water pollution.

CE 747 Analysis of Stream and Estuary Pollution 2½:0:3

Dispersal and decay of contaminants introduced into lakes, streams, estuaries, oceans. Effects of pollutants on chemical quality and ecology of receiving waters.

CE 748 Sanitary Engineering Design 1:2:3

Design of water supply and wastewater treatment systems. Topics of special interest. *Co-Prerequisite:* CE 743.

CE 751 Environmental Health Engineering 2½:0:3

Theory, methodology and instrumentation associated with environmental health. Topics include epidemiology, food vectors, radiation, pest control, heating, ventilation, noise, illumination, hazards of home and community environment, other subjects which affect public health.

CE 752 Air Pollution 2½:0:3

Causes and effects of air pollution. Methods of sampling. Interpretation of data. Meteorological aspects. Methods of air pollution control.

CE 753 Hazardous/Toxic Waste Management 2½:0:3

Methods in the management of hazardous/toxic waste sites. Topics covered include health and safety, legal aspects, contamination of the environment, treatment processes, toxicology and risk assessment.

CE 758 Air Pollution Engineering Control 2½:0:3

Pollutant emissions control; analysis of pollutant properties, concentrations and boundary conditions; absorptive, and reactive recovery processes for moving and stationary sources; formation and removal of gaseous oxides (NO, SO, CO, etc.) and of aerosols and other particulates. *Prerequisite:* Instructor's permission. Also listed under CH 752.

CE 767 Environmental Impact Evaluation 2½:0:3

An examination of legal and technical requirements in the preparation of environmental impact evaluations. Considerations include: legal and technical requirements, the procedure and the interdisciplinary nature of the analysis. Topics include overall impact evaluation, problem definition, quantification of impact, methods used in analysis, field evaluations, mitigations, hearing procedures and management. Practical examples and case studies are used.

CE 770 Solid Waste Management 2½:0:3

Engineering aspects of solid waste collection, transport and disposal, including incineration, sanitary landfill, composting, recovery and reutilization, economic evaluation of factors affecting selection of disposal methods.

CE 771-772 Special Topics in Environmental Engineering I, II 2½:0:3

Current topics including nitrification in natural and treated waters, hazardous and toxic wastes, organic removal from water supplies, water reuse, specialized aspects of biological wastewater treatment, environmental health, solids disposal, and modeling natural waters and

treatment systems. *Prerequisite:* permission of the instructor.

WATER RESOURCES ENGINEERING

Prerequisite for all courses: MA 104, CE 223

CE 712 Water Resources Projects 2½:0:3

Feasibility-level planning and design studies for water resources projects, including water conveyance works; concrete dams and associated waterways; pumping stations; hydroelectric, irrigation, navigation, and flood mitigation projects. Subjects considered include layouts, dimensions and capacity of facilities, hydraulic and structural forces, and stability analyses. *Co-Prerequisite:* CE 340 or CE 715, or permission of instructor.

CE 715 Open Channel Hydraulics 2½:0:3

Theory and computations for uniform flow, gradually varied flow, rapidly varied flow, unsteady flow in prismatic and non-prismatic channels.

CE 716 Applied Hydraulics 2½:0:3

Similarity, dimensional analysis and modeling techniques as applied to hydraulic systems. Pumping systems including hydraulic transients and flow of air, liquids, sludge. Cavitation. *Co-Prerequisite:* CE 340 or CE 715.

CE 722 Hydrology 2½:0:3

Hydrologic cycle. Meteorological considerations. Analyses of precipitation, runoff, unit hydrographs, flood routing and reservoir storage. Principles of groundwater hydrology. Introduction to frequency analysis of floods and droughts. *Prerequisite:* undergraduate degree in engineering or science.

CE 723 Groundwater Hydrology and Pollution 2½:0:3

Characteristics of confined and unconfined flow of water through porous media, groundwater and well hydraulics; quality of ground water; environmental

influences; groundwater pollution; management aspects of groundwater; and groundwater modeling. *Prerequisite:* CE 340 or instructor's permission.

CE 724 Advanced Groundwater Hydrology and Pollution 2½:0:3

Mass and heat transport in porous media. Unsaturated flow and transport. Numerical solutions of governing equations. Stochastic analysis. Groundwater quality monitoring and simulation. Wellhead protection, gas extraction systems, granular carbon absorbers, bioremediation. *Prerequisite:* CE 723 or equivalent.

CE 725 Water Resources Mathematical Modeling 2½:0:3

Studies of hydraulic, hydrologic, water quality and systems models as applied to rivers and streams, embankments, estuaries and basins. Review of basic equations of flow applicable to these models. Appropriate modeling techniques using computer-based solutions reviewed with emphasis on time-varying boundary conditions and problems of calibration and verification. One, two and three-dimensional models considered. Storm-water models and water resource systems modeling. *Prerequisite:* Course in computer programming and *Co-Prerequisite:* CE 715.

CE 726 Computer Applications in Water Resources 2½:0:3

Applications of commercial software in water resources planning and design. Class meets in a computer classroom and hands-on experience is offered. Examples include analysis of flood hydrographs, open channel flow, river hydraulics, pipe networks, watershed hydrology, storm water management, and groundwater flow and transport. *Prerequisite:* CE 340.

CE 728 Optimization Methods in Water Resources 2½:0:3

Advanced theory of mathematical programming and optimal control with applications in planning and operation of water resource systems. *Prerequisite:* CE 722 or equivalent.

CE 735-736 Special Topics in Water Resources and Hydraulic Engineering I, II 2½:3:0

Topics in water resources and hydraulic engineering such as hydroeconomic models; finite difference and finite element models; synthetic hydrology; conjunctive use of surface water and ground water; desalinized and recycled water; thermohydrologic and hydrometeorological problems; flushing of estuaries; hydrodynamics of oil pollution, sludge dumping, and sediment movement; environmental design of hydraulic structures: Problems of macro projects. *Prerequisite:* permission of instructor.

GUIDED READINGS, SEMINARS, PROJECTS AND THESES

Note: Students should obtain a copy of the University's "Regulations on Format, Duplication and Publication of Reports Theses and Dissertations" at the Office of Research and Graduate Affairs.

CE 901 Guided Readings in Civil Engineering 3 units

Individual study of selected literature in civil engineering under guidance of a faculty advisor. Acceptable written report or successful completion of examination required. Only one registration permitted, except with department head's approval. *Prerequisite:* Instructor's approval.

CE 952 Seminar in Civil Engineering nc

Lectures on recent developments in civil engineering given by representatives from industry, other research and education institutions, and Polytechnic graduate students and faculty.

CE 996 Project for Degree of Master of Science 3 units

Analytical, design or experimental studies in civil or environmental engineering under guidance of a faculty advisor, and following Department guidelines. Written report required. *Prerequisite: degree status and project advisor's approval.*

CE 997 Thesis for the Degree of Master of Science 3 units

Original investigation or design in the student's principal field of study prepared under close supervision of a faculty advisor. Candidates must successfully defend thesis orally. Registration for a minimum total of twelve (12) units required. Maximum of 12 units counted toward degree. Allowable registration per semester 3-12 units. *Prerequisite: degree status and thesis advisor's approval.*

CE 999 Dissertation for Degree of Doctor of Philosophy 6 units

Independent original investigation demonstrating creativity and scholarship worthy of publication in recognized engineering journals. Candidates must successfully defend their theses orally. Registration for minimum of 30 thesis units required prior to defense. Registration should be continuous. Preferred registration per semester, 6 units; allowable registration 1-18 units with approval of department head. *Prerequisites: degree status, completion of qualifying examinations and thesis advisor's approval.*

FACULTY

Ilan Juran, Professor of Civil Engineering, Head of Civil and Environmental Engineering Department. B.S.C.E. Technion (Israel); Ph.D., D.Sc. University of Paris VI, Ecole Nationale des Ponts et Chaussees *Geotechnical engineering, soil improvement technologies, geosynthesis engineering, in-situ soil testing*

Alvin S. Goodman, P.E., Professor of Civil Engineering B.C.E. CCNY; M.S.C.E. Columbia University; Ph.D. New York University *Comprehensive water resources planning; water supply studies; hydrologic estimates; systems analysis of water resources; groundwater mathematical models; conjunctive use of surface and ground water*

Shirley M. Motzkin, Professor of Biology B.S., Brooklyn College, A.M., Columbia University; Ph.D. New York University; *Environmental biology*

Alan H. Molof, Associate Professor of Environmental Engineering B.S.Ch.E. Bucknell University; M.S.E. (Ch.E.) M.S.E. (Sanitary Engineering) Ph.D. University of Michigan *Water and wastewater treatment processes; river and stream pollution; industrial waste treatment; hazardous/toxic waste management*

Matthew W. Stewart, P.E. Associate Professor of Civil Engineering B.C.E., M.C.E., Polytechnic Institute of Brooklyn; *Hydraulic design; fluid meters; water resources planning*

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

Angelos L. Protopapas, P.E. Assistant Professor of Civil Engineering Dipl. Eng. (C.E.), National Technical University of Athens (Greece), M.S. (Operations Research & Computer Sc), University of Athens (Greece) M.S.C.E., Ph.D., Massachusetts Institute of Technology *Surface and groundwater hydrology and pollution; water resources systems; urban hydrology; fluid mechanics; irrigation*

Chikashi Sato, Assistant Professor of Environmental Engineering B.S.Ch.E., Fukushima National College of Technology (Japan); M.S. (EHE), University of Kansas; Ph.D., University of Iowa *Water and wastewater treatment processes; transport of toxic chemicals in surface and groundwaters; water quality and ecological studies of water bodies and watersheds; environmental health engineering*

Theva S. Thevanayagan, Assistant Professor Civil Engineering B.S., Peradeniya University (Sri Lanka); M.S.C.E., Ph.D., Purdue University *Geotechnical Engineering; environmental geotechnology; numerical modelling of soils; physico-chemical behavior of soils; in-situ testing.*

ADJUNCT FACULTY

Raul R. Cardenas, Jr., Adjunct Professor of Environmental Engineering B.A., University of Texas; M.S., Ph.D., New York University

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

Mohammad Karamouz, P.E. Adjunct Professor of Civil Engineering B.S.C.E., Pahlavi University (Iran); M.S.C.E., George Washington University; Ph.D., Purdue University

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

Sidhartha Bagchi, P.E. Adjunct Associate Professor of Civil Engineering B.A., Calcutta University; B.E.C.E., Calcutta University; M.E.C.E., Calcutta University; Ph.D., Polytechnic Institute of New York

Rita Meyniger, Adjunct Associate Professor of Environmental Engineering B.S.C.E., Newark College of Engineering, M.S.C.E., New York University

William F. Graner, P.E. Adjunct Assistant Professor of Environmental Engineering B.S.C.E., Ph.D., Polytechnic Institute of New York; M.C.E., New York University;

Paul W. Grosser, P.E. Adjunct Assistant Professor of Civil Engineering B.E., M.E., Stevens Institute of Technology; Ph.D., Polytechnic Institute of New York

Agemmemnon Koutsospyros, Adjunct Assistant Professor of Environmental Engineering Dipl. E. Chem. Eng., National University of Athens (Greece); M.S.C.E., Ph.D., Polytechnic University

Zohreh Shahvar, Adjunct Assistant Professor of Civil Engineering B.S. (Agr. E.) University of Tehran (Iran); M.S. (Water Resources); Ph.D. (Agr. E.), Iowa State University

John T. Tanacredi, Adjunct Assistant Professor of Environmental Engineering B.S. Richmond College, M.S., Hunter College Ph.D., Polytechnic University

Michael J. Sakala, P.E. Lecturer in Civil Engineering B.S., Drexel University; M.S.C.E., Polytechnic Institute of New York

INFORMATION SYSTEMS ENGINEERING

The School of Electrical Engineering and Computer Science in conjunction with New York State's Center for Advanced Technology in Telecommunications (CATT) offers a Master of Science degree program in Information Systems Engineering.

Polytechnic started this masters degree program in 1987 with the express purpose of providing education for industry people faced with the challenges and opportunities of integrating computers and communication systems.

The development of the curriculum was sponsored by CATT at the Polytechnic University which continues to coordinate the program.

The program's development was supported by a private sector advisory board. The board's current functions are to

- (i) monitor the effectiveness of the program,
- (ii) help keep the detailed course syllabi current, and
- (iii) propose changes in the program in light of experience.

The philosophy of the program is to provide rigorous education in the component disciplines of computers and telecommunications with emphasis on the unified field of information systems engineering. The focus is the application of theoretical insights to practical problems. The program combines courses from electrical engineering, computer science, social science and management.

Students are experienced, working professionals in telecommunications or computing with two or more years of working experience.

Classes meet every other week, all day, Friday and Saturday, at Polytechnic's Westchester Graduate Center in Hawthorne, New York. Breakfast, lunch, and coffee breaks are provided. All classes are videotaped with the tapes made available for viewing on campus or at home.

An all-inclusive fee covers tuition and fees, text books and other educational material, special tutorials and lectures, meals on class days, and access to video tapes of all classes and lectures.

ADMISSION REQUIREMENTS AND APPLICATION INFORMATION

Admission to the program requires a bachelor's degree from an accredited institution with a superior undergraduate academic record and demonstrated proficiency in calculus, probability and a programming language. Furthermore, applicants must have a minimum of two years work experience in the field of telecommunications and/or computing and must have employer support.

Applications for admission are accepted throughout the year, but admission is for fall semesters only. Because enrollment is limited, early application is strongly recommended.

DEGREE REQUIREMENTS AND CURRICULUM

The general requirements for Master of Science Degree are stated elsewhere in this catalog.

The curriculum consists of 13 courses (39 academic units) which are offered in a structured program over a two-year period. There are no elective courses in this program.

The courses in the curriculum are:

FALL

First Semester

CS 613	<i>Computer Architecture</i>
EL 635	<i>Principles of Communications Networks</i>
CS 676	<i>Mathematical Techniques for Information Systems</i>

SPRING

Second Semester

CS 623	<i>Operating Systems</i>
EL 735	<i>Communication Networks</i>
CS 606	<i>Software Engineering</i>

FALL

Third Semester

EL 736	<i>Communications Networks II</i>
MG 820	<i>Project Management</i>
SS 907	<i>Human Factors in Information Systems</i>

SPRING

Fourth Semester

CS 630	<i>Input and Output Systems</i>
MG 654	<i>Economics of Information Systems</i>
CS 608	<i>Principles of Data Base Systems</i>

During the second year of study the student completes a project integrating his course experience.

CS 996	<i>Advanced Project in Computer Science</i>

COURSE DESCRIPTIONS

For course descriptions, refer to the appropriate other sections of this catalog (Management, Electrical Engineering, Computer Science).

CS 613 Computer Architecture I
3 units

EL 635 Principles of Communication Networks
3 units

CS 676 Mathematical Techniques for Information Systems
3 units

CS 623 Operating Systems I
3 units

EL 735 Communication Networks I

CS 606 Software Engineering I
3 units

EL 736 Communication Networks II
3 units

MG 820 Project Management
3 units

SS 907 Human Computer Interaction
3 units

CS 630 Input and Output Systems
3 units

MG 654 Economics of Information Systems
3 units

CS 608 Principles of Database Systems
3 units

CS 996 Advanced Project in Computer Science
3 units

FACULTY

Robert R. Boorstyn, Professor of Electrical Engineering and Computer Science; B.E.E., CCNY; M.S., Ph.D., Polytechnic Institute of Brooklyn
Telecommunications

Ivan T. Frisch, Professor of Electrical Engineering and Computer Science and Director of the Center for Advanced Technology in Telecommunications B.S. (Physics), Queens College; B.S., M.S., Ph.D. (Electrical Engineering), Columbia University
Information systems, computer networks and network control.

Melvin Klerer, Professor of Computer Science; B.A., M.S., Ph.D., New York University
Programming systems, languages and Artificial Intelligence.

Shivendra Panwar, Associate Professor of Electrical Engineering T. Tech., Indian Institute of Technology; M.S., Ph.D., University of Massachusetts
Communication networks.

Martin L. Shooman, Professor of Electrical Engineering and Computer Science; S.B., S.M., Massachusetts Institute of Technology; D.E.E., Polytechnic Institute of Brooklyn
Software engineering, reliability, fault-tolerant systems.

Richard Van Slyke, Professor of Electrical Engineering and Computer Science; B.S., Stanford University; Ph.D., University of California at Berkeley
Computer communications, telecommunications.

INDUSTRY PROFESSORS

Robert J. Flynn, Industry Professor of Computer Science
B.S. (Physics), Manhattan College; M.S. (Math), Ph.D. (Math), Polytechnic Institute of Brooklyn
Computer architecture and operating systems.

Barry Jones, Industry Professor of Electrical Engineering and Computer Science; B.S., Cooper Union; M.S., Marist College
Electromechanical systems, real-time computer systems

Nancy J. Needham, Industry Professor of Management
Academic Director, Telecommunications and Computing Management program
B.A., Wellesley College; M.B.A., D.B.A., Harvard University
International telecommunications and financial services.

ADJUNCT FACULTY

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

Charles J. Bontempo, Adjunct Professor of Computer Science
B.A., M.A., University of Maryland
Distributed Data Bases

Mon Song Chen, Adjunct Professor of Computer Science; B.S., National Taiwan University; M.S., University of Washington; Ph.D., Polytechnic University

E. Hart Rasmussen, Adjunct Professor of Management; Director, Management Programs, Westchester Center; B.S., M.S., Technical University of Denmark
Project management.

John C. Thomas, Adjunct Professor of Psychology; B.A., Case Western Reserve University; Ph.D., University of Michigan; *Human-machine interphases*

INDUSTRIAL ENGINEERING

The Department of Mechanical and Industrial Engineering offers programs in industrial engineering at the bachelor's, master's, engineer's, and doctor's level.

Industrial engineering deals with the analysis, design, and utilization of modern large-scale systems, ranging from completely automated processing plants through urban systems (transportation, justice and health care, for example) to managerial systems composed solely of human beings. It concerns itself with those areas in which the systems approach, engineering knowledge and analytical techniques are applied directly to the urgent problems of society.

As noted in a career statement by the Institute of Industrial Engineers, "Industrial engineers deal with people as well as things. They look at the 'big picture' of what makes society perform best--the right combination of human resources, natural resources, and man-made structures and equipment. Industrial engineers bridge the gap between management and operations, dealing with and motivating people as well as determining what tools should be used and how they should be used."

There are opportunities in many diverse areas. For example, industrial engineers are called upon to:

- Design quality into products and processes;
- Apply the principles of total quality management (TQM);
- Develop efficient work methods;
- Locate facilities and design plant layouts;
- Improve productivity and competitiveness;
- Schedule and manage projects;
- Use computers to simulate physical systems and processes;
- Apply their knowledge in manufacturing and service industries, including finance, health care, logistics, and construction.

Industrial engineers seek to allocate limited resources in an optimal manner.

A unifying theme focusing this body of knowledge and methods into a coherent entity is the systems point of view. The search for similarity among concepts, laws and models of different disciplines, the emphasis on the adaptation, integration and exploitation of existing techniques in areas other than their fields of origin, and, above all, a unique point of view dealing with relationships rather than with components -- these characterize industrial engineering. Industrial engineers are thus in a strategic position to bring about the best integration of people, materials, machines, time and money in any endeavor.

These techniques are applied in a very wide range of organizations. There are industrial engineers in banks, hospitals, government, transportation and communications, construction, social service, facilities design, manufacturing, warehousing, and information processing.

Many industrial engineers move from the analysis and design of productive systems to the administration of those systems. While engineering and management are different fields, both require the ability to make decisions based on valid information. Industrial engineers are especially trained to obtain and evaluate such information.

LABORATORIES AND COMPUTING FACILITIES

Departmental laboratories include computational and physical laboratories. The computational laboratory includes a network of PS/2 Model 70's, and an RT Network using CAEDS; this equipment was provided as part of the IBM CIM Alliance. The physical laboratories include CNC machines, two industrial robots, a controls and robotics laboratory,

and research facilities in flexible structures.

The laboratories are used in the work methods, simulation, manufacturing processes, robotics applications, and human factors undergraduate courses. They are also available for graduate research.

The undergraduate student learns to use computer aided drafting in a basic required course (ME101), and later uses that knowledge to design a fracture toughness sample and produce it on CNC machines in the required manufacturing processes course (IE340).

The undergraduate also uses such tools as ProModel, SimFactory, Xcell+ in the Simulation Lab associated with the required Systems Simulation course (IE380).

The senior design course (IE389-390) has focused on practical applications in industrial environments, including an IBM production line and an automated library.

In the manufacturing area within the department, laboratory facilities are available for process and work flow methods, including applications of the LabView software to intelligent KanBan; activity-based costing; quality control and design of experiments using ATT QC Tool Kit, RS-Discover, and other programs; computer aided engineering using CADAM and CAEDS.

For students interested in materials, courses in materials and metallurgy can be reinforced with a project using the laboratories in metallurgy and materials science. These labs include complete mechanical testing, optical and electron microscopy facilities, fabrication, welding and heat treating equipment.

Students may also take electives and select projects focusing on the service industries. The New York metropolitan area is the center of finance, banking, telecommunications, and other services. Polytechnic's IE Program interacts with its neighbors in Metrotech and in other areas of the region.

UNDERGRADUATE PROGRAM

The undergraduate program leads to the degree of bachelor of science in industrial engineering. The program is accredited by the Accreditation Board of Engineering and Technology (ABET).

The undergraduate program requires 136 credit-hours of work, including mathematics, chemistry, physics, humanities, social science, required departmental courses, and technical and free electives. The humanities, technical and free electives permit a flexible program of study in which students have the opportunity to pursue individual interests that build on the core requirements.

While all engineers work primarily toward the creation of better products, industrial engineers are also concerned with the economic and human effects of changing technology. The undergraduate curriculum therefore provides an introduction to economics and psychology in addition to a strong background in the engineering, mathematics and physical sciences. In addition, the industrial engineering courses emphasize applications of these disciplines in industry, government, and service functions such as banking, health care, and education.

SENIOR PROJECT

An important part of the program is the capstone senior design project course. In the senior year, students tackle a real-life problem under the guidance of a faculty advisor. The problems may be provided by industry or other outside sources, and may have a practicing industrial engineer as co-advisor. Oral and written reports help prepare the students for similar activities required in their professional lives.

GRADUATE COURSES

Graduate courses may be taken as electives by qualified juniors and seniors with at least B average, who obtain their advisor's approval. If the total number of credits exceeds those required for bachelor's degree, these graduate credits may be applied toward a graduate degree in accordance with current Polytechnic policy, if the student is admitted to graduate study.

TRANSFER STUDENTS

Transfer students who have completed two years of study at a college of liberal arts and science or a community college, may ordinarily complete requirements for bachelors' degrees in two additional years of study. Assuming that a student has completed 64 credits equivalent to MA 101-104, PH 104-106, PH 115-116, CM 101-102, CM 111-112, CS 200, HU 101, HU 200, SS 104, SS 189, SS250, plus 16 credits of acceptable courses, the student can complete the requirements specified in this document.

PART-TIME AND EVENING STUDY

Students may take less than a full load in one or more semesters. However, when constructing a program for part-time study, students must be aware that prerequisites must always be satisfied. Proper sequencing of courses is therefore very important. Required undergraduate courses are given in only one semester per year. See the full-time program below for an indication of the semester in which a course is given.

There is no evening program for the BS(IE). Part-time students must recognize the need to take courses in daytime hours.

REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE IN INDUSTRIAL ENGINEERING

The requirements for the BS(IE) are shown on the next page.

They are summarized as follows:

		Credits
Mathematics:	MA101, MA102, MA103, MA104, MA223, MA224	20
Science:	CM104, CM102, CM111, CM112, CS200, PH104, PH105, PH106, PH115, PH116	19
Humanities:	HU101, HU110, HU200, SS104, SS189, SS250	18
Engineering:	ME101, ME111, ME321, MT305	12

Other:	MG304, SL101	3
Major:	IE300, IE306, IE311, IE319, IE321, IE327, IE328, IE340, IE380, IE389, IE390	31
Electives:	Chosen by student in consultation with department advisor	33
		136

For detailed information on humanities and social sciences requirements, consult the catalog section on "Humanities and Social Sciences Requirements for Engineering and Computer Science Majors."

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

FRESHMAN YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.
First Semester				
MA 101	Calculus I	4	0	4
CM 101	Gen. Chemistry I	2½	0	2½
CM 111	Gen. Chem. Lab. I	0	1½	½
CS 200	Programming Methods (Pascal)	3	0	3
HU 101	Writing & Hum. I	3	0	3
SS 104	Contemporary World History	3	0	3
SL 101	Freshman Seminar	1	1	0
				16

Second Semester				
MA 102	Calculus II	4	0	4
CM 102	Gen. Chemistry II	2½	0	2½
CM 112	Gen. Chem. Lab. II	0	1½	½
PH 104	Intro. Physics I	3	0	3
HU 200	Writing & Hum. II	3	0	3
SS 189	Intro. to Psychology	3	0	3
				16

SOPHOMORE YEAR

First Semester

MA 104	Appl. Diff. Eqns.	3	0	3
PH 105	Intro. Physics II	3½	0	3½
PH 115	Physics Lab. I	0	1½	½
ME 101	Graphics	1	3	2
ME 111	Mechanics I	3	0	3
SS 250	Basic Economics	3	0	3
HU 110	Report Writing	3	0	3
				18

Second Semester

MA 103	Calculus III	3	0	3
PH 106	Intro. Physics III	2½	0	2½
PH 116	Physics Lab. II	0	1½	½
ME 121	Mech. of Materials	3	0	3
MG 304	Acct. Fundamentals	3	0	3
	Elective (Eng.)	3	0	3
	Elective (HU/SS)	3	0	3
				18

JUNIOR YEAR

First Semester

MA 223	Intro. to Probability	3	0	3
IE 300	Eng. Economy	3	0	3
IE 306	Work Design and Measurement	2½	1½	3
IE 327	Ops. Research I	3	0	3
MT 305	Mech. Prop. of Mils.	3	0	3
	Elective (Free)	3	0	3
				18

Second Semester

MA 224	Intro. to Math Stats.	3	0	3
IE 340	Manuf. Processes	2½	1½	3
IE 328	Ops. Research II	3	0	3
	Elective (IE)	3	0	3
EE 370	Principles of Electrical Engineering	3	0	3
EE 374	Instrumentation Laboratory	0	3	3
				16

SENIOR YEAR

First Semester

IE 311	Quality Control and Quality Management	3	0	3
IE 319	Prod. Plng. & Cntl.	3	0	3
IE 380	System Simulation	2	3	3
IE 389	Project Lab. I	1	3	2
	Elective (I.E.)	3	0	3
	Elective (Hum./SS)	3	0	3
				17

Second Semester

IE 321	Facil. Plng. & Design	3	0	3
IE 390	Project Lab. II	1	3	2
	Elective (I.E.)	3	0	3
	Elective (Free)	3	0	3
	Elective (Tech.)	3	0	3
	Elective (Hum./SS)	3	0	3
				17

* Students may substitute IS140-141 for SS104 and HU200. The 33 credits of electives, all requiring advisor's approval, are to be distributed as follows:

- 12 credits of industrial engineering courses
- 6 credits of engineering courses selected from below (excess credits count as technical electives):
 - CS236 Switching Circuits & Digital Design
 - ME112 Mechanics II
 - ME201 Thermodynamics
- 3 credits of technical electives - engineering or science
- 9 credits of humanities and social sciences (at least 6 credits of which must form a Hum./SS sequence); consult catalog section "Humanities & Social Science Electives for Engineering & Computer Science Management" for details.
- 3 credits of free electives

ROTC: juniors and seniors may substitute three of the following two credit courses: MS301, 303, 401 or 403 for six credits of technical and/or free electives.

MANUFACTURING ENGINEERING CONCENTRATION

The industrial engineering profession originally dealt mostly with manufacturing. Over the years, industrial engineers have enlarged their expertise to include much wider ranges of applications, from hospital management to banking information systems. As a consequence industrial engineering education de-emphasized manufacturing engineering.

Today, manufacturing enterprises must operate with greater efficiency and precision to compete in international markets. To help American industry, Polytechnic has developed a concentration to emphasize manufacturing in its industrial engineering program.

The manufacturing engineering concentration is designed to educate students in productivity, computer-aided design and computer-aided manufacturing (CAD/CAM), robotics, factory automation and computer-integrated manufacturing (CIM).

All courses required for the standard degree are also required in the manufacturing engineering concentration.

The 33 credits of electives must include:

Industrial Engineering:

IE 342 Robotics Applications

Technical Elective:

ME 331 Computational Methods

Free Elective:

ME 332 Solid Modeling

Qualified students in the manufacturing concentration are also encouraged to include IE788 in their program.

GRADUATE STUDIES

The department offers graduate programs in industrial engineering leading to degrees of master of science, engineer, and doctor of philosophy.

Students may specialize in manufacturing systems, system simulation, quality control, man-machine systems, production engineering, production and inventory models, reliability and maintainability, among other areas. Certificate programs are available for more limited graduate studies in specialized topics.

Graduate students come from many engineering fields. Many professionals in Industrial Engineering receive the major part of their training at the graduate level. Common to all our students is the desire to develop techniques for problem-solving and decision-making in a technical world.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE

The general Polytechnic requirements for master of science degree are stated in this catalog under "Degree Requirements." Detailed requirements for this degree are shown below.

Admission to the master of science program requires a bachelor's degree in an engineering discipline from an accredited institution, with a superior under-

graduate academic record. A student not meeting these requirements is considered for admission on an individual basis, and may be admitted subject to the completion of appropriate undergraduate courses to remove deficiencies.

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.

The requirements for the MS(IE) are identified in four groups, plus a computer literacy prerequisite. Courses in Group B may be waived if equivalent courses were taken previously. In such cases, additional Group D courses may be taken.

All students must have a Program of Study (POS) on file, which describes the approved plan of study for the degree.

Prerequisite

Knowledge of computer programming in a high level language, such as FORTRAN, Pascal, BASIC or PL/I, is assumed. Students without this knowledge must take CS 531 or CS 532 without credit.

Group A: Basic Required Courses

(no more than nine graduate units are allowed for courses in this category; all courses in this category must be satisfied).

IE 600	Engineering Economy
IE 606	Work Design & Measurement
IE 627	Operations Research: Deterministic Models
IE 628	Operations Research: Stochastic Models
MA 561	Elements of Probability
MA 562	Statistics

Group B: Required Courses 12 units

IE 611	Quality Control and Improvement
IE 619	Production Planning & Control
IE 621	Facility Planning & Design
IE 680	Discrete System Simulation

Group C: Major Electives 12 units

Select four of the groups shown below, and take at least one course from each of the four groups. In some cases, a course may have a prerequisite which must also be satisfied.

Group C1

IE 682	Factory Simulation
IE 785	Computer Integrated Manufacturing Systems

Group C2

IE 612	Quality Engineering Using Robust Design
IE 685	System Reliability

Group C3

IE 618	Inventory Models
IE 620	Project Planning and Control

Group C4

IE 770	Employee Scheduling
IE 776	Manufacturing Resource Planning
IE 778	Advanced Production Planning

Group C5

IE 645	Productivity Management
IE 788	Manufacturing Systems Engineering
IE 792	Design for Manufacturability

Group C6

IE 631	Linear Programming
IE 650	Queuing Systems I
MA 552	Regression & ANOVA

Group D: Other Relevant Electives

	3-12 units
Minimum total:	36 units

REQUIREMENTS FOR THE ENGINEER DEGREE

The degree of engineer in industrial engineering is a professional degree intended for persons who desire to advance their professional development and training beyond the master's level without the original research required of doctoral students. General requirements for the engineer degree are stated in this catalog under "Degree Requirements." Detailed requirements for this degree are given here.

Admission to the engineer degree program requires possession of a master's degree substantially equivalent to the Polytechnic M.S. in I.E., including all of the group A and B courses, none of which may be counted towards the Engineer's degree. The engineer degree requires a minimum of 72 units beyond the bachelor's degree, including at least 6 units of a design project. On completion of the design project, the candidate will be required to make a final oral presentation before a faculty committee. The project may be waived by the guidance committee for profes-

sionally mature candidates who have previously completed work in their major areas judged to be of exceptional caliber, and for those students who have completed suitable master's theses or projects.

The General Requirements for the Engineer Degree are:

MS level work 36 Units
(Includes all Groups A and B courses, with credit allowed for no more than nine units in Group A)

Two of the following: 6 units

IE 998	Project (unless waived) 6-12 Units
IE 612	Quality Control Using Robust Design
IE 777	Manufacturing Improvement Curves
IE 778	Advanced Production Planning
IE 779	Advanced Work Systems Design

Two of the following: 6 units

IE 631	Linear Programming
IE 632	Nonlinear Programming
IE 650	Queuing Systems II

Two of the following: 6 units

IE 682	Factory Simulation
IE 788	Manufacturing Systems Engineering
IE 792	Design for Manufacturability (DFM)

Electives approved by advisor

	6-12 units
Minimum Total	72 units

Studies for the Engineer Degree must be completed within a three year period after the MS degree or the date of admission, whichever is later, unless there is a formal leave of absence approved prior to the period for which the studies are interrupted.

REQUIREMENTS FOR THE DOCTOR OF PHILOSOPHY DEGREE

The department offers a program leading to the degree of doctor of philosophy in operations research and industrial engineering.

The Ph.D. is a research oriented degree. The student's dissertation is expected to represent an original piece of research advancing the state-of-the-art in the field. Current research areas of the faculty include manufacturing methods, modeling of production systems, human resources development, telecommunications, health care, mathematical programming, and stochastic systems.

Applicants generally must have a master's degree, with a GPA of at least 3.5, from an accredited institution in an area of mathematics, science, engineering, or quantitatively oriented social science.

The general Polytechnic requirements for doctor of philosophy degrees are stated in this catalog under Degree Requirements. Specific requirements for the doctoral program may be found in the department's doctoral student's manual.

Entrance to doctoral candidacy is contingent on passing the qualifying examination. This consists of the Part I preliminary written examination, and the Part II major field written examination; an oral examination may also be required.

The doctoral program requires a minimum of 90 units beyond the bachelor's degree, including a minimum of 24 units of dissertation. No more than 30 units of dissertation may be counted in the minimum total.

The course work for the Ph.D. must include all the course work necessary to satisfy the M.S.(OR) or M.S.(IE).

During the Ph.D. studies, the student must register for IE 920 at least once per academic year.

After passing the written qualifying examination, the candidate selects a thesis advisor and prepares a formal proposal for the dissertation research. A thesis committee is then appointed to judge the merits of the proposed research. After approval of this proposal, the doctoral candidate registers for research. On completion of the dissertation, the candidate must pass an examination in his/her defense. Dissertation grades of U in two consecutive terms will be cause to reconsider whether the student will be permitted to continue doctoral work.

CERTIFICATE PROGRAMS

The department offers certificate programs designed for the professional with work experience. A certificate program requires five courses, which are selected in accordance with the needs of

the individual. Applicants for a certificate program must hold a bachelor's degree. On completion of the sequence with a B average or better, the student is issued a certificate. Students who later are admitted to study for a master's degree are usually able to apply all certificate courses toward the master's degree.

If a student has taken the equivalent of any required courses as an undergraduate, or more than one as a graduate student, then substitute courses must be selected in consultation with the advisor. Additional information may be obtained from the department.

The certificate programs are shown below. Additional certificates are shown in the Operation Research section of this catalog.

Basic Industrial Engineering:

IE 600	<i>Engineering Economy</i>
IE 606	<i>Work Design & Measurement</i>
IE 627	<i>Operations Research: Deterministic Models</i>
MA 561	<i>Elements of Probability</i>
MA 562	<i>Statistics</i>

Advanced Industrial Engineering:

IE 611	<i>Quality Control & Improvement</i>
IE 619	<i>Production Planning & Control</i>
IE 621	<i>Facility Planning & Design</i>
IE 628	<i>Operations Research: Stochastic Models</i>
<i>one of the following:</i>	
IE 778	<i>Advanced Production Planning</i>
IE 779	<i>Advanced Work System Design</i>

Quality Control & Reliability:

MA 561	<i>Probability</i>
MA 562	<i>Statistics</i>
IE 611	<i>Quality Control and Improvement</i>
IE 612	<i>Quality Engineering Using Robust Design</i>
IE 685	<i>System Reliability</i>

Production & Inventory Control:

IE 627	<i>Operations Research: Deterministic Models</i>
IE 618	<i>Inventory Models</i>
IE 619	<i>Production Planning & Control</i>
IE 776	<i>Manufacturing Resource Planning</i>
<i>one of the following:</i>	
IE 680	<i>Discrete System Simulation</i>
IE 778	<i>Advanced Production Planning</i>

UNDERGRADUATE COURSES

NOTE: JUNIOR OR SENIOR STANDING IS REQUIRED FOR ALL UNDERGRADUATE IE COURSES.

IE 300 Engineering Economy 3:0:3

Economic and financial consideration in engineering decisions. Decision criteria under certainty, risk, uncertainty. Cost concepts, financial calculations, capital sources, accounting data, depreciation. Comparison of alternatives by annual cost, present worth and discounted cash flow methods. Minimum cost and maximum profit determination, replacement and economic life, breakeven analysis, effect of taxes, intangible factors. *Prerequisite: junior standing.*

IE 306 Work Design and Measurement 2½:1½:3

Principles and techniques of designing work methods and work simplification programs. Theory and techniques of work measurement, including time study, work sampling and standard data systems. Laboratory sessions in methods analysis, rating, work allowances and stopwatch time study. *Prerequisite: junior standing.*

IE 311 Quality Control and Quality Management 3:0:3

Introduction to the concepts of the cost of quality, quality assurance, quality process control, and total quality management. Emphasis on process management and control. Control charts and their use: the concept of "out of control"; charts based upon variables and charts based upon attributes. Specifications and tolerances. Acceptance sampling by lots, including the concepts of producers and consumers risks. Course project required. *Prerequisite: MA224 or permission of instructor.*

IE 319 Production Planning and Control 3:0:3

Analytical techniques for designing and operating production systems. Assembly-line balancing, job sequencing, inventory control, project planning with PERT and CPM. Applications of linear programming algorithms to shop loading and production scheduling of single and multiple products. *Prerequisite: IE 327.*

IE 320 Project Planning and Control* 3:0:3

Network planning techniques for project management and resource allocation. Emphasis on PERT, CPM, and probabilistic generalized network. Heuristic models for multi-project scheduling and resource leveling. Other topics include network development, computer adaptation, progress reports and project monitoring. *Prerequisite: CS200 or equivalent, and junior standing.*

IE 321 Facility Planning and Design 3:0:3

Development of quantitative models for analysis of facility layout and location problems. Solutions by both mathematical optimization and heuristic algorithms. Locations of single and multiple facilities in existing and new layout design. Other topics include computerized layout planning, materials handling systems, evaluation and improvement of facility productivity. *Prerequisites: IE 306 and IE 327.*

IE 327 Operations Research I 3:0:3

Development of mathematical models for solving decision problems of deterministic nature. Classical optimization, Lagrange multipliers, linear programming, transportation method, network procedures, games. Dynamic programming. *Prerequisite: MA 103 and junior standing.*

IE 328 Operation Research II 3:0:3

Mathematical models for solving decision problems of stochastic nature. Queuing, Markov processes, Inventory models, reliability, probabilistic dynamic programming. *Prerequisites: IE 327 and MA 223.*

IE 340 Manufacturing Processes 2½:1½:3

Properties of materials relating to fabrication methods. Casting. Metal cutting mechanics, cutting fluids, thermal and vibrational aspects of machining. Machinability criteria. Deformation processing, hot and cold, mechanics of deformation. Joining and welding. Unconventional processing. Electrochemical and electrodischarge machining. Numerical control. Metrology. *Prerequisites: MT 305 and junior standing. Also listed under MT 340*

IE 342 Robotics Applications* 2½:1½:3

Applied robotics and integration of robots into manufacturing processes. The course will cover robotic work space design and selection of robot types to suit each phase of industrial engineering. Laboratory experiments will include construction and use of robots and scaled models. Plant visits, field trips and case studies. *Prerequisite: Junior standing.*

IE 346 Operational Design of Public Systems* 3:0:3

Description, analysis and optimization of public systems. Population, economy, resource allocation, land use, transportation networks and facility location. Case studies of pollution control, criminal justice system, library management, fire fighting strategies and public health. *Prerequisites: IE 327 and IE 328.*

IE 350 Logistics* 3:0:3

Analysis of logistic problems and procedures applied to inventory control, materials handling systems, packaging, warehousing, transportation, facility location, information/communications, and customer service. Cost trade-offs between the various components in optimization of the total logistic system. Logistics systems design and productivity measures. Business and military cases and applications. *Prerequisite: IE 328.*

IE 365 Human Factors in Engineering Design* 2½:1½:3

Study of research techniques that yield information important in man-machine systems design. Man's learning, prob-

lem-solving, physiological and information processing capacities; performance under various environmental conditions. *Prerequisite: SS 189 and junior standing.*

IE 375 Industrial Safety Engineering* 3:0:3

Analysis and design of industrial accident prevention, control and management systems. Effect of OSHA, Workmen's Compensation and environmental factors in implementing safety programs. Project work involves safety inspection, detection and control of hazards. *Prerequisite: junior standing.*

IE 376 Manufacturing Resource Planning* 3:0:3

Quantitative models for analysis of production and inventory management systems. Topics covered include bill of material structures, time-phased parts requirements, shop loading and capacity constraints, priority planning and control, and schedule regeneration. Development of computer-based MRP systems. *Prerequisites: IE 319, or permission of instructor, and knowledge of computer programming.*

IE 380 Systems Simulation 2:3:3

Modeling and simulation of discrete stochastic systems, including random variables and statistical phenomena. Use of simulations languages; introduction to PC-based simulation software packages. Students develop, code, run, and experiment with several simulation models. *Prerequisite: MA 224 and knowledge of computer programming.*

IE 389-390 Project Laboratory I, II
IE 389 1:3:2
IE 390 Credit as Arranged

IE 390 credit as arranged. Independent project combining elements of theory, experimentation, design and construction used to learn methods of approach, design of experiments, modeling, validation and utilization of results which are common to undertaking of project development. Student-faculty seminars discuss individual projects to encourage students exchange of ideas and methods, and to enhance each student's abilities in oral and written communication in engi-

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neering endeavors. *Prerequisite: senior standing.*

IE 391-392 Selected Topics 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 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 advisor, instructor, and department chairman.*

IE 396 Industrial Engineering Internship* credit arranged

Supervised, creative engineering experience of at least two months' duration culminating in written and oral report presented to industrial and faculty supervisors. Faculty visits and conferences during internship. Arrangements to be made prior to beginning internship experience. *Prerequisite: completion of junior year and departmental approval.*

IE 399 Senior Honors Work credit arranged

Independent work undertaken by qualified honors students in industrial engineering or operations research under faculty guidance. *Prerequisites: senior standing and advisor approval.*

GRADUATE COURSES

IE 600 Engineering Economy 2½:0:3

Economic and financial consideration in engineering decisions. Decision criteria under certainty, risk, uncertainty. Cost concepts, financial calculations, capital sources, accounting data, depreciation. Comparison of alternatives by annual cost, present worth and discounted cash flow methods. Minimum cost and maximum profit determination, replacement

and economic life, breakeven analysis, effect of taxes, intangible factors. (Not open to students who have taken IE 300)

IE 606 Work Design and Measurement 2:1:3

Principles and techniques of designing work methods and work simplification programs. Theory and techniques of work measurement, including time study, work sampling and standard data systems. Laboratory sessions in methods analysis, rating, work allowances and time study. (Not open to students who have taken IE 306.)

IE 611 Quality Control and Improvement 2½:0:3

Review of the concepts of the cost of quality, quality assurance, quality process control, and total quality management. Emphasis on process and product design changes to improve quality and on process management and control. Control charts and their use: the concept of "out of control"; charts based upon variables and charts based on attributes. Specifications and tolerances. Acceptance sampling by lots, including concepts of producer's and consumer's risks. Course projects required. (Not open to students who have taken IE 311) *Prerequisite: MA 562; Also listed as MN 611.*

IE 612 Quality Engineering Using Robust Design 2½:0:3

The design approach practiced by G. Taguchi. Fundamental principles of robust design and quality loss are developed. Design of experiment techniques based on orthogonal arrays are developed in detail. Applications of these procedures in design of products and processes and to on-line troubleshooting are illustrated through cases ranging from optimization of wave-soldering to banking. *Prerequisite: IE 611. Also listed under MN 612*

IE 618 Inventory Models* 2½:0:3

Study of inventory systems. Deterministic and probabilistic models. Fixed versus variable reorder intervals. Dynamic and multistage models. Statistical forecasting of demands and lead times. Control of dynamic inventory systems with lead times. *Prerequisites: MA 561 and either IE 627 or IE 631.*

IE 619 Production Planning and Control 2½:0:3

Analytical techniques for designing and operating production systems. Assembly-line balancing, job sequencing, inventory control, project planning with PERT and CPM. Applications of linear programming algorithms to shop loading and production scheduling of single and multiple products. (Not open to students who have taken IE 319.) *Prerequisite: IE 627 or IE 631.*

IE 620 Project Planning and Control 2½:0:3

Network planning techniques for project management and resource allocation. Emphasis on PERT, CPM, and probabilistic generalized network. Heuristic models for multi-project scheduling and resource leveling. Other topics include network development, computer adaptation, progress reports and project monitoring. (Not open to students who have taken IE 320.) *Prerequisite: knowledge of computer programming. Also listed under MG 810 and CE 828.*

IE 621 Facility Planning and Design* 2½:0:3

Development of quantitative models for analysis of facility layout and location problems. Solutions by both mathematical optimization and heuristic algorithms. Locations of single and multiple facilities in existing and new layout design. Other topics include computerized layout planning, materials handling systems, evaluation and improvement of facility productivity. (Not open to students who have taken IE 321.) *Prerequisites: IE 606 or permission of instructor and either IE 627 or IE 631.*

IE 627 Operations Research: Deterministic Models 2½:0:3

Development of mathematical models 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.*

**IE 628 Operation Research:
Stochastic Models** 3:0:3

Mathematical models for solving decision problems of stochastic nature. Queuing, Markov processes, inventory models, reliability, probabilistic dynamic programming. IE 628 and IE 627 constitute standard one-year survey course in operations research. (Not open to students who have taken IE 328 or equivalent.) *Prerequisite: MA 561.*

IE 631 Linear Programming 2½:0:3

Theory and application of linear programming techniques. Simplex and revised simplex algorithms. Duality theory, dual simplex method, postoptimality analysis. Degeneracy. Transportation and assignment problems. Applications, problem formulation, computer solutions. *Prerequisite: MA 153.* Also listed under MA 813.

IE 632 Nonlinear Programming* 2½:0:3

Optimization of nonlinear functions. Classical methods. Constraints and Lagrangian methods. Kuhn-Tucker theory. Duality and economic interpretation. Separable programming, feasible directions, gradient projection. Quadratic and convex programming. Industrial and engineering applications. *Prerequisite: IE 631.* Also listed under MA 818.

IE 642 Robotics Applications* 2:1:3

Applied robotics and integration of robots into manufacturing processes. The course will cover robotic work space design, selection of robot types to suit each phase of industrial engineering, flexible manufacturing and work cells. Laboratory experiments will include construction and use of robots and scaled models, plant visits, case studies. (Not open to students who have taken IE 342)

IE 645 Productivity Management 2½:0:3

Modern approaches to productivity measurement, evaluation, planning and improvement in both manufacturing and

service industries. Participants will develop productivity models for various types of organizations. Also listed under MG 645.

IE 650 Queuing Systems I 2½:0:3

Development of elements of queuing and loss theory. Single and multiple servers, Markovian and non-Markovian arrival and service time distributions, various queue disciplines. Applications to inventory control, maintenance, transportation, communication. Model building and basic solution techniques stressed rather than formal theoretical development. *Prerequisite: MA 561.*

IE 680 Discrete System Simulation 2½:0:3

Modeling and simulation of discrete stochastic systems. Generation of pseudo-random numbers, variates from discrete, continuous, theoretical and empirical distributions. Use of SIMSCRIPT, introduction to other languages. Students program, code and run several simulation models. (Not open to students who have taken IE 380.) *Prerequisite: Knowledge of computer programming and IE 608 or equivalent.*

IE 682 Factory Simulation* 2½:0:3

Modeling and simulation of complex industrial, commercial, and service systems, such as factories and hospitals. Students develop, run and experiment with several simulation models using different software packages. *Prerequisites: knowledge of computer programming and MA 561 or equivalent.*

IE 685 System Reliability* 2½:0:3

Structural reliability, redundancy, bounds on reliability of complex systems. Repairable systems: Markov models, maintainability and availability. Optimization of spare parts inventories, inspection intervals and replacement times. Failure models: accumulated shocks and stress-strength-time, Marginal failures, dependent failures. *Prerequisite: EL 531 or MA 561 or equivalent.* Also listed under EL 617.

IE 754 Logistics* 2½:0:3

Analysis of logistic problems and procedures applied to inventory control, materials handling systems, packaging, warehousing, transportation, facility location, information/communications, and customer service. Cost tradeoffs between the various components in optimization of the total logistic system. Logistics systems design and productivity measures. Business and military cases and applications. (Not open to students who have taken IE 350.) *Prerequisite: IE 627 and IE 628, or instructor's permission.* Also listed under TR 754.

**IE 757 Technology Transfer to
Developing Countries*** 2½:0:3

Mechanisms of technology transfer. Ecological, social and economic factors in technology selection and utilization. Local efforts to adapt technology to local needs. National and international means to stimulate or block technology transfer. Technology and political influence. Case studies of technology transfer to newly industrializing countries. Also listed under SS 675.

**IE 765 Human Factors in
Engineering Design*** 2:1:3

Study of research techniques that yield information important in man-machine systems design. Man's learning, problem-solving, physiological and information processing capacities, performance under various environmental conditions. (Not open to students who have taken IE 365.) *Prerequisite: SS 189, or permission of instructor.*

IE 770 Employee Scheduling* 2½:0:3

Study of employee scheduling, issues, problems and methods. Students develop, analyze, and solve a variety of problems on days-off scheduling, work tours, integration of work week, scheduling part-time employees, rest periods and vacations using available software. Project work includes determining staffing requirements. Case examples from service and manufacturing industries. Also listed as MG 619

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IE 775 Industrial Safety Engineering* 2½:0:3

Analysis and design of industrial accident prevention, control and management systems. Effect of OSHA, Workmen's Compensation and environmental factors in implementing safety programs. Project work involves safety inspection, detection and control of hazards. (Not open to students who have taken IE 375.)

IE 776 Manufacturing Resource Planning* 2½:0:3

Quantitative models for analysis of production and inventory management systems. Topics covered include bill of material structures, time-phased parts requirements, shop loading and capacity constraints, priority planning and control, and schedule regeneration. Development of computer-based MRP systems. (Not open to students who have taken IE 376.) *Prerequisites:* IE 619, or instructor's permission, knowledge of computer programming.

IE 785 Computer Integrated Manufacturing Systems (CIMS) 2½:0:3

Introduction to the basic concepts of manufacturing complex products with complex processes. This type of manufacturing implies a strong use of and reliance on computer and data processing technologies. All aspects relative to product and process: planning, design, manufacturing and shipping will be addressed from a variety of perspectives. Elements of the production system and interfaces between these elements will be defined. Methods and techniques for studying, managing, and optimizing manufacturing and engineering productivity will be explored. Also listed as MN 785

IE 788 Manufacturing Systems Engineering 2½:0:3

Contemporary techniques for product design and manufacturing. Financials of the manufacturing firm, quality and reliability, Taguchi's methods for design of products and processes, scale-up and partitioning, design of experiments, characterization of manufacturing flows, and descriptions of modern manufacturing methods such as JIT/TQC, pull and synchronized manufacturing. Cultural factors associated with the introduction of these new techniques. Financial and performance metrics are developed for each new process. Applications are illustrated by case studies of successes and disasters. Also listed as MN 788

IE 792 Design for Manufacturability (DFM) 2½:0:3

Concepts and techniques involved in designing products so that they can be economically manufactured, functionally sound and of high quality. Technical guidelines for utilizing several manufacturing processes effectively, managerial and organizational approaches and case studies of products that were successfully designed or redesigned for easy manufacture. Particular attention is given to designing for easy assembly, both robotics and manual, and to the effective use of plastics to reduce the cost of manufactured products. Students are given some simple projects so that they can experience the procedure first hand. Also listed as MN 792

IE 911-912 Selected Topics in IE & OR 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 Seminar in IE & OR 1:0:NC

Examination of selected advanced topics at research frontiers of department's graduate program areas. Presentations by graduate students, faculty, visiting scientists. *Prerequisite:* candidacy status for a graduate degree or permission of the course coordinator.

IE 930-931 Readings in Industrial Engineering I, II each 3 units

Individual reading of selected papers and current literature in specialized area of study, guided by faculty member. *Prerequisite:* approval of advisor, instructor and department head.

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. *Prerequisite:* degree status and approval of supervising professor, advisor and department head.

IE 998 Project for Degree of Engineer each 3 units

Post-master's investigating of significant problem, utilizing modern techniques of analysis and design. Project to be selected and developed in consultation with faculty member. Written report required, after which student is examined orally. Six units must be accumulated. *Prerequisites:* degree status and supervising professor's approval.

IE 999 Dissertation for Degree of Doctor of Philosophy each 3 units

Doctoral dissertation must give evidence and embody results of extended research in specific field of industrial engineering, constituting original contribution. Candidate required to take oral examination on subject of thesis and on related topics. Minimum of 24 units required. *Prerequisite:* completion of qualifying examination and guidance committee's approval.

The following graduate courses are offered irregularly in response to student demand:

- IE 633 Integer Programming
- IE 634 Dynamic Programming
- IE 635 Advanced Linear Programming
- IE 636 Network Flows and Application
- IE 651 Queuing Systems II
- IE 720 Optimum Seeking Methods
- IE 727 Case Studies in Industrial Engineering and Operations Research
- IE 777 Manufacturing Improvement Curves
- IE 778 Advanced Production Planning
- IE 779 Advanced Work Systems
- IE 846 Urban Systems Analysis
- IE 851 Stochastic Processes
- IE 870 Games and Decisions

FACULTY

William R. McShane, P.E., Professor of Industrial and System Engineering; Head, Department of Mechanical and Industrial Engineering; Director, Transportation Training and Research Center. B.E.E., Manhattan College, M.S., Ph.D., Polytechnic Institute of Brooklyn; Professional Engineer (N.Y., Cal. (Traffic)).
Quality control, controls and simulation, engineering economics, laboratory development.

Walter Helly, Professor of Operations Research
B.A., Cornell University; M.S., University of Illinois; Ph.D., Massachusetts Institute of Technology
Stochastic modeling, telecommunications and vehicular traffic, urban systems.

Charles W. Hoover, Jr., Professor of Manufacturing Engineering
B.E.M.E., Yale University; B.S.E.E., Massachusetts Institute of Technology; M.S., Ph.D., Yale University.
Physical Design; manufacturing processes; electronic device assembly.

Charles A. Kelly, Industry Professor of Manufacturing and Industrial Engineering
B.S., Syracuse University; M.S., University of Detroit
Work methods, design of manufacturing systems, computer aided engineering.

Joachim I. Weindling, P.E., Professor of Operations Research and System Engineering and Director of Operation Research Program
B.M.E., City College of New York; M.S., Ph.D., Columbia University; Professional Engineer (N.Y., P.A.)
Mathematical programming, optimum design, economic evaluation.

Ravinder Nanda, Associate Professor of Industrial Engineering and Operations Management
B.Sc., Banaras Hindu University (India); M.S., Ph.D., University of Illinois
Production and operations planning, productivity analysis, project control.

ADJUNCT FACULTY

Robert T. Farley, Adjunct Lecturer
B.A., Physics, LaSalle University, Philadelphia
Quality control and quality management

David Friedman, Adjunct Professor
B.S., Johns Hopkins; M.S., Ph.D., Georgia Tech

Cal Oltrogge, Adjunct Professor
B.A., University of California at Los Angeles; M.A., Stanford; Ph.D., New York University
Thermal management of manufacturing systems

John Thomas, Adjunct Associate Professor
B.A., University of Michigan; M.B.A., University of Rochester
Thermal management of manufacturing systems

John S. Zuk, Adjunct Lecturer in Industrial and Manufacturing Engineering; B.M.E., Union College; M.S. (IE), Polytechnic University
Thermal management of manufacturing systems

MANUFACTURING ENGINEERING

Polytechnic has a strong commitment to manufacturing engineering including an M.S. program and diverse programs leading to undergraduate concentrations in manufacturing.

In recent years, much has been written and said about the growing inability to compete of U.S. industry. As markets have become more global, and manufacturing operations have moved off-shore, many manufacturing jobs have been lost in the United States and the trade deficit has grown large. In response, many new approaches for improving competitiveness have been introduced. These include technologies such as automation, robotics and CIM (Computer Integrated Manufacturing), new methods for production such as JIT/TQC, "Pull", and cycle-time accounting, and many new methods for design of products and processes.

It is now clear that there is no single panacea. Manufacturing Engineers must become adept at recognizing opportunities for productivity improvement and be able to choose and apply appropriate sets of these new methods. Hence, education and training of the engineering workforce is the key.

Polytechnic's new comprehensive program in manufacturing engineering focuses this array of new techniques and technologies and directly addresses the needs of industry. It draws upon Polytechnic's long-term, well-established strengths in Engineering, Science, and Management. The program is interdisciplinary and is designed for working professionals who have responsibilities in manufacturing and for those who plan to enter manufacturing after completing the Masters Program.

THE M.S. IN MANUFACTURING ENGINEERING

The M.S. in Manufacturing Engineering can be taken by full-time students in Brooklyn and by part-time students on both the Brooklyn and Westchester Campuses. We also plan to offer the program to full-time students on the Westchester Campus in the future.

Ph.D. level work in manufacturing can be pursued in the industrial engineering or mechanical engineering programs.

Students are drawn from a wide variety of manufacturing firms, large and small. Representative firms include ARKO, Standard Motor Products, Pfizer Pharmaceutical, IBM, Loral, Medical Labs Automation, Guild Molders, John Brown and Company, and AT&T Bell Labs.

The program emphasizes the following topics:

- **Design** - because 70% of product cost is committed in design.
- **Quality engineering** - because profitability and competitiveness rest on quality.
- **New manufacturing methods** - such as JIT/TQC, and synchronous manufacturing.
- **Leadership** - in introducing new methods of work that require cultural change.
- **New management accounting methods** - such as Activity-Based Costing.

The approach embodied in this program is intended to:

- Empower the engineer to build from the bottom up.
- Utilize cooperative programs with industry to provide experience in design and production.

- Provide hands-on experience in the use of software for design and simulation.
- Develop and demonstrate applications using our CIM test bed.

Students graduating from this program will be equipped with working knowledge of advanced methods and techniques in manufacturing that are in use throughout the world. They will have sufficient knowledge and hands-on experience to enable them to contribute significantly to their employer's programs for improved productivity and to provide leadership that such programs require. They will be well positioned to advance their own careers.

UNDERGRADUATE CONCENTRATION IN MANUFACTURING

All undergraduate engineering programs at Polytechnic are accredited by ABET. The programs in industrial engineering, metallurgical engineering, and mechanical engineering explicitly allow students to use their electives to form concentrations in manufacturing.

DESIRABLE BACKGROUNDS FOR GRADUATE STUDENTS

The program is of interest to engineers, scientists, and managers responsible for manufacturing process design and operations and all engineers who design for manufacture.

Admission to this graduate program is open to those holding an accredited engineering degree (BS or BE), and to graduates in Physics, Chemistry, Materials Science, and the Biological Sciences.

International students with equivalent

backgrounds are eligible to participate in the program.

REQUIREMENTS FOR THE M.S. (MANUFACTURING ENGINEERING) DEGREE

The degree program requires 36 units, typically made up of eleven courses and a master's report. Some students may take twelve courses and not do a master's report. Credit may be granted for up to three relevant graduate-level courses (9 units) completed elsewhere with a grade of B or better.

Prerequisite Knowledge (Courses or equivalent knowledge):

Probability and Statistics
(MA562 or equivalent)

Engineering Economy
(IE600 or equivalent)

Computer Aided Graphics
(ME101 or equivalent)

Deterministic Models in OR
(IE627 or equivalent)

Up to six units of graduate courses in this category of prerequisite knowledge can be counted for degree credit as electives, although the electives needed for the student's concentration must also be satisfied.

Required:

Core Courses: 15 Units

MN 788	<i>Manufacturing Systems Engineering</i>
MN 785	<i>Computer Integrated Manufacturing Systems</i>
MN 792	<i>Design for Manufacturability (DFM)</i>
MN 618	<i>Introducing New Methods: Leading Change</i>
IE 611	<i>Quality Control and Improvement</i>

Other Courses: 21 Units

Students are encouraged to organize their electives into "concentrations" within manufacturing engineering. Illustrative concentrations are shown below. Students are also encouraged to take a three or six unit MS report (MN996-997) by using

elective credits, in addition to the minimum report effort required. A course in environmental engineering should be considered as part of the MS studies.

Illustrative Concentrations:

Product Realization Concentration (choose three or more)

MN 612	<i>Quality Engineering Using Robust Design</i>
IE 620	<i>Project Planning and Control</i>
MN 794	<i>Physical Design</i>
MN 796	<i>Affordable Automation</i>

Production Concentration (choose three or more)

IE 682	<i>Factory Simulation</i>
MN 612	<i>Quality Engineering Using Robust Design</i>
MN 776	<i>Manufacturing Resources Planning (MRP)</i>
MN 622	<i>Manufacturing Strategies</i>

Electronics Devices Concentration (choose three or more)

MN 612	<i>Quality Engineering Using Robust Design</i>
MN 802	<i>Thermal Design of Electronics Systems for Performance and Reliability</i>
MN 804	<i>Thermal Issues in Manufacturing Processes</i>
MT 707	<i>Thin Film Technology</i>
MT 709	<i>Integrated Circuits (VLSI) Fabrication Techniques</i>

Other concentrations may be constructed by the student and the advisor, suited to the student's needs and interests.

LABORATORY AND PROJECT WORK

Students may use the laboratory facilities at Polytechnic in their master's report work or in special courses focused on such tools. Consult the academic advisor to arrange for a special offering if needed.

MASTER'S REPORT

The M.S. Report is usually 3 units. It may be expanded to 6 units by use of MN997 as an elective.

The M.S. Report shall be done in an industrial lab setting whenever possible,

with the cooperation of employers and program sponsors.

Part-time students may draw upon their work to provide appropriate master's reports or theses. Full-time students may also work on projects in industry whenever this can be arranged but may also work on theoretical or experimental research projects at Polytechnic. In all cases, a faculty advisor will be assigned. Oral presentations of the project/thesis proposal are required at the start of the work. A written report and an oral presentation are required upon completion of the project.

LABORATORY FACILITIES AT POLYTECHNIC

The laboratories related to the Manufacturing Engineering Program include departmental computational and physical laboratories. The computational laboratory includes a network of PS/2 Model 70's, and a network of RT computers using CAEDS; this equipment was provided as part of the IBM CIM Alliance. The physical laboratories include scale CNC machines, two industrial robots, a controls and robotics laboratory, and research facilities in flexible structures and in thermal sciences.

The laboratory and project activities associated with Manufacturing include:

Simulation Laboratory, using such tools as ProModel, SimFactory, Xcell+, and other tools;

Design for Manufacturability Project, using DFM software to study and evaluate designs, such as vehicle subsystems (a recent project with Ford Motor Company);

Process and Work Flow Methods, including applications of LabView; for efficient real time data collection and closed loop control;

Controls and Robotics Laboratory, including EDI applications, control of CNC machines, control of flexible structures, and repair robots for space structures;

Sensors and Actuators Laboratory, established in conjunction with the M.E. Program's focus on smart sensors and on process control. The emphasis is on data acquisition in CIM environment;

Students may also develop projects around the concepts of activity-based costing or MRP; quality control or design of experiments using ATT QC Tool Kit, RS-Discover, and other tools; computer aided engineering using CADAM, and other tools.

For students interested in materials, a course sequence in materials and metallurgy can be reinforced with a project using the laboratories in metallurgy and materials science. These labs include complete mechanical testing, optical and electron microscopy facilities, fabrication, welding and heat treating equipment.

GRADUATE COURSES

The courses with MN designations are shown below, followed by a set of courses from other programs which are commonly taken by Manufacturing Engineering students.

MN 611 Quality Control and Improvement 2½:0:3

Review of the concepts of the cost of quality, quality assurance, quality process control, and total quality management. Emphasis on process and product design changes to improve quality and on process management and control. Control charts and their use: the concept of "out of control"; charts based upon variables and charts based on attributes. Specifications and tolerances. Acceptance sampling by lots, including concepts of producer's and consumer's risks. A course project is required. *Prerequisite: Probability and Statistics.* Also listed as IE 611.

MN 612 Quality Engineering Using Robust Design 2½:0:3

Fundamental principles of robust design and quality loss are developed. Design of experiment techniques based on orthogonal arrays are developed in detail. Applications of these procedures in design of products and processes and to on-line troubleshooting are illustrated through cases ranging from optimization of wave-soldering to banking. The design approach practiced by G. Taguchi.

Prerequisite: IE 611. Also listed as IE 612.

MN 618 Introducing New Methods: Leading Change 2½:0:3

Successful introduction of new methods of work embodied in new production paradigms such as JIT/TQC and "pull", computer-mediated work, the end-to-end Product Realization Process, and new methods of design, require management and workers to change long-established ways of working. This course provides students with insight into human issues in evolving corporate settings. The impact of culture on new product development and product realization are described. Cultural factors in the introduction of computer-mediated work are described. Leadership, education and training techniques appropriate to the new environment are studied. Also listed as MG 618.

MN 622 Manufacturing Strategies 2½:0:3

Strategies, tools, processes and techniques for improving the profitability and competitiveness of modern manufacturing businesses. Emphasis is on developing the proper interrelationship between manufacturing processes, systems and organization structure for a business to prosper through a process of ongoing improvement. Students will develop unique business strategies, including actions, changes in systems and structure to accomplish the chosen strategy. Also listed as MG869.

MN 785 Computer Integrated Manufacturing Systems (CIMS) 2½:0:3

Introduction to the basic concepts of manufacturing complex products with complex processes. This type of manufacturing implies a strong use of and reliance on computer and data processing technologies. All aspects relative to product and process: planning, design, manufacturing and shipping will be addressed from a variety of perspectives. Elements of the production system and interfaces between these elements will be defined. Methods and techniques for studying, managing, and optimizing manufacturing and engineering produc-

tivity will be explored. Also listed as IE 785.

MN 788 Manufacturing Systems Engineering 2½:0:3

Contemporary techniques for product design and manufacturing. Financials of the manufacturing firm, quality and reliability, Taguchi's methods for design of products and processes, scale-up and partitioning, design of experiments, characterization of manufacturing flows, and descriptions of modern manufacturing methods such as JIT/TQC, pull and synchronized manufacturing. Cultural factors associated with the introduction of these new techniques. Financial and performance metrics are developed for each new process. Applications are illustrated by case studies of successes and disasters. Also listed as IE 788.

MN 792 Design for Manufacturability (DFM) 2½:0:3

Concepts and techniques involved in designing products so that they can be economically manufactured, functionally sound and of high quality. Technical guidelines for utilizing several manufacturing processes effectively, managerial and organizational approaches and case studies of products that were successfully designed or redesigned for easy manufacture. Particular attention is given to designing for easy assembly, both robotic and manual, and to the effective use of plastics to reduce the cost of manufactured products. Students are given some simple projects so that they can experience the procedure first hand. Also listed as IE 792.

MN 794 Physical Design of Products 2½:0:3

Structured design approaches and how to use them to produce superior product designs. Dimensioning, tolerancing and metrology. Applications of partitioning, finite element analysis, heat transfer, and Monte Carlo studies to set standards and define performance windows. Choice of materials and human factors including ergonomics and aesthetics. Manufacturability studies including environmental stress testing and the effects of vibration, transportation, and so forth. Governmental regulations.

MN 796 Affordable Automation ½:0:3

Practical approaches currently available for constructing flexible automatic production equipment using inexpensive modular components which are commercially available. Equipment for inspection, sorting, transportation, assembly and processing can be assembled by using these off-the shelf components including programmable controllers, personal computers and programs. During the course, several such devices will be made by the students and similar apparatus in use in industry will be observed.

MN 798 Electronic Data Interchange (EDI) 2½:0:3

Impact of EDI on business functions. EDI management and technical issues. Standards, structure and technical issues for networking and communications. Measuring EDI costs and benefits. Case studies of key EDI application areas.

MN 802 Thermal Design of Electronics Systems for Performance and Reliability 2½:0:3

Thermal modeling and simulation of electronic equipment and systems, forced and natural air cooling, cooling with water and other liquids, cryogenic cooling, use of cooling correlations, approximate numerical formulations, fan characteristics, fan and disc acoustic noise, chip thermal profiles, thermal influence on the reliability of semiconductor circuits. Also listed as ME 717.

MN 804 Thermal Issues in Manufacturing Processes 2½:0:3

Thermal modeling and simulation of manufacturing and materials processing, thermally driven processes, dip coating, thin films, soldering, laser welding and cutting, heat removal from processes generating parasitic heat, thermal management of machining. Also listed as ME 718.

MN 911-912 Selected Topics in Manufacturing Engineering I-II 3 units

Areas not covered in other courses. Specific topics vary according to the instructor, who may be a visiting professor. Topics and prerequisites will be announced during the term prior to the offering.

MN 930-931 Readings in Manufacturing Engineering I-II 3 units

Individual reading of selected papers and current literature in specialized area of study, guided by faculty member. The topic must be beyond the scope of regularly offered courses. The topic must be agreed upon by the student and advisor prior to registration. A written report on the topic is required. *Prerequisite: approval of advisor, instructor, and department head.*

MN 996 M.S. Report I 3 units

Independent project demonstrating professional maturity and graduate-level knowledge completed under guidance of departmental advisor. Experimental work, software development, extensive analysis are commonly expected. Report must include results in one or more of these areas and a critical analysis and interpretation of pertinent literature and should represent worthwhile contribution to the field. Written report (unbound) is required.

MN 997 M.S. Report II 3 units

With the approval of the graduate advisor, some students may undertake a six credit MS report. This should be planned in advance, during the registration for MN996. In such cases, MN997 is used for the second half of the registration. A grade of "S" or "U" is awarded in MN996 in these cases, and the letter grade given in MN997 applies to all six units. *Prerequisite: Advisor's approval.*

IE 619 Production Planning and Control 2½:0:3

Analytical techniques for designing and operating production systems. Assembly-line balancing, job sequencing, in-

ventory control, project planning with PERT and CPM. Applications of linear programming algorithms to shop loading and production scheduling of single and multiple products. (Not open to students who have taken IE 319). *Prerequisite: IE 627 or IE 631.*

IE 620 Project Planning and Control 2½:0:3

Network-planning techniques for project management and resource allocation. Emphasis on PERT, CPM and other probabilistic generalized networks. Heuristic models for multi-project scheduling and resource leveling. Other topics include network development, computer adaptation, project reports and project monitoring. (Not open to students who have taken IE 320.) *Prerequisite: knowledge of computer programming.*

IE 621 Facility Planning and Design 2½:0:3

Development of qualitative models for analysis of facility layout and location problems. Solutions by both mathematical optimization and heuristic algorithms. Location of single and multiple facilities in existing and new layout design. Other topics include computerized layout planning, materials handling systems, evaluation and improvement of facility productivity. (Not open to students who have taken IE 321.) *Prerequisites: IE 606 or permission of instructor and either IE 627 or IE 631.*

IE 645 Productivity Management 2½:0:3

Modern approaches to productivity measurement, evaluation, planning and improvement in both manufacturing and service industries. Participants will develop productivity models for various types of organizations. Also listed as MG 645.

IE 682 Factory Simulation 2½:0:3

Modelling and simulation of complex industrial, commercial and service systems, such as factories and hospitals. Students develop, run, and experiment with several simulation models using different software packages. *Prerequisite: knowledge of computer programming.*

IE 776 Manufacturing Resource Planning 2½:0:3

Quantitative models for analysis of production and inventory management systems. Topics covered include bill of materials structures, time-phased parts requirements, shop loading and capacity constraints, priority planning and control, and schedule regeneration. Development of computer-based MRP systems.

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 709 - Integrated Circuit (VLSI) Fabrication Techniques 3:0:3

Study of process technology used to produce integrated circuits. Silicon technology: bipolar, MOS, and VLSI processes. Process requirements defined in terms of circuit structure, i.e., concentration profiles and topographical layout as defined by mask set previously determined. Steps from crystal growth through diffusion, ion implantation, oxidation, photolithography, metallization, interconnection, and packaging to final test are analyzed. The impact of process on design rules are pointed out.

OTHER GRADUATE COURSES RELATED TO MANUFACTURING

The manufacturing engineering orientation of several engineering programs is described in this section.

INDUSTRIAL ENGINEERING

Manufacturing is one of the natural application areas of industrial engineers, and the entire curriculum can be considered as oriented to this.

The department's highest priority of laboratory growth relates to production and assembly and affordable automation.

Illustrative courses in industrial engineering related to manufacturing engineering include the following (in addition to those listed above):

- Work Design and Measurement
- Productivity Management
- Industrial Safety Engineering

Appropriate focus in manufacturing can also be provided at the graduate level by thesis work.

MECHANICAL ENGINEERING

Mechanical Engineering is, by its nature, involved in the design and implementation of man-made systems - machines, vehicles, tools, spacecraft and reactor vessels. It logically extends to the manufacturing of these systems.

At Polytechnic, mechanical engineering undergraduates have a strong background in manufacturing through such courses as:

- Finite Element Analysis
- Thermal Design
- Synthesis of Mechanical Systems
- Analysis/Design of Machine Elements
- Computer Graphics in CAD

Appropriate focus in manufacturing can also be provided at the graduate level by course selection and by theses and dissertation work.

CHEMICAL ENGINEERING

Chemical engineers are involved in the manufacture of a wide variety of materials ranging from semiconductors and plastics to pharmaceuticals and chemicals. Chemical engineering courses which could relate to manufacturing include the following:

- Fundamentals of Biochemical Engineering
- Chemical Processes
- Kinematics I and II
- Polymer Processing
- Environmental Engineering

METALLURGY AND MATERIALS SCIENCE

The Department of Metallurgy and Materials Science is the operation most directly concerned with the materials and

techniques of manufacturing. It has the most significant interest in such special programs as electronic materials fabrication.

Existing courses of direct relevance to manufacturing include:

- Mechanical Metallurgy
- Fabrication Technology
- Process Metallurgy
- Metallurgical Failure Analysis
- Ceramic Refractory Materials
- Materials Selection
- Welding Metallurgy
- Powder Metallurgy
- Mechanical Behavior of Materials
- Engineering Materials

Courses in semiconductor technology are also cross-listed with electrical engineering.

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

The manufacturing aspects of EE/CS have to do with the control, communications, and computer applications of the manufacturing process. A wide range of courses in computer systems, signal processing, systems theory, control theory, computer graphics, artificial intelligence, data base systems, distributed processing, VLSI design, and software reliability are thus directly relevant.

The following courses illustrate the subjects available:

- Semiconductor Technology
- Systems Reliability
- VLSI Systems Design and Fabrication
- Computer Architecture
- Software Design and Engineering
- Data-base Management Systems
- Microprocessors
- Data Communications Networks
- Computer Graphics and Image Processing
- Interactive Computer Graphics
- Artificial Intelligence
- Pattern Recognition

These encompass both graduate and undergraduate offerings.

FACULTY

The faculty for the Polytechnic M.S. Program in Manufacturing Engineering includes persons from both academia and industry. Each faculty member brings to the program some unique background experience and training applicable to the course of study. Suitable industrial experience weighed as heavily as proper academic credentials in the faculty selection process. For example, Prof. Hoover was formerly Executive Director of Interconnection Technology and Power Systems at AT&T-Bell Labs. Prof. Bralla was Vice President, Operations for Alpha Metals and is Editor of McGraw-Hill's Handbook of Product Design for Manufacturing. Prof. Sutphen was Vice President, Operations of the Dresser Pump Division of Worthington Corporation.

Charles W. Hoover, Jr., Industry Professor and Director of the Manufacturing Engineering Program.
B.E., Yale University; B.S., MIT; M.S. and Ph.D., Yale
Manufacturing systems engineering and physical design.

James G. Bralla, Industry Professor.
P.E.; B.S.M.E., Princeton University
Design for manufacturability and manufacturing processes.

Charles A. Kelly, Professor of Manufacturing and Industrial Engineering.
B.S., Syracuse University;
M.S., University of Detroit
Work methods, design of manufacturing systems, computer aided engineering

George C. Vradis, Assistant Professor of Mechanical Engineering.
Dipl. ME National Technical University (Greece); M.S., Ph.D. Polytechnic University.
Fluid/thermal studies, unsteady flows, energy transfer.

William R. McShane, P.E., Professor of Industrial and System Engineering; Head, Department of Mechanical and Industrial Engineering; Director, Transportation Training and Research Center.
B.E.E., Manhattan College;

M.S., Ph.D., Polytechnic Institute of Brooklyn; Professional Engineer (N.Y., Cal. [Traffic]).
Quality control, controls and simulation, engineering economics, laboratory development.

Walter Helly, Professor of Operations Research
B.A., Cornell University; M.S., University of Illinois; Ph.D., Massachusetts Institute of Technology.
Stochastic modeling, telecommunications and vehicular traffic, urban systems.

Joachim I. Weindling, P.E., Professor of Operations Research and System Engineering and Director of Operation Research Program
B.M.E., City College of New York.
M.S., Ph.D., Columbia University;
Professional Engineer (N.Y., P.A.)
Mathematical programming, optimum design, economic evaluation

Ravinder Nanda, Associate Professor of Industrial Engineering and Operations Management.
B.Sc., Banaras Hindu University (India);
M.S., Ph.D., University of Illinois.
Production and operations planning; productivity analysis and control.

Irving B. Cadoff, Professor of Materials Science
B.M.E., City College of New York;
M.M.E., D.Eng.Sc., New York University.
Electronic materials; liquid metal embrittlement, thin film epitaxy.

Sunil Kumar, Assistant Professor of Mechanical Engineering
B. Tech., Indian Institute of Technology; M.A., M.S., State University of New York, Ph.D., University of California at Berkeley.
Thermal management of manufacturing systems.

M. Karim Moallemi, Assistant Professor of Mechanical Engineering
B.S.M.E., Pahlavi University (Iran); M.S.M.E., Ph.D., Purdue University.
Thermal analysis and design, thermal testing and evaluation and thermal aspects of materials processing and manufacturing systems.

Anthony Tzes, Assistant Professor of Mechanical Engineering.
B.S.M.E., University of Patras (Greece); M.S., Ph.D., Ohio State.
Robotics, automation and expert control.

Terance Kinsky, Instructor of Mechanical Engineering.
B.S.M.E., University of Maryland
Engineering graphics, computer aided engineering, manufacturing applications.

ADJUNCT FACULTY

David Friedman, Adjunct Professor
B.S., Johns Hopkins; M.S., Ph.D., Georgia Tech.

Cal Oltrogge, Adjunct Professor.
B.A., University of California at Los Angeles; M.A., Stanford; Ph.D., New York University.
Change management, work design, personnel research, retraining and resource balancing.

Subramani Rajaram, Adjunct Professor.
B.E., Bangalore University (India); M.A.Sc., University of Waterloo (Canada); Ph.D., State University of New York at Buffalo.
Heat transfer and thermal design.

Duncan D. Sutphen, Adjunct Professor
B.A., Princeton. Formerly Vice President, Operations, Dresser Pump Division of Worthington Corporation.
Manufacturing operations and manufacturing strategies.

Ronald Tartaro, Adjunct Associate Professor.
B.S., M.S., Columbia University.
Robust design and quality control.

John Thomas, Adjunct Associate Professor.
B.A., University of Michigan; M.B.A., University of Rochester.
Production control and manufacturing resources planning.

John Zuk, Adjunct Lecturer.
B.S., Union College; M.S., Polytechnic University.
Modeling of manufacturing systems, computer simulation and robotics.

MATERIALS SCIENCE AND ENGINEERING (METALLURGY)

Materials scientists are specialists in the most effective utilization of metals, alloys, ceramics, semiconductors, composites, plastics and polymers. Their expertise is vital to the solution of problems arising from the intensive quest for superior materials in our rapidly advancing technological age.

During the last three decades, we have witnessed increasing demands for ultra-high strength corrosion and heat resistant alloys, such as alloy steels, tungsten, titanium, beryllium, and molybdenum as well as nonmetallic epoxy-carbon composites. In electronics, we have witnessed tremendous growth in the use of silicon and other semiconductor materials for integrated circuits. Yet we have utilized only a fraction of the theoretical potentials of materials.

Challenges remain for imaginative individuals to probe, understand, process, fabricate and use effectively metallic materials, semiconductors and composites in fields ranging from electronic devices and integrated circuits to new energy production processes and aerospace applications.

MATERIALS SCIENCE

It is estimated that nearly 40% of all engineering RESEARCH is in the area of materials science, which is defined as the study of the interrelation among atomic structure, crystal structure, microstructure and properties of materials. The fundamental principles, which involve basic physics and chemistry, are universally applied to metals, ceramics, polymers, semiconductors and composites. With this understanding it is possible to "tailor make" materials requiring specific properties for particular applications. The instrumentation used to characterize the materials and the processes used to fabricate them share a common basis.

ENGINEERING METALLURGY

Traditionally, the study of structure-property relationships was the specialty of the physical metallurgist. As result of this history there exists a strong emphasis in metals in the materials science curriculum and a student may elect to pursue a major in this discipline.

Engineering applications of metallic materials directly reflect on the electronic, aerospace, energy and chemical production and transportation industries. Metallurgical engineers play vital roles in materials selection and process optimization. They have thorough knowledge of existing metallic materials, their properties and limitations. Borrowing fundamental knowledge from physical metallurgy, they constantly search for new and better materials to improve processes and products.

Some areas in which metallurgical engineers work are prevention of corrosion and environmental degradation, welding processes for alloys and composites, failure analysis, product reliability and safety, quality control, materials characterization and alloy development.

Furthermore, metallurgists may work in research and development, plant operations or do consulting. Metallurgists contribute to progress in oceanography, medical prosthetics, dental materials, environmental protection and electronic devices.

PROGRAMS OF STUDY

Bachelor of Science in Material
Science & Engineering

Master of Science

- *Metallurgical Engineering*
- *Materials Science*

Engineer

- *Metallurgical Engineering*

Ph.D.

- *Materials Science*

UNDERGRADUATE PROGRAM

The program for full-time study is designed to establish a firm base from which the graduate may proceed along any avenue of professional development from graduate study and research to industrial employment. Scientific understanding and utilization of basic concepts - rather than dependence on purely factual knowledge - are the Department's aim, providing the capability to solve present problems and the ability to keep pace with technological advancements and to be able to solve the increasingly complex problems of the future.

Specifically, the curriculum consists of 39 credits in mathematics, physics and chemistry; 24 credits in the humanities and social sciences; 53 credits in engineering science, materials sciences, engineering design and systems; 9 credits of technical electives; 3 credits of free electives; and 8 credits of thesis.

During their junior and senior years students have the flexibility of 12 credits of electives which may be used to focus on a minor area of interest or to broaden their education scope. They should

consult with their department advisor for guidance in selecting appropriate technical electives.

Students may (with advisor's approval) elect to substitute for thesis MT 496-497 (6 credits) applied computer courses: AM 331 Devices and Computational Methods in Computer-Aided Design (3 credits) and AM 332 Computer Graphics in Computer-Aided Design (3 credits).

Humanities and social science requirements for all engineering students are given in the section entitled "Degree Requirements".

Freshman and sophomore years of metallurgical engineering curricula may be taken on the Long Island Campus. Junior and senior metallurgy courses are offered only on the Brooklyn Campus. Any non-metallurgy courses listed in the last two years may also be taken at the Long Island Campus, provided they are offered.

GRADUATE PROGRAMS

The Department of Metallurgy and Materials Science prepares students for the degrees of Master of Science in materials science or metallurgical engineering, the degree of Engineer, and the degree of Doctor of Philosophy in materials science. The courses of study and research leading to these degrees are designed for students holding baccalaureate degrees in metallurgy or materials science. Students holding baccalaureate degrees in related disciplines are admitted and may be required to remove undergraduate deficiencies, if any.

Both fundamental and applied research are carried on within the Department. Excellent facilities are available for work in electron microscopy, x-ray diffraction, deformation and fracture and other fields. Fundamental research is carried out on alloy hardening, deformation and fracture, phase transformations, thermomechanical working, ternary diffusion and rapid solidification. In applied research, the Department is involved in studies of materials for aerospace, electronic applications and energy related applications. The rules governing admittance to graduate studies are applicable to all students.

Typical Course of Study for the Bachelor of Science Degree in Materials Science & Engineering

FRESHMAN YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.
<i>First Semester</i>				
CM 101	<i>Gen. Chem. I</i>	2½	0	2½
CM 101	<i>Gen. Chem. Lab. I</i>	0	1½	½
CS 100	<i>Intro. Computer Programming</i>	2	0	2
HU 101	<i>Writing & the Humanities I</i>	3	0	3
MA 101	<i>Calculus I</i>	4	0	4
SS 104	<i>Contemporary World History</i>	3	0	3
SL 101	<i>Freshman Seminar</i>	1	1	0
				15

Second Semester

CM 101	Gen. Chemistry II	2½	0	2½
CM 102	Gen. Chem. Lab II	0	1½	½
HU 200	Writing and Hum. II	3	0	3
MA 102	Calculus II	4	0	4
PH 104	Intro. to Physics I	3	0	3
	Hum./Soc.Sci. Elective	3	0	3
				16

SOPHOMORE YEAR

First Semester

ME 111	Mechanics I	3	0	3
ME 101	Graphics	1	3	2
PH 105	Intro. to Physics II	3½	0	3½
PH 115	Physics Laboratory I	0	1½	½
MA 103	Calculus III	3	0	3
	Hum./Soc.Sci. Elective	6	0	6
				18

Second Semester

EE 370	Principles of E.E.	3	0	3
EE 374	Instru. Lab.	0	3	2
ME 112	Mechanics II	2	0	2
ME 121	Mech. of Materials	3	0	3
MA 104	Appl. Diff. Equations	3	0	3
PH 106	Intro. to Physics III	2½	0	2½
PH 116	Physics Laboratory II	0	1½	½
				16

JUNIOR YEAR

First Semester

MT 401	Physical Metallurgy I	3	0	3
MT 402	Mech. Metallurgy I	3	3	4
MT 404	Metallography Lab.	0	6	2
MT 405	Metallurgical Thermodynamics	3	0	3
	Hum./Soc.Sci. Elective*	3	0	3
				18

Second Semester

CM 161	Physical Chemistry I	3	0	3
MT 403	Physical Metallurgy II	3	0	3
MT 406	Mech. Metallurgy II	3	0	3
MT 407	Phase Transformation	3	0	3
MT 408	Phys. Metallurgy Lab	0	6	2
CM 515	Polymer Organic Chemistry	3	0	3
				17

SENIOR YEAR

First Semester

MT 410	Solid-State Metallurgy	3	0	3
MT 416	Electrometallurgy and Corrosion	2	3	3
MT 421	Metallurgical Failure Analysis	2	3	3
MT 496	Thesis	0	9	3
CM 771	Intro. to Polymer Chemistry	3	0	3
	Elective*	3	0	3
				18

Second Semester

MT 413	Process Metallurgy	3	0	3
MT 423	Ceramic Materials	3	0	3
MT 497	Thesis	0	9	3
	Hum./Soc.Sci. Elective*	3	0	3
				16

- 1 Students may be placed in alternative courses based upon placement examination results.
- 2 Students may be placed in MA100/MA110 based upon placement examination results.
- 3 HU/SS electives must be chosen in accordance with the requirements listed under DEGREE REQUIREMENTS, subsection "Humanities & Social Science Electives for Engineering and Computer Science Majors".

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE

In order to be admitted to the master's program, an applicant must have the equivalent of a bachelor's degree in metallurgy or materials science. An applicant with a bachelor's degree in a field of science or engineering other than metallurgy or materials science may have to remove some undergraduate deficiencies as determined by the Department Advisory Committee.

Full-time graduate students enrolled in the master's program will generally be required to do a master's thesis. Part-time students will be required to complete a master's project. Under special circumstances students may take courses and pass an oral examination in lieu of a thesis or project.

A minimum of 36 units of required and elective courses and thesis or project is necessary for the M.S. degree.

M.S. Metallurgical Engineering Required Course Work:

Take 9 units from:

No.	Class	Units
MT 600	Structure-Property Relationships	3
MT 610	Thermodynamics of Metals and Alloys	3
MT 620	Plastic Deformation & Fracture	3
MT 630	Theory of Metals	3
MT 640	Reactions in Solids	3
MT 650	Advanced Engineering Metallurgy	3
		9

Project or Thesis*

MT 996	Project for M.S. or	3-6
MT 997	Thesis for M.S.	9-12

Elective Course Work:

9-24 units chosen from the Department courses listed on subsequent pages of this Catalog. 9-24

Engineering or Science Electives:

With advisor's approval may be chosen from among University courses offered in this Catalog. 0-6
Total 36

M.S. Materials Science

Enrollment in the program is open to students with undergraduate degrees in engineering or the physical sciences. Depending on the undergraduate background, two 500 level courses may be required to satisfy principal prerequisite requirements.

CM 515	Polymer Organic Chemistry
MT 540	Survey of Metallurgical Principles

(These courses may not carry credit towards degrees Required Course Work (12 Units)

MT 600	Structure-Property Relationships	3
MT 640	Reactions in Solids	3
MT 660	Ceramic Technology	3
CM 771	Introductory Polymeric Chemistry	12

Project or Thesis*

MT 996	Report Project for M.S. or	3-6
MT 997	Thesis for M.S.	9-12

Elective Course Work:

With advisor's approval courses from Catalog and others in areas related to materials science, e.g., metallurgy, physics, chemistry and polymers. 12-21

Total 36

* Part-time students take Project.

REQUIREMENTS FOR THE ENGINEER DEGREE

Applicants for admission to this program must hold a master's degree (or equivalent) comparable in content to that of the Department. This must include at least the equivalent of three of the required courses in the MT 600-650 series listed under the requirements for the master's degree. An applicant holding a master's degree for which the requirements vary substantially from those

indicated above may be admitted to the engineer program if the deficiencies, as evaluated by the Department graduate advisor, are removed during the time the student is enrolled in the program.

MT 621-622	Special Topics in Plastic Deformation & Fracture	6
MT 651-652	Special Topics in Advanced Engineering	6
MT 760-761	Seminar in Metallurgical Engineering	3
MT 998	Project for Engineer Degree	6

Selected electives in science, mathematics, economics or engineering, in consultation with Department advisors.

Total 36

REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

Requirements for doctor's degree conform to regulations in Degree Requirements. Special doctoral requirements are available from the Departmental Administrative Assistant in the publication, Guide for Doctoral Students in Metallurgy or Materials Science.

A typical program consists of a minimum of 24 units of research for the doctoral dissertation and sufficient units of graduate course work for a total of 90 units required by Polytechnic. A minimum of 48 units of graduate course work beyond the bachelor's degree is normally required by the Department.

Courses include a major concentration in metallurgy/materials science of 36 units and minor concentrations of 12 units in related areas of physics, chemistry, mathematics, mechanical engineering, etc.

UNDERGRADUATE COURSES

MT 401 Physical Metallurgy I 3:0:3

Introduction to physical metallurgy. Relations of properties to microstructures in pure metals. Recovery, recrystallization and grain growth. Phase diagrams. Solidification, Iron-carbon alloy systems. Ferrous alloys. Prerequisites: PH103, CM 102 and CM 112.

MT 402 Mechanical Metallurgy I 3:3:4

Behavior of metallic materials under stress. Mechanical properties in tension, compression, direct shear, torsion, flexure. True stress-strain. Cold work, hardness, impact, fracture mechanics, fatigue properties. Effects of temperature on mechanical behavior of metals. Creep. Stress rupture. *Prerequisite: MA 103.*

MT 403 Physical Metallurgy II 3:0:3

Non-ferrous alloys. Diffusion-controlled phase transformations. Distortion-controlled phase transformations. Elementary alloy theory. *Prerequisite: MT 302 or MT 401.*

MT 404 Metallography Laboratory 0:6:2

Metallographic preparation of samples, mounting, polishing, etching. Electropolishing and etching of ferrous and non-ferrous alloys. Macroetching and sulphur prints. Temperature measurement: thermocouple and pyrometry. Photomicrography and photographic techniques. Sample preparation techniques for electron microscopy.

MT 405 Metallurgical Thermodynamics 3:0:3

Law of thermodynamics. Free energy of heterogeneous reactions. Phase equilibria. Introduction to statistical thermodynamics. Thermodynamics of solutions and defects. *Corequisite: MT 401.*

MT 406 Mechanical Metallurgy II 3:0:3

Elements of dislocation theory. Dislocation reactions, multiplications, movement under force. Dislocation interaction with impurities and point defects. *Prerequisite: MT 402.*

MT 407 Phase Transformations 3:0:3

Equilibrium in single component systems and binary solutions. Binary phase diagrams. Interstitial and substitutional diffusion. Solidification of pure solids. Alloy solidification. Diffusional trans-

formations in solids. Diffusionless transformations. *Prerequisite: MT 403.*

MT 408 Physical Metallurgy Laboratory 0:6:2

Experiments to illustrate principles of physical metallurgy, including phase equilibria, recrystallization, solid-solution and precipitation hardening. Heat treatment of steel. Structure property relationships. *Prerequisite: MT 404.*

MT 410 Solid-State Metallurgy 3:0:3

Free electron theory of metals. Band and zone theory. Bonding in solids. Thermal, electrical and magnetic properties of metals and alloys. Effects of metallurgical variables. Metallurgical aspects of semiconductor and superconductor phenomena. *Prerequisite: MA 104.*

MT 413 Process Metallurgy 3:0:3

Casting, metal forming, surface modification by electron beam, laser beam and ion implantation; powder metallurgy, rapid solidification processing, composite materials processing. *Prerequisite: MT 405.*

MT 416 Electrometallurgy and Corrosion 2:3:3

Electrode potential and overvoltage. Electrode kinetics. Corrosion types. Corrosion protection. Electroplating. Laboratory experiments include potentiostatic and galvanostatic methods for studying corrosion. *Prerequisite: MT 403*

MT 421 Metallurgical Failure Analysis 2:3:3

Metallurgical principles applied to analyses of in-service failures of materials. Discussions of actual case histories. Laboratory assignments require students to prepare written reports and given oral presentations analyzing six in-service failures. *Prerequisites: MT 404 and MT 408.*

MT 423 Ceramic Materials 3:0:3

Mineral raw materials. Forming and thermal treatments to obtain ceramic products. Glasses, glazes and enamels on metals. Introduction to physical ceram-

ics. Equilibria and reactions between ceramics. Recrystallization, grain growth and microstructures of ceramics. Plastic and viscous deformations in ceramics. Physical properties of ceramics.

TECHNICAL ELECTIVE COURSES

MT 409 Materials Selection 3:0:3

Knowledge base of metallurgy and materials science applied to engineering materials selections. Value engineering approach and organization for materials selections. Elementary statistics applied to specifications, quality standards, quality controls. *Prerequisite: MT 403 and MT 411.*

MT 412 X-ray Diffraction 2:3:3

Production and properties of x-rays. Elements of crystallography. Stereographic projection. Powder and single crystal diffraction techniques. Structures and crystal orientation. Stress analyses and phase diagram determinations by x-ray techniques. Qualitative and quantitative chemical analyses by x-ray techniques. *Prerequisites: MA 104 and PH 103.* Also listed under PH 372

MT 414 Metallurgical Kinetics 3:0:3

Statistical and empirical approaches to kinetics. Diffusion in metals and alloys. Theories of nucleation and growth. Kinetics of recrystallization, martensitic transformations. *Prerequisite: MT 405.*

MT 415 Metallurgy of Magnetic Materials 3:0:3

Macroscopic concepts of magnetism. Magnetization curves. Technological requirements for and applications of ferromagnetic materials. Ferromagnetic domains. Properties of ferromagnetic single crystals. Metallurgical factors affecting ferromagnetic properties, iron silicon, iron-nickel and other alloys. Permanent magnet materials. *Prerequisite: MT 410 or equivalent.*

MT 417 Welding Metallurgy 3:0:3

Metallurgical aspects of welding. Theories and applications of arc, gas, resistance and solid state welding processes. Modern methods of procedure, control, tests, inspection. Examinations of micro and macrostructures of welds and adjacent areas. Applications of welding. Weldability criteria. *Prerequisites: MT 302 or MT 401 or equivalent.*

MT 419 Strengthening Mechanisms in Metals and Alloys 3:0:3

Theories of alloy strengthening. Role of solute distribution on dislocation movement in binary and complex alloys. Multiphase aggregate strengthening. Composite materials and unidirectionally solidified eutectics. Thermomechanical processing and strength. High temperature effects. *Prerequisites: MT 403 and MT 406.*

INTERDEPARTMENTAL COURSES

MT 305 Mechanical Properties of Materials 3:0:3

Structure-property relationships of engineering materials. Testing methods and interpretation of tests, mechanical properties of materials. Engineering properties of ferrous and non-ferrous alloys and non-metallic materials including polymers, ceramics and composites. Strong emphasis is placed on engineering applications and case histories of product and component failures.

MT 306 Nature and Properties of Structural Materials 2:3:3

Physical and mechanical properties of concrete, metals, plastics, composites and asphaltic materials related to structures. Experimental investigation of mechanical properties of selected structural materials and physical properties of cement and concrete mixes. Introduction to polymeric materials including geosynthetics. Jointly developed and taught by Civil & Environmental Engineering and the Metallurgy & Materials Science Departments. Also listed under CE 306.

MT 340 Manufacturing Processes 3:0:3

Mechanical behavior of metals. Properties of materials relating to fabrication methods. Metal cutting mechanics, cutting fluids, thermal and vibrational aspects of machining. Machinability criteria. Deformation processing, hot and cold, mechanics of deformation. Unconventional processing: EDM and ECM. Numerical control. Metrology. *Prerequisite: MT 305.* Also listed under IE 340.

MT 375 Semiconductor Technology 3:0:3

Principal techniques involved in design and fabrication of semiconductor devices and integrated circuits, including material preparation, junction forming, circuit integration, packing. Also listed under EE 119.

MT 399 Senior Honors Work in Metallurgical Engineering *credit to be arranged*

Independent work undertaken by qualified honors students in metallurgical engineering. Course materials arranged by faculty steering committee.

MT 420 Engineering Materials 3:0:3

Structures, properties and uses of polymers and metals as engineering materials. Crystal structures, defects, heat treatments, corrosion and its prevention. Manufacture and processing of polymers. Mechanical behavior of polymers and their thermal and electrical properties. *Prerequisites: CM 161, CM 162, CM 123 and CM 124.* Also listed under CH 371.

GRADUATE COURSES

MT 540 Survey of Metallurgical Principles 2½:0:3

Crystals structures, alloying, phase diagrams, diffusion phenomena, mechanical deformation of metals and alloys, recrystallization, age hardening. *Prerequisite: instructor's consent.*

MT 600 Structure-Property Relationships in Materials 2½:0:3

Dependence of properties, e.g., mechanical and electrical, on structure of materials. Crystalline vs. amorphous structure, occurrence and role of defects. Bonding and structure. Anisotropy of properties related to crystal symmetry. Polycrystal vs. single crystal vs. textured polycrystals. *Prerequisite: MT 410 or equivalent.*

MT 601-602 Special Topics in Structure-Property Relationships, I, II 2½:0:3

Advanced or specialized topics in structure-property relationships in materials presented at irregular intervals. *Prerequisite: MT 600.*

MT 603 Introduction to Electron Microscopy I 2½:0:3

Resolving power. Lens aberrations. Properties of magnetic lenses. Designs of Transmission and Scanning Electron Microscopes, their applications and limitations. Real and Reciprocal lattices. Scattering of fast electrons by atoms. Theories of electron diffraction. Bragg Law. Ewald sphere construction.

MT 604 Introduction to Electron Microscopy II 2:2:3

Image formations. Fresnel half period zones. Kinematical theory of image formation. Column approximation. Images of perfect and imperfect crystals, stacking faults, dislocations, precipitates. Amplitude phase diagram and its applications. Breakdown of Kinematical theory. Introduction to dynamical theory of image formation. Specimen preparation techniques: thin foil, replicas. Uses of the Scanning and Transmission Electron Microscopes.

MT 610 Thermodynamics of Metals and Alloys 2½:0:3

Fundamentals of classical and statistical thermodynamics with emphases on solid states, phenomenology of metallic surfaces, phase equilibria in multicomponent metallic systems, calculations of phase diagrams, thermodynamics of lattice defects and substructure. *Prerequisite: MT 405.*

MT 611-612 Special Topics in Thermodynamics and Statistical Mechanics of Metals, I, II*each 2½:0:3*

Advanced or specialized topics in thermodynamics and statistical mechanics of metals. *Prerequisite: MT 610.*

MT 620 Plastic Deformation and Fracture*2½:0:3*

Classical concepts of slip related to dislocation theories of stress-strain behavior of single crystals. Mechanical twinning and its relationship to crystal structure. Theories of yielding, brittle and ductile fracture in polycrystalline materials. *Prerequisite: MT 406.*

MT 621-622 Special Topics in Deformation and Fracture I, II*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, influences of structural imperfections on properties of metals and alloys. *Prerequisite: MT 410 or equivalent.*

MT 631-632 Special Topics in theory of Metals I, II

Advanced or specialized topics in electronic properties of materials. *Prerequisite: MT 630*

MT 640 Reaction in Solids*each 2½:0:3*

Mechanism and kinetics of diffusion-controlled and diffusionless phase transformations in solid metallic systems; diffusion in multiphase, multicomponent metallic systems; theories of precipitation, of grain boundary migration and grain growth, of eutectoid transformation and martensitic transformations. *Prerequisite: MT 414.*

MT 641-642 Special Topics in Reactions in Solids I, II*each 1½:0:3*

Advanced or specialized topics in reactions in solids. *Prerequisite: MT 640 or instructor's consent.*

MT 650 Advanced Engineering Metallurgy*2½:0:3*

Requirements for resistance to stress, oxidation and corrosion, and to structural instability in metals and alloys for low, normal and high temperature service, theories of high temperature deformation and fracture, of alloy designs and designs of alloys for challenging environments. *Prerequisite: MT 405.*

MT 651-652 Special Topics in Advanced Engineering Metallurgy I, II*each 2½:0:3*

Advanced or specialized topics in advanced engineering metallurgy presented at regular intervals. *Prerequisite: MT 405.*

MT 660 Ceramic Technology*2½:0:3*

Chemistry, structure and properties of ceramics and glasses. Emphasis on relation of microstructure to properties and control of microstructure via time-temperature as well as chemistry. Key engineering properties: strength, thermal resistance, dielectric behavior will be analyzed.

MT 706 Magnetism and Magnetic Materials*2½:0:3*

Origin of magnetism in atoms and solids. Diamagnetic vs. paramagnetic behavior. Ferromagnetic domain theory. Antiferromagnetism and ferromagnetism. 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 708 Semiconductor Materials and Devices*3:0:3*

Nature of semiconductor materials, stressing interrelations among band structure, chemistry and microstructure of materials. Elemental, compound, amorphous and polymeric semiconductors. Examples of applications of materials for devices are given to illustrate how materials properties are matched to device characteristics for optimum performance.

MT 709 Integrated Circuit (VLSI) Fabrication Techniques*3:0:3*

Study of process technology used to produce integrated circuits. Silicon technology: bipolar, MOS and VLSI processes. Process requirements defined in terms of circuit structure, i.e., concentration profiles and topographical layout as defined by mask set previously determined. Steps from crystal growth through diffusion, ion implantation, oxidation, photolithography, metallization, interconnection and packaging to final test are analyzed. The impact of process on design rules are printed out. Also listed under EL 646.

MT 714 Electrochemical Processes*2½:0:3*

A presentation of the fundamentals of electro-chemical reactions, focussing on those aspects which have application to metals and semiconductors. Electrode reactions; kinetics of electrode processes, theory and applications of chemical etching; corrosion of metals and alloys; electro-solution and deposition.

MT 720 Advanced in Materials Analyses Mechanisms in Metals*each 2½:0:3*

Characterization of microstructure, defects, dopants and impurities, composition profiles. What to use when and why. Hands on uses of selected equipment. Applications discussed based on interest of students.

MT 760-761 Seminar in Metallurgical Engineering*each 0:2½:1½*

Recent progress in metallurgical engineering addressed in lectures by engineers from industry, research and educa-

tional institutions. One or more seminar topics from current literature in metallurgical fields assigned each student for presentation. Students expected to read each assigned topic and to be conversant with topics presented. (Attendance required for two semesters. Part-time students may substitute a three unit metallurgy course).

MT 762 Seminar in Metallurgical Engineering 0:2½:0

Preparation of presentation by students of seminars on topics of metallurgical engineering, in which students critically review technical papers selected by students with approval of faculty advisors. For students enrolled in metallurgical engineering degree programs.

MT 763-764 Seminar in Metallurgy and Materials Science each 0:2:½

Preparation and presentation by students of seminars on topics of physical metallurgy, metallurgical engineering or materials science in which students critically review technical papers selected by students with approval of faculty advisors. For students enrolled in doctoral programs.

MT 996 Report Project for the Degree of Master of Science 3-6 units

Independent project demonstrating professional maturity and graduate level knowledge completed under guidance of departmental advisors. Reports include critical analysis and interpretation of pertinent literature and should represent worthwhile contributions to the field. Oral final examinations and project reports required.

MT 997 Thesis for the Degree of Master of Science 9-12 units

An original topic of research for the master's degree is decided upon by student and faculty advisor. Close contact is to be maintained between student and faculty advisor during the thesis investigation. After the thesis is written up and approved the student is required to defend his thesis during an oral examination.

MT 998 Project for the Engineer Degree 3-6 units

Engineering project at post-master's level pursued with guidance of faculty members. Candidates required to take oral examination on subject matter of project and on related topics.

MT 999 Dissertation for the Degree Doctor of Philosophy 3-6 units

Dissertation presents results of original research in physical metallurgy. Work must demonstrate originality and creativity and be worthy of publication in recognized scientific journals. Candidates must take oral examinations on thesis subject and related topics. Minimum of 35 units required.

The following graduate courses are offered irregularly in response to student demand:

- MT 700 Welding Metallurgy
- MT 710 Powder Metallurgy II
- MT 715 Corrosion & Oxidation Mechanism in Metals
- MT 725 Noble Metal Metallurgy
- MT 726 Metallurgy of Nuclear Reactor Materials
- MT 727 Bioengineering Metallurgy
- MT 740 Materials in Manufacturing

FACULTY

Irving B. Cadoff, Professor of Materials Science and Acting Head of Metallurgy and Materials Science
B.M.E., C.C.N.Y.; M.M.E., D.Eng.Sc., New York University
Electronic materials; liquid metal embrittlement, thin film epitaxy

Carmine D'Antonio, Professor of Metallurgy; B.Met.E., M.Met.E., Polytechnic Institute of Brooklyn
Mechanical properties; thin films; failure analysis

Harold Margolin, Professor of Metallurgy; B.Eng., M.Eng., D.Eng., Yale University. *Plastic deformation and fracture; titanium metallurgy; fatigue of metals and alloys*

Sung H. Whang, Professor of Metallurgy; B.S., Seoul National University (Korea); M.S., D.Eng.Sc., Columbia University. *Alloy phase stability; rapid solidification processing; superconducting materials processing; deformation in ordered intermetallic materials*

Said Nourbakhsh, Associate Professor of Metallurgy; B.S., Arya-Mehr University of Technology (Iran); Ph.D., Leeds University (England)
Phase transformation, electron microscopy and mechanical behavior

Sharmila M. Mukhopadhyay, Assistant Professor of Metallurgy; M.S.(Physics), Indian Institute of Technology (India); M.S. (Materials Science & Engineering), Ph.D., Cornell University
Ceramics, properties of surfaces and interfaces and electron spectroscopy

ADJUNCT FACULTY

Sung K. Kang, Adjunct Professor Metallurgy; B.S., Met.E., Seoul National University, Korea; Ph.D., Met.E., University of Pennsylvania.

Ernest Levine, Adjunct Professor of Metallurgy; B.Met.E., Rensselaer Polytechnic; Ph.D., New York University

Sankar Sastri, Adjunct Professor of Metallurgy; B.S., Indian Institute of Science (India); M.S., Columbia University; Ph.D., Polytechnic Institute of New York

Sheldon Weinig, Adjunct Professor of Materials Science; Fellow of the Polytechnic University; B.S. (ME), New York University; Ph.D., Columbia University

EMERITUS FACULTY

Louis S. Castleman, Professor Emeritus of Metallurgy; S.B., Sc.D., Massachusetts Institute of Technology
Diffusion in solids, biomaterials

George J. Fischer, Professor Emeritus of Metallurgy; B.Met.E., M.Met.E., Polytechnic Institute of Brooklyn
Corrosion and welding metallurgy

MECHANICAL ENGINEERING

The undergraduate degree in mechanical engineering is offered on both the Brooklyn and Long Island campuses, and may be taken by full-time students at either location. Some laboratories are shared in the senior year. Co-op students can be accommodated with no difficulty. Part-time students take the same classes as full-time students; there is no evening program. Transfer students are welcome; there are pre-planned programs or articulation agreements with several schools which ease the transfer. Consult the Admissions Office for details.

Graduate degrees in mechanical engineering are offered on the MS, Engineer, and PhD levels. For each level, the student may choose a specialty area in thermal and fluid sciences, mechanical analysis or design controls and robotics. By selecting certain electives, the student may also have a focus in manufacturing within any of these three specialties.

All mechanical engineering graduate degrees are offered to both full-time and part-time students at the Brooklyn campus. PhD students may work on their dissertation at the campus most suited to the advisor and the topic.

THE MECHANICAL ENGINEERING PROFESSION

Mechanical engineering is a dynamic and evolving profession. Mechanical engineers develop the physical systems and devices that modern society needs or wants from automobiles to air conditioning units, robots to power plants, people movers to artificial limbs, and rocket engines to communications satellites. It has a long tradition of leadership in helping to develop the natural environment while breaking the ground in such areas as resource conservation through

better maintenance techniques, improved efficiency of energy-consuming devices such as integrated circuits, development of codes for a safer technological environment and new energy sources such as solar power, co-generation, fuel cells, and wind power.

While undergraduate and graduate programs in mechanical engineering are designed primarily to develop talents in these areas, graduating students eventually apply their training to the additional diversified fields of bioengineering, manufacturing, astronautics, systems engineering, management, and patent law. As students mature and realize their abilities, their professional lives may center on engineering research, government, business, or education.

UNDERGRADUATE PROGRAM

For undergraduates in mechanical engineering, a strong program in mathematics, physics, chemistry, and computer usage provides the base for the more professional courses in engineering sciences such as solid and fluid mechanics, thermodynamics, controls, and dynamic system analysis. The curriculum then develops engineering analysis and concludes with engineering design and energy conversion. Project work in the senior year integrates the diverse disciplines of mechanical engineering. The program offers the basic and engineering sciences as the foundation for subsequent graduate studies and outstanding career opportunities.

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

TRANSFER STUDENTS

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

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

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

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

SPECIAL DEPARTMENTAL REQUIREMENTS

The standard requirements for the bachelor's degree in mechanical engineering are shown in the table on the next page. Students are encouraged to participate in ASME and/or SAE student chapters, and to make use of departmental space for study and interaction with other students in the program.

Seniors with GPA's of 3.5 or better may take honors work (ME381-2) and certain graduate courses as electives with the departmental advisor's approval.

In addition to the University requirement of a 2.00 GPA for graduation, ME students must also earn a 2.00 overall GPA in their ME courses (i.e. all those with "ME" prefixes in the "Typical Course of Study", plus the technical electives).

Students must have a "C" average in three sophomore-level courses (ME111, ME112, ME121) before proceeding to junior-level courses. Students must have a "C" average in four junior-level courses (ME201, ME202, ME231, ME232) before proceeding to senior-level courses. Those not satisfying these requirements must repeat the courses which earned less than a "C" grade before proceeding.

Students on academic probation are usually permitted to preregister for the next semester, but are obliged to consult with the ME advisor after their grades are posted, and before the beginning of classes.

HUMANITIES AND SOCIAL SCIENCE REQUIREMENTS

Elective courses are chosen in consultation with the mechanical engineering undergraduate advisor according to the following university and departmental guidelines:

In humanities and social sciences, students must take HU101, HU110 and either HU200 and SS104 or IS140 and IS141 (total 12 credits). Students placed in HU103 on the basis of the English Composition Placement Test administered at Polytechnic to all incoming students may substitute HU103 for HU101. Students placed in HU008 or HU009 must complete this non-credit course before taking HU101 (or HU103). All students must elect 12 additional credits in humanities and social sciences to bring to 24, the total of such credits.

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

FRESHMAN YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.
First Semester				
MA 101	<i>Calculus I</i>	4	0	4
MA 101	<i>Calculus I</i>	4	0	4
CM 101	<i>Gen. Chemistry I</i>	2½	0	2½
CM 111	<i>Gen. Chem. Lab I</i>	0	1½	½
CS 100	<i>Introduction to Programming</i>	2	0	2
HU 101	<i>Writing & Hum. I</i>	3	0	3
SS 104	<i>Contemporary World History*</i>	3	0	3
SL 101	<i>Freshman Seminar</i>	1	1	0
				15

Second Semester

MA 102	Calculus II	4	0	4
CM 102	Gen. Chemistry II	2½	0	2½
CM 112	Gen. Chem. Lab. II	0	1½	½
PH 104	Intro. Physics	3	0	3
HU 200	Writing & Humanities II*	3	0	3
	Hum./SS Elective***	3	0	3
				16

SOPHOMORE YEAR

First Semester

MA 104	Appl. Diff. Equations	3	0	3
PH 105	Intro. Physics II	3½	0	3½
PH 115	Intro. Physics Lab. I	0	1½	½
ME 101	Graphics	1	3	2
ME 111	Mechanics I	3	0	3
MT 305	Mech. Prop. of Materials	3	0	3
HU 110	Report Writing I	3	0	3
				18

Second Semester

MA 103	Calculus III	3	0	3
PH 106	Intro. Physics III	2½	0	2½
PH 116	Intro. Physics Lab. II	0	1½	½
ME 112	Mechanics II	3	0	3
ME 121	Mech. of Materials	3	0	3
	Hum./SS Elective***	3	0	3
EE 370	Princ. of Electrical Engineering	3	0	3
				18

JUNIOR YEAR

First Semester

ME 201	Thermodynamics I	3	0	3
ME 231	Fluids I	3	0	3
ME 261	Vibrations	3	0	3
ME 321	Instrumentation	2½	1½	4
ME 331	Computational Methods in Mech. Eng.	2½	1½	3
				16

Second Semester

ME 202	Thermodynamics II	3	0	3
ME 232	Fluids II	3½	1½	4
ME 271	Fund. of Stress Analysis	3	0	3
ME 301	Synthesis of Mech. Systems	3	0	3
ME 322	Automated Controls	3½	1½	4
				17

SENIOR YEAR

First Semester

ME 203	Heat Transfer	3	0	3
ME 272	Stress Analysis of Mechanical Comps.	3½	1½	4
ME 302	Analysis/Design Machine Elements	3	0	3
ME 351	Heat Transfer Lab. I	½	1½	1
ME 361	Design Project I	0	6	2
	Technical Elective**	3	0	3
	Hum./SS Block Sequence***	3	0	3
				19

Second Semester

ME 204	Design of Energy Transfer	3	0	3
ME 341	Finite Elements	3½	1½	4
ME 352	Heat Transfer Lab. II	½	1½	1
ME 362	Design Project II	0	9	3
	Technical Elective**	3	0	3
	Hum./SS Block Sequence***	3	0	3
				17

* Students may substitute IS 140-141 for SS 104 and HU 200.

** Technical electives must be of Senior-Year quality, taken during the Senior Year after the approval by an ME Advisor has been secured.

*** The two Hum./SS courses taken during the Senior Year together with one of the two previously taken Hum./SS electives, must form required Hum./SS sequences.

At least 18 of the credits selected in the humanities and social sciences must meet the requirements of the Accreditation Board for Engineering and Technology (ABET). These credits may not include skills-oriented courses such as technical writing, public speaking, or English as a second language. Courses in literature, foreign languages, history, economics, and others are acceptable. Students should consult their ME advisors to ensure that these criteria are met. Management courses and ROTC courses may not be used as substitutes for Hum/Soc. Sci. electives, and the HU/SS sequence requirement must be satisfied.

For further information, students should refer to the section of this catalog entitled "Humanities and Social Sciences Requirements for Engineering and Computer Science Majors".

GRADUATE PROGRAM

Programs of study leading to the MS, Engineer, and PhD degrees in Mechanical Engineering are available in each of three specialty areas:

- Thermal and Fluid Sciences
- Mechanical Analysis and Design
- Systems, Controls, and Robotics

Within each of these specialties, a student may choose to concentrate some of the electives in manufacturing engineering.

A bachelor's degree and good academic record in mechanical engineering from a suitable college or university is generally required for admission to the graduate program. Applicants with degrees from fields other than mechanical engineering may be admitted, but have to undertake additional studies to achieve a comparable background¹. The courses required to achieve this are specified as part of the admission evaluation or first advising session. Undergraduate courses specified for this purpose cannot count toward credits needed for the degree.

Graduate programs are subject to the prior approval of the graduate advisor designated by the department. All students are required to have a GPA of 3.00 or better in each of the following:

in all graduate courses taken at Polytechnic; in all ME courses submitted for the degree; in all guided studies (readings, projects, thesis, dissertation).

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE

The requirements for the MS degree in mechanical engineering are suited to the applicant's specialty, which is specified by the student in the admissions process or the first advising session.

Full-time MS students are expected to undertake a research project or thesis as part of the program.

Students must take at least 27 units of the MS Program at Polytechnic. No more than a total of nine units may be attributed to transfer and readings courses. Validation credit is not allowed, but specific requirements may be waived (and an appropriate substitute designated) by the graduate advisor, based upon the student's prior studies or experience.

Studies for the MS must be completed within a four year period, unless there is a formal leave of absence approved prior to the period for which the studies are interrupted.

Thermal and Fluid Sciences

The required courses are:

No.	Class	Units
ME 600-625	<i>Applied Computational Methods</i>	3
ME 601	<i>Thermodynamics I</i>	3
ME 605	<i>Heat Transfer Fundamentals</i>	3
ME 610	<i>Fluid Dynamics Fundamentals</i>	3
ME 706	<i>Convection</i>	3
ME 711	<i>Viscous Flow and Boundary Layer</i>	3
ME 991-2	<i>Seminar in Mechanical Engineering</i>	0 18

The remaining 18 units must include at least 6 units within the ME Program and no more than 12 units from non-ME courses. Full-time students must take project or thesis work totalling from 6 to 12 units, and may take no more than 9 units of non-ME courses. All courses and program details are subject to advisor approval.

Mechanical Analysis and Design

The required courses are:

No.	Class	Units
ME 600	<i>Applied Computational Methods</i>	3
ME 621-22	<i>Stress Analysis I-II²</i>	6
ME 643	<i>Energy Methods in Structural Analysis</i>	3
ME 644-45	<i>Mechanical Vibrations I-II</i>	6
ME 991-2	<i>Seminar in Mechanical Engineering</i>	0 18

The remaining 18 units must include at least 6 units within the ME Program and no more than 12 units from non-ME courses. Full-time students must take project or thesis work totalling from 6 to 12 units, and may take no more than 9 units of non-ME courses. All courses and program details are subject to advisor approval.

System, Controls, and Robotics

The required courses are:

No.	Class	Units
ME 600	<i>Applied Computational Methods</i>	3
ME 660	<i>Discrete Time Feedback Control</i>	3
ME 661	<i>Sensor Based Robotics</i>	3
ME 670	<i>Linear Systems</i>	3
ME 671	<i>State Space Design for Linear Control Systems</i>	3
ME 644	<i>Mechanical Vibrations I</i>	3
ME 991-2	<i>Seminar in Mechanical Engineering</i>	0 18

The remaining 18 units must include at least 6 units within the ME Program and no more than 9 units from non-ME courses. Full-time students must take project or thesis work totalling from 6 to 12 units, and may take no more than 6 units of non-ME courses. All courses and program details are subject to advisor approval.

MANUFACTURING

Students in any one of the three preceding specialties may concentrate some of their electives in manufacturing.

The following courses are strongly recommended:

IE 611	<i>Quality Control and Improvement</i>
MN 788	<i>Manufacturing Systems Engineering</i>

plus at least a third elective selected from:

ME 717	<i>Thermal Design of Electronics Systems</i>
ME 718	<i>Thermal Issues in Manufacturing Processes</i>

Other relevant courses may be approved by the graduate advisor.

REQUIREMENTS FOR THE ENGINEER DEGREE

The Engineer Degree is a terminal degree beyond the MS, focused on engineering practice rather than research.

An MS degree in mechanical engineering with a specialization in one of the three departmental areas (thermal and fluid sciences, mechanical analysis and design, systems/controls/robotics) is required for admission to the Engineer Degree Program. A grade point average (GPA) of 3.3 or better in the MS work is generally required for admission.

The Engineer Degree must be focused in the same area of specialization as the MS degree.

In cases in which it is unclear that the required MS specialization has been satisfied, the MS degree requirements of the preceding section shall be used to define the necessary preparation. The same criterion shall be used when the MS degree is in other engineering disciplines³.

The General Requirements for the Engineer Degree are:

<i>MS level work, with appropriate specialty</i>	36
<i>Other ME graduate courses in specialty</i>	9
<i>Approved Elective:</i>	
ME courses	9
ME or other relevant courses	9
<i>Engineer Project (ME998)</i>	9
<i>ME 991-2 Seminar in Mechanical Engineering</i>	0
	72

Studies for the Engineer Degree must be completed within a four year period after the MS degree or the date of admission, whichever is later, unless

there is a formal leave of absence approved prior to the period for which the studies are interrupted.

The ME991-2 registration is required during the Engineer Degree studies, even if seminars were taken during the MS study. The purpose is to assure exposure to current work in the field, and participation in the ME Program.

REQUIREMENTS FOR THE DOCTOR OF PHILOSOPHY DEGREE

The PhD Degree is a terminal degree beyond the MS, focused on engineering research. Students are expected to advance the state of the art in their specialty by original and creative work.

An MS degree in mechanical engineering with a specialization in one of the three departmental areas (thermal and fluid sciences, mechanical analysis and design, systems/controls/robotics) is required for admission to the PhD Degree Program. A grade point average (GPA) of 3.5 or better in the MS work is generally required for admission.

In cases in which it is unclear that the required MS specialization has been satisfied, the MS degree requirements of the preceding section shall be used to define the necessary preparation. The same criterion shall be used when the MS degree is in other engineering disciplines.

The department has a "Set of Guidelines for the PhD Program in Mechanical Engineering" which describe the requirements related to Qualifying Examinations, Dissertation Proposals, Guidance Committees, Dissertation Defense, and other relevant matters. Polytechnic's Office of Research and Graduate Affairs has information on admission to candidacy, dissertation preparation, and other matters. Students are encouraged to obtain copies of these documents.

The General Requirements for the PhD Degree are:

	Units
<i>Major work related to specialty</i>	30-36
<i>Approved courses in two minor areas⁴</i>	24-30
<i>PhD Dissertation (ME999)</i>	24-30
<i>ME 991-2 Seminar in ME (each semester)</i>	0
	90

Studies for the PhD Degree must be completed within a five year period following the MS degree or the date of admission, whichever is later, unless there is a formal leave of absence approved prior to the period for which the studies are interrupted.

Once the dissertation is begun, the student must register for at least three units of ME999 in each Fall and Spring semester. Actual registration should reflect the pace of the work and the activity of the student. An exception to the minimum registration requirement may be made in the last semester of registration, if that semester is primarily devoted to finalizing the work and dissertation document. Dissertation grades of "U" in two consecutive terms will be cause to reconsider whether the student will be permitted to continue doctoral work.

The ME991-2 registration is required during each semester of the PhD Degree studies. The purpose is to assure exposure to current work in the field, and participation in the ME Program.

UNDERGRADUATE COURSES

ME 101 Graphics 1:3:2

Sketching, drawing, and computer-aided drafting. Projection theory: multiview, axonometric, oblique. Auxiliaries, sections, convection, dimensions, fasteners, working and assembly drawings. Introduction to blueprint reading. Overview of CIM, and CAD integration with other CIM concepts. Design project incorporating developed skills in visualization, drawing techniques and standards, and CAD.

ME 102 Computer-Aided Drafting 2:3:3

State-of-the-art developments in computer-aided drafting techniques. The user-computer interface in operating computer-aided drafting packages. Visual representation of projection schemes, dimensioning techniques, sections, and assembly drawings on various display devices. *Prerequisite: ME 101*

ME 111 Mechanics I 3:0:3

Three-dimensional vector treatment of the static equilibrium of particles and rigid bodies. Equivalent force and couple systems. Distributed force systems. Static analyses of trusses, frames and machines. Friction, impending motion. Methods of virtual work. Potential energy, and stability of equilibrium. *Prerequisites: MA 102 and PH 104.*

ME 112 Mechanics II 3:0:3

Three-dimensional vector treatment of the kinematics and kinetics of particles and rigid bodies using various coordinate systems. Newton's laws, work, energy, impulse, momentum, conservative force fields, impact. Rotation and plane motion of rigid bodies. *Prerequisite: ME 111.*

ME 121 Mechanics of Materials 3:0:3

Beam shear and bending moment diagrams and analysis. Beam boundary and discontinuity conditions. Hooke's law. Stresses and strains in members under direct force, torsion, and bending. Calculation of displacements; statically determinate and indeterminate problems. Compound stresses. *Prerequisite: ME 111.*

ME 201 Thermodynamics I 3:0:3

Properties of pure substances; concepts of work and heat; closed and open systems; the fundamental laws of thermodynamics; Carnot and Clausius statements; entropy and entropy production; heat engines, refrigerators, heat pumps; efficiencies, coefficients of performance. *Prerequisites: MA104 and PH105.*

ME 202 Thermodynamics II 3:0:3

Irreversibility and availability. Power and refrigeration cycles. Maxwell's equations and other thermodynamic relations. Properties of mixtures; air-conditioning. Energy and equilibrium aspects of chemical reactions; flame temperatures. Introduction to phase and chemical equilibrium. *Prerequisite: ME201*

ME 203 Heat Transfer 3:0:3

Conduction, convection, and radiation heat transfer. Steady-state and transient analyses of multidimensional conduction systems. Numerical solutions augmented with computer programs for various modes of heat transfer. *Prerequisites: ME 201 and ME 231.*

ME 204 Design of Energy Transfer and Conversion Systems 3:0:3

Principles of thermodynamics, fluid dynamics, and heat transfer applied to design of heat exchangers. Applications of first and second laws of thermodynamics to design and evaluation of energy conversion cycles. Detailed heat exchangers or energy system design required of students. *Prerequisites: ME 202 and ME 301.*

ME 212 Air Conditioning and Refrigeration* 3:0:3

Application of thermodynamics and other sciences needed for rational approaches to solutions of engineering problems in air conditioning and refrigeration. Senior Elective. *Prerequisite: ME 202.*

ME 213 Transport Processes* 3:0:3

Extensions of principles developed in ME 201, ME 231, and ME 203. Energy release and momentum, heat and mass transfer processes. Unified treatment using transport phenomena methods. *Prerequisite: ME 203.*

ME 231 Fluids I 3:0:3

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

ME 232 Fluids II 3½:1½:4

Flow in pipes and ducts. Students required to design flow measuring and piping systems. One dimensional gas dynamics. Convergent-divergent nozzles.

Normal and oblique shocks. Expansion fans. Effects of friction and heat addition. Laboratory experiments related to: fluid properties, streaklines and streamlines, laminar-turbulent transition pipe flow, sonic pipe flow, converging and diverging nozzle flow. *Prerequisite: ME 211.*

ME 243 Turbomachinery* 3:0:3

Thermodynamics, fluid mechanic principles, and elements of turbomachinery (fans, pumps, compressors, turbines) including design principles and operation of turbomachines. *Prerequisites: ME 202 and ME 232*

ME 261 Vibrations 3:0:3

Mechanics of vibrating systems. Equations of motion, Lagrange's equations and Rayleigh's method. Free vibrations of undamped and damped single degree of freedom systems. Forced vibrations. Two degrees of freedom vibration. Methods in multi-degree of freedom systems. *Prerequisite: ME 112.*

ME 271 Fundamentals of Stress Analysis 3:0:3

The concepts of stress and strain; stress-strain relations, equilibrium equations, compatibility conditions, superposition, strain energy. Bending of beams: unsymmetric bending of arbitrary section beams, bending stresses, deflections, shear stresses on thin-walled section beams, shear center. *Prerequisite: ME 121.*

ME 272 Stress Analysis of Mechanical Components 3½:1½:4

Thick-walled cylinders; shrink fits; rotating disks. Analysis of torsion of noncircular cylinders; application to thin-walled cylinders. Energy methods in structural analysis. Castigliano's theorems; application to statically determinate and indeterminate trusses, beams, frames, and rings. Laboratory measurements of strain; determination of material properties; experimental determination of principal axes and principal values of stress and strain; experiments in unsymmetric bending, determination of shear center, and torsion. *Prerequisite: ME 271.*

ME 301 Synthesis of Mechanical Systems 3:0:3

Kinematic analysis of linkages; velocity and acceleration images; instantaneous centers. Design of cams, gears, gear trains. Geometric and algebraic methods of synthesis for path and function generation. *Prerequisite: ME 112.*

ME 302 Analysis and Design of Machine Elements 3:0:3

Study of working stress and failure criteria; brittle and ductile materials; modified Goodman diagram; stress concentrations; steady and fluctuating loads, fatigue failure; fatigue life and Miner's equation. Design of selected machine elements, e.g., shafting, springs, screws, belts, brakes, welded and riveted connections, bearings, gears. *Prerequisites: MA 271.*

ME 321 Instrumentation 3½:1½:4

Measurement statistics: standard deviation, curves of regression, accumulation of errors. Instrument systems and components: transduction of mechanical information into analog and digital signals; signal processing and filtering devices; readout devices. Static and dynamic measurements of mechanical components and systems; computer simulation studies. Laboratory: Active transduction, measurements of mechanical characteristics, computer simulation: air compressibility. *Prerequisite: EE 370.*

ME 322 Automated Controls 3½:1½:4

Feedback and development of control systems. Transfer functions. Block and signal flow diagrams. Responses to aperiodic and periodic excitations. Error considerations. Stability: Routh-Hurwitz criterion, root locus, Bode-plot techniques. Laboratory: component studies, servo systems, compensation and stabilization, robot link systems. *Prerequisite: ME 321.*

ME 323 Advanced Controls and Robotics. 2½:1½:3

Control design of linear systems in the complex and frequency domain. Sampled data systems and Z transform techniques. State space methods and matrix solutions. Control considerations in robotic systems. Robotic kinematics and dynamics. Application of Lagrange formulation to a commercial manipulator. *Prerequisite: ME 322*

ME 331 Computational Methods 2½:1½:3

Introduction to numerical techniques: curve fitting, interpolation, linear algebraic equations, integration, differentiation, finite differencing; introduction to ordinary and partial differential equations. Laboratory sessions reinforce classroom instruction through use of computers to solve various representative problems. *Prerequisite: MA 104.*

ME 332 Solid Modeling and Analysis 2:3:3

Study of 3D solid modeling techniques; application of these techniques using CAD workstations; constructive solid geometry and boundary rep methods to generate 3D objects and assemblies; mass and inertial property analysis; finite element analysis; interference checking and kinematic analysis. An independent design project at the end of this course requires application of all of these techniques. *Prerequisite: ME 101, ME 331.*

ME 341 Finite Elements 3½:1½:4

The finite-element method as it applies to continuum-type, boundary-value problems; introduction to calculus of variation and weighted residuals; the Ritz vs. the Galerkin method; one and two-dimensional simplex and complex elements. Special purpose programs for obtaining numerical solutions to differential equations governing engineering problems in structural mechanics, elasticity, heat transfer, and fluid flow. *Prerequisite: ME 272 and senior-year status.*

ME 351 Heat Transfer Lab. I ½:1½:1

Experiments related to thermodynamics: heat capacity, thermal conductivity. The refrigeration cycle; the centrifugal pump. Two dimensional and numerical conduction; radiation heat transfer. *Prerequisites: ME 202 and ME 232.*

ME 352 Heat Transfer Lab. II ½:1½:1

Experiments related to thermodynamics; the gasoline engine. Conduction in composite bars; forced and natural convection; shell and tube heat exchangers; heat and mass transfer analogies. *Prerequisite: ME 351.*

ME 361 Design Project I 1:3:2

Seniors are required to take a two course sequence in which they are exposed to principles of design and the design process, and then undertake one or more specific designs. The designs are generally specified by the course instructor, or selected by the student from a list of available projects. Students work in small groups. Written and oral status reports are required. The two course sequence often involves experienced design engineers from industry. The grade in ME361 is either "S" or "U". *Prerequisite: Senior-year status.*

ME 362 Design Project II 1:6:3

The second semester of the senior design sequence (see ME 361). Written and oral presentations are required, and are part of the grading, as is the design product itself. The assigned grade is applied to both ME361 and ME362. *Prerequisite: A grade of "S" in ME361.*

ME 381-382 Senior Honors Work in ME I-II credit to be arranged

Independent work undertaken by qualified honors students in mechanical engineering. Course material arranged by faculty steering committee. *Prerequisite: Senior-year status.*

**ME 391-392 Guided Studies in
ME I-II** *credit to be arranged*

Senior-year sequence for qualified students in mechanical engineering. Course material arranged by committee of faculty members. *Prerequisite: Senior-year status.*

GRADUATE COURSES

**ME 600 Applied Computational
Methods** *2½:0:3*

Computational methods used in formulation and solving problems that occur in engineering. Methods of interpolation, numerical differentiation and integration, solution of linear and non-linear equations and eigenvalue problems. Finite difference methods. Particular attention to continuum techniques, e.g., Rayleigh-Ritz, Galerkin, and Collocation. *Prerequisite: ME 331 or equivalent. Also listed as AE 623.*

ME 700 Finite Elements *2½:0:3*

Derivation of element stiffness matrices. Construction of general stiffness matrices in global coordinates. Application to problems in plane stress, plates, and shells under static and dynamic loads. Applications in thermal, heat transfer, and fluid mechanics. Emphasis on problems involving analysis of systems with many unknowns. *Prerequisite: ME 600.*

THERMAL AND FLUID SCIENCES

ME 601 Thermodynamics I *2½:0:3*

Availability functions, general thermodynamic relations, equations of state, general thermodynamic equilibrium criteria. *Prerequisite: ME 202 or equivalent.*

**ME 605 Heat Transfer
Fundamentals** *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. *Prerequisites: ME204 or equivalent.*

**ME 610 Fluid Dynamics
Fundamentals** *2½:0:3*

Conservation laws of mass momentum and energy. Elements of potential theory and gas dynamics. Applications of inviscid flow to simple internal and external geometries; control volume and differential approach to fluid dynamic problems. *Prerequisite: ME 232 or equivalent.*

ME 701 Thermodynamics II *2½:0:3*

Continuation of ME 605. Applications of thermodynamic equilibrium criteria to various problems, including chemical reactions. *Prerequisite: ME601.*

ME 706 Convective Heat Transfer *2½:0:3*

Developments and applications of laminar hydrodynamic and thermal boundary layer equations for fluid media. Mechanics of turbulence; formulation and analysis of turbulent hydrodynamics and thermal applications; natural convection and film evaporation and condensation. *Prerequisite: ME 605.*

ME 707 Conductive Heat Transfer *2½:0:3*

Theoretical development of transient and steady-state temperature distributions in finite and infinite solids. Appropriate mathematical techniques introduced as required. Solids undergoing phase change and two-dimensional fields. *Prerequisite: ME 605.*

ME 708 Radiative Heat Transfer *2½:0:3*

Fundamentals of radiative mechanisms of energy transfer. Definitions of basic quantities. Equations of transfer, radiative heatflux vector and conservation equations. Properties of surfaces and participating media. Applications to engineering systems. *Prerequisite: ME 605.*

**ME 711 Viscous Flow and Boundary
Layers** *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. *Prerequisites: ME 610.*

ME 712 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. *Prerequisites: ME 610.*

ME 713 Compressible Flow *2½:0:3*

Subsonic, transonic, and supersonic flows over two dimensional and axisymmetric bodies. Shock wave development in both one-dimensional unsteady and two-dimensional steady flow systems. Internal and external flows are considered. *Prerequisite: ME 601, 610.*

**ME 715 Computational Methods in
Thermal- Fluid Sciences** *2½:0:3*

Numerical analyses. Finite difference approximations, error and stability analyses, numerical dispersion and damping, matrix inversion methods. Implicit and explicit procedures, SOR, ADI, hopscotch and direct solvers for evaluating linear and nonlinear diffusion and convection problems. *Prerequisites: ME 600 and ME605 or ME610. Also listed under AE 732.*

**ME 716 Experimental Methods in
Thermal-Fluid Sciences** *2½:0:3*

Integrated survey of the principal techniques and instrumentation used for obtaining experimental data in thermal-fluid sciences. Topics include: calibrations, accuracy, generalized performance characteristics, various devices for measuring flow, velocity, pressure, temperature, heat flux, computerized data acquisition, planning experimental programs, parametric mapping, and noise in measuring systems. *Prerequisite: ME 605 or permission of graduate advisor.*

ENGINEERING

ME 717 Thermal Design of Electronics Systems for Performance and Reliability 2½:0:3

Thermal modeling and simulation of electronic equipment and systems, forced and natural air cooling, cooling with water and other liquids, cryogenic cooling, use of cooling correlations, approximate numerical formulations, fan characteristics, fan and disc acoustic noise, chip thermal profiles, thermal influence on the reliability of semiconductor circuits. *Prerequisite: ME605 or permission of graduate advisor.* Also listed under MN802.

ME 718 Thermal Issues in Manufacturing Processes 2½:0:3

Thermal modeling and simulation of manufacturing and materials processing, thermally driven processes, dip coating, thin films, soldering, laser welding and cutting, heat removal from processes generating parasitic heat, thermal management of machining. *Prerequisite: ME605 or permission of graduate advisor.* Also listed under MN804.

ME 803 Combustion 2½:0:3

Chemical characteristics of flames. Heat of formation and of reaction; phase and reaction equilibrium and adiabatic flame temperature; and special concentration in stationary and flowing reacting systems. Chemical kinetics of homogeneous and heterogeneous reacting systems. Branching chain reactions and explosion limits. *Prerequisite: ME 601, 706.*

ME 809 Multiphase Heat Transfer 2½:0:3

Conservation equations for two-phase flow systems with emphasis on gas-liquid mixtures. Bubbly, slug, annular and fog flow regimes. Pressure drops and heat transfer. Nucleate and film boiling; dropwise and film condensation. Critical heat flux. *Prerequisites: ME 601 & ME 706*

MECHANICAL ANALYSIS AND DESIGN

ME 621 Stress Analysis I 2½:0:3

Review of theory of beam bending. Use of energy methods applied to statically indeterminate structures. Columns,

beam columns, beams on elastic foundations. Circular cylindrical shells. Discontinuity analysis in complex structures. *Prerequisite: ME 272 or equivalent.*

ME 622 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 classic two dimensional problems, including those of stress concentration and thermal stress. Torsion of prismatic bars, open and closed thin-walled structures, and multi-cellular structures. *Prerequisite: ME 621.*

ME 643 Energy Methods in Structural Analysis 2½:0:3

Unified treatment of structural analysis using the principles of virtual work, total potential energy, total complementary potential, and mixed-energy. Applications to trusses, beams, frames, rings, sandwich structures, and to plane stress and plane strain problems. Rayleigh-Ritz procedure, Galerkin method. *Prerequisite: mechanical engineering advisor's approval.*

ME 644 Mechanical Vibrations I 2½:0:3

Dynamics of one, two, and multidegree of freedom systems with and without damping. Application to balancing of multicylinder engines, crank mechanism dynamics, and rotating machinery. *Prerequisite: ME 261.*

ME 645 Mechanical Vibrations II 2½:0:3

Free and forced longitudinal, torsional and transverse vibrations of bars, shafts, and beams. Lagrange's equations. Rayleigh-Ritz and Dunkerley's approximations. Holzer's and transfer matrix methods. *Prerequisite: ME 644.*

ME 647 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: ME 261.* Also listed under AE 651.

ME 648 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. *Prerequisite: ME 647.* Also listed under AE 652

ME 721-722 Elasticity I,II each 2½:0:3

Stress and strain tensors; generalized Hooke's Law. Formulation of elasticity problems. Plane stress and strain problems; solutions 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: ME 622*

ME 724 Stress Analysis of Composite Materials 2½:0:3

Composite materials (high strength filaments embedded in a matrix) have relatively large strength to weight ratio as well as other desirable characteristics. Composites are analyzed first from a micromechanics point of view. The relations between the material properties of their components and those of the composite, a material stress concentration factor, and its behavior beyond the elastic range are considered. The stress-strain law of composites, as a function of the directional moduli of elasticity and the directional Poisson's ratios, are presented. It is used in the analysis of various structural components of current interest. *Prerequisite: ME 622.*

ME 735 Fracture Mechanics 2½:0:3

Introduction to fracture mechanics. Linear elastic, elastic-plastic and fully plastic fracture mechanics modelling and design. Fatigue and design against fatigue failures. Standard fracture mechanics testing procedures and related material properties. Micromechanics of fracture. Dynamic fracture. Continuum damage mechanics. *Prerequisite: ME721 or*

Permission of department advisor. Also listed under CE 645 and MT 645.

ME 741 Structural Dynamics 2½:0:3

Dynamic response of single degree of freedom systems. Theory of vibration of multidegree of freedom systems; influence coefficient method; analytical and numerical solution of dynamic response problems. Nonlinear analysis of single degree of freedom system; emphasis on computer analysis of large complex systems. *Prerequisite:* ME 645. Also listed under CE 625.

SYSTEMS, CONTROLS, AND ROBOTICS

ME 660 Discrete Time Feedback Control 2½:0:3

Introduction to discrete systems, z-transform, s-to-z transformation, system stability criteria, digital control design via continuous design (root locus technique, frequency domain compensation), discrete design of digital control, sampling rate selection, quantization errors. *Prerequisite:* ME 322 or equivalent.

ME 661 Sensor Based Robotics 2½:0:3

Robot mechanisms, robot arm kinematics (direct kinematics, inverse kinematics), Robot arm dynamics (Lagrange-Euler formulation and Hamiltonian formulations), trajectory planning, sensing, end-effector mechanisms, force and moment analysis, introduction to control of robot manipulators. *Prerequisite:* ME 660. Also listed under EL522.

ME 670 Linear Systems 2½:0:3

Basic system concepts. Equations describing continuous and discrete-time linear systems. Time domain analysis, state variables, transition matrix, impulse response. Transform methods. Time-variable systems. Controllability, observability and stability. Also listed under EL 610

ME 671 State Space Design For Linear Control Systems 2½:0:3

Topics to be covered included: canonical forms; control system design objectives; feedback system design by pole placement; linear observers; the separation principle; linear quadratic optimum control; random processes; Kalman filters as optimum observers; the separation theorem; robust control; the servo compensator problem. *Prerequisite:* ME 670. Also listed under EL 725.

ME 761 Nonlinear Control 2½:0:3

Phase-plane analysis of nonlinear systems, describing functions, introduction to Lie algebra, input-output linearization, local and global system decomposition, perturbation control, sliding control. *Prerequisite:* ME 660 and ME 671.

ME 771 Optimal Control Theory 2½:0:3

Optimal control problem for deterministic systems with various constraints. Solution for both continuous and discrete-time systems using the maximum principle and dynamics programming. Hamilton-Jacobi theory as applied to the synthesis problem. *Prerequisite:* ME 671. Also listed under EL823.

ME 860 Application of Nonlinear Control to Robotics 2½:0:3

Differential geometric approaches for control of nonlinear systems and applications to robot manipulators. Introduction to Lie algebra and Lie bracket. Multi-variable inverses for nonlinear systems, external feedback linearization, zero dynamics. Application of nonlinear control to robotics: inverse dynamics, feed-forward control, PD and PID controllers, variable-structure control, adaptive control techniques (STR and MRAC), and force control. *Prerequisites:* ME661 and ME 671. Also listed under EL822.

ME 870 H[∞] Frequency Domain Methods in Control 2½:0:3

Systems and operators, stabilizability, parameterization of stabilizing controllers, H[∞] weighted sensitivity minimization for rational plants, H² and H[∞] controller design. *Prerequisite:* ME 671. Also listed under EL724.

ME 871 Adaptive Control 2½:0:3

Controllable and observable system models, parameter estimation (least squares, projection algorithm, lattice filters), one and multi-step ahead prediction control, minimum variance, pole placement, LQG control, model reference adaptive control. *Prerequisite:* ME 671. Also listed under EL826.

ME 872 Stochastic Control 2½:0:3

Introduction to stochastic control, stochastic processes, covariance and spectral density, stochastic state models, spectral factorization of continuous or discrete time processes, parametric optimization, introduction to prediction and filtering theory. *Prerequisite:* ME 771. Also listed under EL827.

ME 873 Large Scale Systems and Decentralized Control 2½:0:3

Introduction to analysis and synthesis of large scale systems. System order reduction algorithms, interconnected system stability, series expansion and singular perturbation. Decentralized control: decentralized fixed modes, LQR, frequency shaped cost functional, and overlapping decompositions. *Prerequisite:* ME 771. Also listed under EL825.

MANUFACTURING

For the primary listings in this area, refer to the "Manufacturing Engineering" and "Industrial Engineering" sections of the Catalog. Also, refer to ME615 and ME616 in the Thermal and Fluids section, and ME657-658 in the Mechanical Analysis and Design section.

SELECTED TOPICS, SEMINAR, PROJECTS, THESIS, AND DISSERTATION

ME 786-787 Special Topics 2½:0:3

These numbers are reserved for special topics which are offered periodically by the ME Program and are open to first year graduate students. When offered, the specific subject matter is indicated as part of the title after the words "Special Topics:", and the more complete title appears on the student's transcript. *Prerequisites are tailored to the offering.*

ME 886-887 Advanced Topics 2½:0:3

These numbers are reserved for advanced topics which are offered periodically by the ME Program and are open to second year and more advanced graduate students. When offered, the specific subject matter is indicated as part of the title after the words "Advanced Topics:", and the more complete title appears on the student's transcript. *Prerequisites are tailored to the offering.*

Offerings in the advanced topics might include kinematic synthesis of mechanisms, thermal stress analysis, nonharmonic and random vibrations, vibrations of space structures, vibrations of plates and shells, and continuum mechanics.

ME 901-904 Guided Readings I, II, III, IV each 3 units

Open to qualified graduate students interested in special advanced topics. Directed study including analytical work and/or laboratory investigations. *Prerequisite: written permission of department head.*

ME 991-992 Seminar in Mechanical Engineering 0

Recent developments through lectures by representatives from industry, research, educational institutions. Discussions from floor. Satisfactory attendance required of master's or engineer students for two semesters; four additional semesters required for Ph.D. students.

ME 996 M.S. Project each 3 units

Engineering project pursued with guidance of faculty member. Project titles submitted in writing to department head and appointed advisor. May be extended to thesis with project advisor's recommendation. Credit only upon completion of project. Re-registration fee: 3-unit charge. *Prerequisite: degree status.*

ME 997 M.S. Thesis each 3 units

Master's thesis to present results of original investigation in field of student's specialty. Thesis an extension of ME 996, on recommendation of project advisor. Continuous registration required. Maximum of twelve units of ME 996-997 counted toward degree. Re-registration fee: 3-unit charge. *Prerequisite: ME 996.*

ME 998 Engineer Project each 3 units

Analytical, experimental, or design project under guidance of faculty member. Oral examination on project and related topics required of candidates. Continuous registration required until satisfactory project completed. Minimum of six, maximum of twelve units of ME 996-997 counted toward degrees. Re-registration fee: 3-unit charge. *Prerequisite: post-master status.*

ME 999 Ph.D. Dissertation each 3 units

Doctor's dissertation evincing independent study and original contributions in field of specialization. Oral examination on subject of dissertation and related topics required. Minimum of 24 units; also continuous registration at minimum of 3 units per semester required until dissertation completed. Re-registration fee: 3-unit charge. *Prerequisite: degree status.*

The following graduate courses are offered on an irregular basis in response to student demand:

- ME 633 Limit Analysis of Structure
- ME 635 Pressure Vessel Analysis
- ME 657 Computational Geometry for CAD
- ME 658 Computer Aided Design
- ME 723 Experimental Stress Analysis
- ME 725 Theory of Plates
- ME 726 Theory of Shells
- ME 733 Applied Plasticity
- ME 821 Continuum Mechanic
- ME 831 Stability of Structures

FACULTY

William R. McShane, P.E., Professor of Industrial and System Engineering; Head, Department of Mechanical and Industrial Engineering; Director, Transportation Training and Research Center. B.E.E., Manhattan College; M.S., Ph.D., Polytechnic Institute of Brooklyn. *Quality control, controls and simulation, engineering economics, laboratory development.*

Anthony E. Armenakas, P.E., Professor of Mechanical and Aerospace Engineering B.S., Georgia Institute of Technology; M.S., Illinois Institute of Technology; Ph.D., Columbia University. *Dynamic analysis of structures, fracture, wave propagation, numerical techniques.*

Charles W. Hoover, Jr., Professor of Manufacturing Engineering B.E.M.E., Yale University; B.S.E.E., Massachusetts Institute of Technology; M.S., & Ph.D., Yale University. *Physical Design, manufacturing processes, electronic device assembly.*

Murray Imber, P.E., Professor of Mechanical Engineering B.S., University of Illinois; M.S., Eng. Sc.D., Columbia University. *Energy conversion, heat transfer, applied mathematics.*

Jerome M. Klosner, P.E., Professor of Mechanical and Aerospace Engineering B.C.E., City College of New York; M.S., Columbia University; Ph.D., Polytechnic Institute of Brooklyn. *Structural dynamics, fluid-structure interaction, thermal stress analysis.*

Frank J. Romano, P.E., Professor of Mechanical Engineering and Administrative Officer B.M.E., M.S., Ph.D., Polytechnic Institute of Brooklyn. *Solid mechanics, structures, thermodynamics.*

Bernard W. Shaffer, P.E., Professor of Mechanical Engineering; B.M.E., CCNY; M.S., Case Institute of Technology; Ph.D., Brown University
Rational design, elasticity, plastic stress analysis.

William P. Vafakos, P.E., Professor of Mechanical Engineering
B.M.E., M.M.E., Ph.D., Polytechnic Institute of Brooklyn;
J.D., Brooklyn Law School
Solid mechanics, structures, vibrations.

Richard S. Thorsen, Associate Professor of Mechanical Engineering
Dean of Research and Graduate Studies.
B.M.E., City College of New York;
M.M.E., Ph.D., New York University
Heat transfer, nuclear reactor safety, solar energy, CAD.

Sunil Kumar, Assistant Professor of Mechanical Engineering
B.Tech., Indian Institute Technology; M.A. & M.S., State University of New York (Buffalo); Ph.D. University of California (Berkeley).
Thermal fluid sciences, applied mathematics.

M. Karim Moallemi, Assistant Professor of Mechanical Engineering
B.S.M.E., Pahlavi University;
M.S.M.E., Ph.D., Purdue University
Experimental and computational heat transfer, fluid mechanics, energy conversion, combustion.

Anthony P. Tzes, Assistant Professor of Mechanical Engineering
B.S.E.E., University of Greece;
M.S.E.E., Ph.D., Ohio State University
Robotics, adaptive control, computer integrated manufacturing, artificial intelligence, neural networks.

George C. Vradis, Assistant Professor of Mechanical Engineering
Dipl. ME, Nat'l. Tech. University (Greece); M.S., Ph.D. Polytechnic University
Fluid/thermal studies, unsteady flows, energy transfer.

Terance Kinsky, Instructor of Mechanical Engineering
B.S.M.E., University of Maryland
Engineering graphics, computer aided engineering, manufacturing applications.

Raresh Pascali, Instructor of Mechanical Engineering; B.Ae.E., Polytechnic University
Computer graphics, CAD/CAM, stress analysis.

EMERITUS FACULTY

Philip Abrami, Associate Professor Emeritus
B.M.E., M.S., Polytechnic Institute of Brooklyn

William B. Blesser, Professor Emeritus
B.M.E., Rensselaer Polytechnic Institute; M.E.E., Polytechnic Institute of Brooklyn

Martin H. Bloom, Institute Professor
B.M.E., M.S., Ph.D., Polytechnic Institute of Brooklyn

Robert Corry, Associate Professor Emeritus
A.B., Columbia College; B.S., M.S., Ph.D., Columbia University

John R. Curreri, Professor Emeritus
B.M.E., M.E.E., Polytechnic Institute of Brooklyn, Adelphi University

Joseph Kempner, Professor Emeritus
B.Ae.E., M.Ae.E., Ph.D., Polytechnic Institute of Brooklyn

Wheeler K. Mueller, Jr., Professor Emeritus
B.S., Iowa State College; M.S., Ph.D., University of Illinois

Huo-Hsi Pan, Professor Emeritus
B.S., National Southwest Associated University (China); M.S., Texas A&M; M.S., Kansas State University; Ph.D., University of California (Berkeley)

Sharad A. Patel, Professor Emeritus
B.Sc., Benares Hindu University; M.Ae.E., Ph.D., Polytechnic Institute of Brooklyn

ADJUNCT FACULTY

Robert Atkatsch, Adjunct Lecturer
B.C.E., City College of New York;
M.S., Harvard University;
Ph.D., Columbia University
Numerical analysis, finite elements, plasticity.

Subramani Rajaram, Adjunct Professor
B.E. Bangalore University (India);
M.A.Sc., University of Waterloo (Canada); Ph.D. State University of New York at Buffalo
Heat transfer and thermal design.

Bernard Roth, Adjunct Lecturer
B.M.E., M.S., City College of New York
Mechanics, mechanics of materialism.

NOTES

1. Students who are interested in applied mechanics but do not meet the requirements of "comparable background" may pursue the MS(Applied Mechanics) or Engineer(Applied Mechanics) degrees. The degree requirements are comparable to the ME degree in the solid mechanics area. Interested students should consult the departmental academic advisor.
2. Students with a very strong undergraduate background in stress analysis are encouraged to discuss waiving this requirement with their advisor. In its place, the student would take ME 721-722 (Elasticity I-II). Any student eligible for ME 721-722 on this basis is also immediately eligible to take courses which have ME 621-622 as prerequisites.
3. In these cases, note that the MS degree itself requires a strong background in mechanical engineering core courses on the BS level.
4. The minors are each 12-15 units of graduate study, and are generally chosen to strengthen the student's ability to pursue the dissertation work. They are developed in concert with the graduate advisor and/or dissertation advisor. At least one minor must be within the ME Program. See the "Set of Guidelines" for illustrations of approved minors.

OPERATIONS RESEARCH

The Department of Mechanical and Industrial Engineering offers programs in operations research at the master's and doctoral levels.

This curriculum encompasses the related fields of operations research and management science. It is directed toward the analysis and design of managerial systems comprised of human, technological and economic resources.

Operations analysts address themselves to problems of production, distribution, marketing, industrial and governmental operations, public planning and services, and military analysis. Their services are sought by all levels of government, public agencies, industry and non-profit research organizations.

Operations research is concerned with the development and application of advanced analytical techniques to the operation of complex systems and the optimal allocation of resources. The last few decades have witnessed increasing use of mathematical models in nearly all fields. Trained professionals are needed who can play important roles in the development of quantitative models and solution techniques for challenging problems.

Operations researchers address problems in production, distribution and marketing, allocation of urban resources, and industrial and government operations. 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 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.
- Evaluate proposed traffic control procedures
- Measure the effectiveness of advertising and marketing policies
- Evaluate effectiveness of urban solid waste collection and removal systems
- Develop computer simulations of man-machine systems
- Study the effects of feedback and automation in society and industry
- Analyze the behavior of queues in computer and communications systems

Operations researchers seek to allocate limited resources in an optimal manner. A unifying theme focusing this body of knowledge and methods into a coherent entity is the system point of view. The search for similarity among concepts, laws and models of different disciplines, the emphasis on the adaptation, integration and exploitation of existing techniques in areas other than their fields of origin, and, above all, a unique point of view dealing with relationships rather than with components - these characterize this orientation.

Students may pursue graduate studies in specialized areas such as system simulation, management science, mathematical programming, production engineering, production and inventory models, queuing theory and applications, reliability and maintainability.

Certificate programs are available for more limited graduate study in a wide range of specialized topics.

Graduate students come with diverse academic training. Most professionals in these areas of specialization receive the major part of their training at the graduate level. One ingredient common to our students is the desire to develop techniques for problem-solving and decision-making in a technological world.

LABORATORIES AND COMPUTING FACILITIES

The departmental laboratories include computational and physical laboratories. The computational laboratory includes a CAEDS modeling on an eleven-station RT network, twelve PS/2 Model 70's, with a LAN and file server; this equipment was provided as part of the IBM CIM Alliance. The physical laboratories include scale computer numerical control (CNC) machines, two industrial robots, a controls and robotics laboratory, and related research facilities.

The laboratories are used in the work methods, simulation, manufacturing processes, robotics applications, and human factors courses. They are also available for graduate research.

The Simulation Lab has available programs including SIMSCRIPT, ProModel, SimFactory, and Xcell+ for coursework and research.

In the manufacturing area within the department, laboratory facilities are available for process and work flow methods, including applications of the LabView software to intelligent KanBan; activity-based costing for MRP using MAPICS; quality control and design of experiments using ATT QC Tool Kit, RS-Discover, and other programs; computer aided engineering using CADAM and CATIA.

MASTER OF SCIENCE DEGREE

The Polytechnic requirements for the Master of Science degree are stated in this catalog under "Degree Requirements." Detailed requirements for the M.S. (OR) are shown below.

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.

Admission to the program requires a bachelor's degree in science, math, engineering, or quantitative social science, from an accredited institution, with a superior undergraduate academic record. Applications should be made to the department with operations research indicated as the area of specialization.

Students are encouraged to seek waivers for all required courses in which they can demonstrate competence so that they can use their time most effectively.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE IN OPERATIONS RESEARCH

Prerequisites

All students must have taken a course in computer programming in their prior education, and have a working knowledge of a higher-level language such as FORTRAN, Pascal, Basic or C. Students who do not meet this prerequisite requirement must take CS530 or CS531 without credit.

Competence in calculus (equivalent to MA 103) is required.

Group A.

Basic Required Courses 0-9 units

All group A courses are required unless they are specifically waived by the advisor because the student either (a) has taken an equivalent undergraduate or graduate course, or (b) passes a validation examination for the course. Up to three group A

courses actually taken may be credited toward the degree requirements; if more than three must be taken, the degree requirements are increased accordingly.

Certain Group A courses will be waived if the student takes specified advanced courses, for which full credit is given.

For IE 627: IE 631 and IE 632

For IE 628: IE 650 and either

IE 618 or IE 619

For MA 153: MA 705 or MA 837

or MA 838

Full-time students who have not had the equivalents of MA 561 and/or MA 562 are urged to take these courses during the summer preceding their first term.

IE 600 *Engineering Economy*

IE 627 *Operations Research: Deterministic Models*

IE 628 *Operations Research: Stochastic Models*

MA 153 *Linear Algebra*

MA 561 *Elements of Probability*

MA 562 *Statistics*

Group B.

Required Courses 12 units

IE 631 *Linear Programming*

IE 632 *Non-Linear Programming*

IE 650 *Queueing Systems I*

IE 680 *Discrete System Simulation*

Group C.

Major Electives 12 units

Select four of the groups shown below, and take at least one course from each of the four groups. In some cases, a course may have a prerequisite which must also be satisfied.

Group C1

IE 682 *Factory Simulation*

IE 785 *Computer Integrated Manufacturing Systems*

Group C2

IE 611 *Quality Control and Improvement*

IE 685 *System Reliability*

Group C3

IE 618 *Inventory Models*

IE 619 *Production Planning & Control*

Group C4

IE 620 *Project Planning and Control*

IE 636 *Network Flows and Applications*

Group C5

MA 552 *Regression & ANOVA*

MA 555 *Design of Experiments*

MA 556 *Correlation and Multivariate Methods*

Group D.

Other Relevant Electives 3-12 units

Group D electives are chosen with advisor's approval to bring total units to 36 plus any excess of group A courses beyond 9 units. They may include thesis, additional courses from group C, or other graduate courses in this or other departments. Because of substantial overlap with IE courses, no credit will be given for MG 502, MG 503, MG 505 and MG 630.

Minimum total: 36 units

THE DOCTOR OF PHILOSOPHY DEGREE

The department offers a program leading to the degree of doctor of philosophy in operations research and industrial engineering.

The Ph.D. is a research oriented degree. The student's dissertation is expected to represent an original piece of research advancing the state-of-the-art in the field. Current research areas of the faculty include manufacturing methods, modeling of production systems, human resources development, telecommunications, health care, mathematical programming, and stochastic systems.

Applicants generally must have a master's degree, with a GPA of at least 3.5, from an accredited institution in an area of mathematics, science, engineering, or quantitatively oriented social science.

The general Polytechnic requirements for doctor of philosophy degrees are stated in this catalog under Degree Requirements. Specific requirements for the doctoral program may be found in the department's doctoral student's manual.

Entrance to doctoral candidacy is contingent on passing the qualifying examination. This consists of the Part I preliminary written examination, and the Part II major field written examination; an oral examination may also be required.

The doctoral program requires a minimum of 90 units beyond the bachelor's degree, including a minimum of 24 units of dissertation. No more than 30 units of dissertation may be counted in the minimum total.

The course work for the Ph.D. must include all the coursework necessary to satisfy the M.S.(IE) or the M.S.(IE).

During the Ph.D. studies, the student must register for IE920 at least once per academic year.

After passing the written qualifying examination, the candidate selects a thesis advisor and prepares a formal proposal for the dissertation research. A thesis committee is then appointed to judge the merits of the proposed research. After approval of this proposal, the doctoral candidate registers for research. On completion of the dissertation, the candidate must pass an examination in its defense. Dissertation grades of U in two consecutive terms will be cause to reconsider whether the student will be permitted to continue doctoral work.

CERTIFICATE PROGRAMS

The department offers certificate programs designed for the professional with work experience. A certificate program requires five courses, which are selected in accordance with the needs of the individual. Applicants for a certificate program must hold a bachelor's degree. On completion of the sequence with a B average or better, the student is issued a certificate. Students who later are admitted to study for a master's degree are usually able to apply all certificate courses toward the master's degree.

If a student has taken the equivalent of any required courses as an undergraduate, or more than one as a graduate student, then substitute courses must be selected in consultation with the advisor. Additional information may be obtained from the department.

The certificate programs are shown below. Additional certificates are shown in the Industrial Engineering catalog.

Basic Operations Research

- MA 153 Elements of Linear Algebra
- MA 561 Elements of Probability
- MA 562 Statistics
- IE 627 Op.Res.: Deterministic Models
- IE 628 Op.Res.: Stochastic Models

Advanced Operations Research

- IE 631 Linear Programming
- IE 650 Queuing Systems I
- IE 680 System Simulation
- Two of the following:
- IE 618 Inventory Models
- IE 619 Production Planning & Control
- IE 632 Nonlinear Programming

Mathematical Programming

- IE 631 Linear Programming
- IE 632 Nonlinear Programming
- Three of the following:
- IE 633 Integer Programming
- IE 634 Dynamic Programming
- IE 635 Advanced Linear Programming
- IE 720 Optimum Seeking Methods
- IE xxx Approved elective

GRADUATE COURSES

All graduate lecture and laboratory courses in Operations Research are listed in the Industrial Engineering section of this catalog.

OR 930-931 Readings in Operations Research I,II each 3 units

Individual reading of selected papers and current literature in specialized area of study, guided by faculty member. *Prerequisites: approval of advisor, instructor 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, advisor and department head.*

OR 999 Dissertation for Degree of Doctor of Philosophy each 3 units

Doctoral dissertation must give evidence of and embody results of extended research in a specific field of operations research, constituting original contribution. Candidate required to take oral examination on subject of thesis and on related topics. Minimum of 24 units required. *Prerequisites: passing of qualifying examination and guidance committee's approval.*

FACULTY

William R. McShane, P.E., Professor of Transportation and Industrial Engineering; Head, Department of Mechanical and Industrial Engineering; Director, Transportation Training and Research Center; B.E.E., Manhattan College; M.S., Ph.D., Polytechnic Institute of Brooklyn; Professional Engineer (New York, California (Traffic))

Traffic engineering, highway capacity, expert systems in transportation, PC applications and models, economics and finance

Ivan T. Frisch, Professor of Electrical Engineering and Computer Science and Provost

B.S. (Physics), Queens College; B.S. (EE), M.S. (EE), Ph.D. (EE), Columbia University

Information systems, computer networks and network control

Walter Helly, Professor of Operations Research; B.A., Cornell University; M.S., University of Illinois; Ph.D., Massachusetts Institute of Technology
Stochastic modeling, tele- and vehicular traffic, urban systems

Richard Van Slyke, Professor of Electrical Engineering and Computer Science and Director of the Center for Advanced Technology in Telecommunications
B.S., Stanford University; Ph.D., University of California (Berkeley)

Computer communications, telecommunications

Joachim I. Weindling, P.E., Professor of Operations Research and System Engineering, and Director of Operations Research Program

B.M.E., City College of New York; M.S., Ph.D., Columbia University; Professional Engineer (New York, Pennsylvania)

Mathematical programming, optimum design, economic evaluation

Ravinder Nanda, Associate Professor of Industrial Engineering and Operations Management

B.Sc., Banaras Hindu University (India); M.S., Ph.D., University of Illinois
Production and operations planning, productivity analysis, project control

ADJUNCT FACULTY

Maureen Dolan, Adjunct Assistant Professor; B.A., Molloy College; M.S., Stevens Institute of Technology; M.S., Ph.D., Polytechnic University
Operations research models, solar energy systems

John Zuk, Adjunct Lecturer in Industrial and Manufacturing Engineering; B.M.E., Union College; M.S. (IE), Polytechnic University
Modeling of manufacturing systems, computer simulation, robotics

POLYMER SCIENCE AND ENGINEERING

For many years, Polytechnic University has had a traditional commitment to strong polymer programs of worldwide renown. At the present time, the Departments of Chemical Engineering and Chemistry jointly offer graduate programs leading to the degrees of master of science and doctor of philosophy in polymer science and engineering.

ADMISSION TO GRADUATE STUDY

An undergraduate degree in either chemical engineering or chemistry with a mathematics background which includes at least one course in differential equations is usually required for admission to the graduate program. Applicants who have earned bachelor's degrees from foreign institutions are required to submit Graduate Record Examinations and TOEFL scores. Applicants with degrees in other fields or from other colleges may be admitted with undergraduate or graduate deficiencies after the consent of a graduate advisor is given.

The program leading to the degree of master of science is designed to meet the needs of engineers and chemists well versed in the fundamental principles of polymer science and engineering.

REQUIREMENTS FOR THE DEGREE MASTER OF SCIENCE IN POLYMER SCIENCE AND ENGINEERING

Candidates for the degree of Master of Science in Polymer Science and Engineering are to plan their programs in accordance with the following required courses:

No.	Course	Units
CH 921	<i>Polymer Processing</i>	3
CH 922	<i>Polymer Processing Laboratory</i>	3
CH 926	<i>Engineering Properties of Polymers</i>	3
CM 771	<i>Introductory Polymer Chemistry</i>	3
CM 783	<i>Laboratory Methods in Polymer Chemistry</i>	3
CH 991-992	<i>Seminar</i>	0

Guided Study/Thesis Option

<i>Either</i>		
CH 930	<i>Guided Studies in Polymer Science and Engineering</i>	6
<i>Electives</i>		15
<i>or</i>		
CH 997	<i>Thesis for Degree of Master of Science in Polymer Science and Engineering</i>	12
<i>Electives</i>		9

As electives, any graduate courses in Chemistry and Chemical Engineering may be chosen. The approval of the graduate advisor will be needed in order to take courses in other disciplines.

<i>Total</i>	<i>36</i>

To meet graduate requirements, students must have an overall B average in all courses and must not obtain more than three grades of C in required subjects.

REQUIREMENTS FOR THE DEGREE DOCTOR OF PHILOSOPHY IN POLYMER SCIENCE AND ENGINEERING

The program for the degree of doctor of philosophy in polymer science and engineering includes advanced graduate work for qualified students interested in research and development. Students enrolled in the program may select elec-

tive courses either from polymer chemistry or from polymer engineering offerings. Polymer science and engineering may also be chosen as a minor by students in the chemistry department or the chemical engineering department.

Programs of study are planned individually with each candidate by members of the Departments of Chemical Engineering and Chemistry. Systematic study toward the Ph.D. is carried out under the direction of a guidance committee appointed by the dean of research and graduate studies for each candidate. The program is planned to give students a thorough polymer science and engineering background accompanied by study in a minor field chosen by the candidate. Students must pass a comprehensive qualifying examination in polymer science and engineering and present a doctoral dissertation.

Each candidate for the doctorate must complete a minimum of 90 units of academic work beyond the Bachelor's Degree, including a minimum of 48 units of dissertation research. Although the student may elect to take more than 48 units of Ph.D. thesis, only 48 units of Ph.D. thesis can be counted in the required 90 unit minimum, and these must be taken at Polytechnic. A minimum of 24 graduate units beyond the Bachelor's degree (not including Ph.D. or M.S. Thesis units) are required in Polymer Science and Engineering subjects, of which at least 9 must be taken at the Polytechnic in the required subjects. A minor is required within a science or engineering department and must consist of at least 9 units taken at the Polytechnic. The minor must meet the approval of the graduate advisor in polymer science and engineering.

Once the student has started the dissertation, registration must be continuous (excluding summer sessions) until it is completed and accepted.

Attendance is required at Chemical Engineering Seminars for at least four semesters. To meet graduation requirements, students must have an overall B

average in all courses, excluding Thesis, and must not obtain more than three grades of C in required subjects.

Candidates for the degree of Doctor of Philosophy in Polymer Science and Engineering are to plan their programs in accordance with the following requirements:

No.	Course	Units
CH 921	<i>Polymer Processing</i>	3
CH 922	<i>Polymer Processing Laboratory</i>	3
CH 926	<i>Engineering Properties of Polymers</i>	3
CH 771	<i>Introductory Polymer Chemistry</i>	3
CH 781	<i>Solution Properties of High Polymers</i>	3
CH 782	<i>Macromolecules in the Solid State</i>	3
CH 783	<i>Laboratory Methods in Polymer Chemistry</i>	3
CH 772	<i>Synthesis of High Polymers</i>	3
CH 991-92	<i>Seminar in Chemical Engineering</i>	0
Electives:	3 courses	9
Any graduate courses in Chemistry and Chemical Engineering may be chosen. The approval of the graduate advisor will be needed in order to take courses in other disciplines.		
Minor:	3 courses	9
A minor must be taken in another science or engineering department with the approval of the graduate advisor in Polymer Science and Engineering.		
CH 989	<i>Dissertation for Degree of Doctor of Philosophy in Polymer Science and Engineering</i>	48
Up to twelve units of Master's Thesis can be included here.		
Total		90

Students interested in the Ph.D. program should obtain brochures outlining procedures and requirements, available from the office of the polymer science and engineering program director.

GRADUATE COURSES

CH 862 Rheology of Non-Newtonian Fluids 2½:0:3

Classifications of non-Newtonian viscoelastic fluids. Derivation of rheological equations of state from continuum mechanics points of view. Molecular viscoelastic theories will be discussed. Experimental characterizations of non-Newtonian fluids; steady and dynamic experiments, measurements of normal stress differences in shear flow. Engineering applications to polymer processing operations. *Prerequisites:* CH 631, MA 531 and MA 532 or equivalent.

CH 917 Introduction to Polymeric Materials 2½:0:3

Principles of technological aspects of polymerization, compounding and processing of polymeric materials, their properties and applications. Thermoplastic materials such as polyethylene, polypropylene, poly(vinyl chloride), polystyrene, acrylics and engineering plastics are discussed. Thermosetting materials covered include phenolics, epoxies, unsaturated polyesters, aminoplastics, polyurethanes and silicones. *Prerequisite:* CM 123 or equivalent.

CH 921 Polymer Processing 2½:0:3

Applications of engineering principles to polymer processing. Non-Newtonian polymeric systems. Extrusion theory and applications. Discussions and problem-solving in injection molding, fiber spinning, film blowing, and co-extrusion, as well as other polymer engineering processes. *Prerequisite:* CH 220 and CH 221 or instructor's permission.

CH 922 Polymer Processing Laboratory 0:4:3

Engineering principles and processes involved in polymer processing and analysis. Experiments include injection molding, extrusion, thermoforming, mixing and compounding, melt rheology, flat- and blown-film extrusion, blow molding. *Prerequisite:* CH 921.

CH 924 Polymerization Reaction Engineering 2½:0:3

Principles of polymerization reactions, such as chain polymerization and heterogeneous polymerization reactions, from engineering points of view, including mixing and thermal effects. Mathematical modeling techniques for describing molecular weight moments. Copolymer composition and sequence distribution. Principles of polymer reactor design. Model parameter estimation and reactor control. *Prerequisite:* CH 781 or equivalent.

CH 926 Engineering Properties of Polymers 2½:0:3

Mechanical properties and structures of solid polymers. Viscoelastic theory and response of amorphous, crystalline and composite materials in stress-strain, creep, stress relaxation and dynamic tests. Effects of orientation and previous history of mechanical behavior. *Prerequisites:* CH 917, CM 771.

CH 928 Polymer Composites 2½:0:3

Production, properties and durability of polymer composites. Emphasis on fiber-reinforced thermosets. Chemical compositions, cure kinetics, processing, viscoelasticity and fracture mechanics. Behavior of composites in service analyzed in terms of their structures. *Prerequisites:* CH 921, CH 926.

CH 933 Coatings Technology 2½:0:3

Chemistry, manufacture and applications of organic film formers; solvents and solubility principles; mechanisms and methods of film application, formation, conversion. Chemistry, manufacture and applications of pigments. Principles and methods of pigment dispersion and coatings preparation, including influence of rheology and surface chemistry. Principles of formulation of important paints and clear coatings. Specifications and test methods for coatings. *Prerequisite:* CM 123 or equivalent.

ENGINEERING

CH 940-941 Selected Topics in Polymer Science and Engineering, I, II each 2½:0:3

Topics of special interest in polymer science and engineering are announced in advance of each semester offering. *Prerequisite: advisor's approval.*

CM 771 Introductory Polymer Chemistry 2½:0:3

Synthesis of polymers by step reaction and addition polymerization, formation of three-dimensional networks, block and graft polymers, polymer degradation, characterization of polymers in solution, rubber elasticity, polymer crystallization, spectroscopic techniques for polymer study, properties of commercial polymers. *Prerequisites: CM 123, CM 125 and CM 162.*

CM 772 Syntheses of High Polymers 2½:0:3

Organic aspects. Chemistry of monomer and polymer formation. Modern mechanistic analyses of reactions. Stereochemistry of polymer structures and forces of stereoregulation. Condensation, free radical (bulk, suspension, emulsion, solution), ionic, ring-opening and non-classical 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. Synthetic and biological macromolecules are covered. *Prerequisites: CM 161, and CM 771 or CM 783.*

CM 782 Macromolecules in the Solid State 2½:0:3

Crystalline-amorphous systems, thermodynamics of crystallization, defect structures, morphology of polymer crystals. Characterization of polymeric solids by x-ray and electron diffraction, potential energy calculations, electron microscopy, absorption spectroscopy and nuclear magnetic resonance. Electrical and optical properties of polymer solids. *Prerequisite: CM 771.*

CM 783 Laboratory Methods of Polymer Chemistry 0:5:3

Experiments on free radical, condensation, ionic and copolymerization, absorption, and NMR spectroscopy, intrinsic viscosity, light scattering, gel permeation chromatography, x-ray diffraction, thermogravimetric analysis, differential scanning calorimetry, dilatometry, concentrated solution viscosity, and other aspects of polymer synthesis and characterization. Lab fee required. *Prerequisite: CM 771.*

CM 785 Special Topics in Polymer Chemistry 2½:0:3

Presentation at intervals of various advanced or specialized topics in polymer chemistry.

PROJECTS, THESES AND SEMINARS

CH 930 Guided Studies in Polymer Science and Engineering 6 units, each 2 units

Presentations of a comprehensive report of some problem involving polymer science and engineering, such as polymer synthesis, processing, evaluation, or equipment design is required. Candidates for master's degree are required to submit three unbound copies of typewritten project report to advisors one week before last day of classes. *Prerequisite: degree status.*

CH 987 Thesis for Degree of Master of Science in Polymer Science and Engineering 12 units, each 3 units

Thesis for master's degree in polymer science and engineering should give results of original investigations of problem in polymer science and engineering. Theses may involve experimental research, theoretical analyses, or process designs, and possibly a combination thereof. Candidates for master's degree are required to submit four typewritten unbound thesis copies to advisors before or on seventh Wednesday prior to commencement. *Prerequisite: degree status.*

CH 989 Dissertation for Degrees of Doctor of Philosophy in Polymer Science and Engineering 48 units, each 3 units

Dissertation must give results of independent investigations of problem in polymer science and engineering and may involve experimental and/or theoretical work. Thesis must show original contributions to polymer science and engineering worthy of publication in recognized journals. The candidate is required to take an oral examination on subject of thesis and on related topics. Candidates for a doctoral degree are required to submit five unbound thesis copies to advisors before or on the seventh Wednesday prior to commencement. *Prerequisite: degree status and a qualifying examination on quantitative aspects of polymer science and engineering.*

CH 991-992 Seminar in Chemical Engineering 0:2½:0

Recent developments in the field of chemical engineering or polymer science and engineering will be presented through lectures given by experts from industry, research, and educational institutions, by staff members, or by qualified graduate students. Required for two semesters of all graduate students seeking degrees.

FACULTY

Chang Dae Han, University Professor,
Director of Polymer Science and Engineering Program

Mark M. Green, Professor of
Chemistry

T.K. Kwei, Professor of Polymer
Chemistry

Yoshiyuki Okamoto, Professor of
Chemistry

Eli M. Pearce, University Professor
Director, Polymer Research Institute

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

Guiliana Tesoro, Research Professor of
Chemistry

Otto Vogl, Herman F. Mark Professor
of Polymer Science

Mary K. Cowman, Associate Professor
of Biochemistry

Jovan Mijovic, Associate Professor of
Chemical Engineering

Kale Levon, Assistant Professor of
Chemistry

SYSTEMS ENGINEERING

Systems engineering is based on the body of theoretical knowledge that underlies the engineering of modern complex systems. Systems 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 systems engineer may receive assignments crossing traditional lines of engineering applications. Systems engineering is presently applied in areas such as transportation, urban services, bioengineering, resource management, power and energy, and environmental and pollution control.

The program in systems 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 computers. The systems 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 administers the program leading to the degrees of master of science, and engineer in systems engineering. Outstanding students should apply for financial aid in the form of research fellowships, teaching fellowships or partial tuition remission.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE

The entrance requirement for the master of science in systems engineering is a bachelor's degree in engineering or science from an accredited institution, with a superior undergraduate record, including undergraduate courses in differential equations, probability, linear systems, feedback control and computer programming. Students with deficiencies in these areas may be admitted if they take appropriate introductory courses, to remove these deficiencies.

To satisfy the requirements for the M.S. in systems engineering degree, the student must complete a total of 36 units of courses, as described below. An overall grade average of B in all courses is required by the University. In addition, a B average is required in specific groups of courses, as indicated below.

1. Core Courses

Three courses from among the following:

EL 531	<i>Probability</i>
EL 610	<i>Linear Systems</i>
EL 611	<i>Signals, Systems and Transforms</i>
EL 613	<i>Applied Matrix Theory</i>
EL 621	<i>Feedback Control I</i>
MA 861	<i>Statistical Inference I</i>

9 Units

2. Two approved one-year sequences, which may include the above courses. At least one of these sequences must be in EL or CS courses.

6-12 Units

3. Approved electives.

21-15 Units

Total: 36 Units

A complete course of study, including the choice of the one-year sequences, should be arranged in consultation with an advisor. A master's thesis of 9 units may be included as part of the elective courses. At least 24 of the 36 units must be in courses in engineering subjects, computer science or operations research, and at least 18 units must be in EL or CS prefixed courses.

An overall B-average is required in the combination of five to seven courses offered to satisfy categories (1) and (2) in the above table.

The EE Department *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 systems engineering degree must have a program of study approved by an advisory committee. This program must contain a minimum of 72 units beyond the B.S. degree, and the candidate must have satisfied the requirements for a master's degree in systems 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.

GRADUATE COURSES

SE 997 Thesis for Degree of Master of Science in Systems Engineering *each 3 units*

Independent engineering project, demonstrating professional maturity, performed under guidance of advisor. Oral thesis defense and formal, bound thesis volume required. Registration of 9 units required (continuous thesis registration required). *Prerequisite: Degree status.*

SE 998 Project for Degree of Engineer in Systems Engineering *each 3 units*

Comprehensive planning and design of engineering project under guidance of faculty advisor. Emphasis on up-to-date techniques. Oral examination and formal, bound report required. Scope of projects is 6-12 units by prior agreement with advisor (continuous project registration required). *Prerequisite: Degree status.*

FACULTY

Joseph J. Bongiorno, Jr., Professor of Electrical Engineering

Richard A. Haddad, Associate Professor of Electrical Engineering

Walter Helly, Professor of Operations Research

Farshad Khorrami, Assistant Professor of Electrical Engineering

William R. McShane, Professor of Industrial and Systems 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

Peter Voltz, Assistant Professor of Electrical Engineering

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

Dante C. Youla, University Professor

TRANSPORTATION

Polytechnic offers graduate degree programs in transportation, leading to the degrees of:

Master of Science

- *Transportation Planning and Engineering*
- *Transportation Management*

Engineer's Degree

- *Transportation Engineering*

Doctor of Philosophy

- *Transportation Planning and Engineering*

The MS degrees are practice-oriented, with a strong foundation in underlying principles and methods. The MS (Transportation Management) is available only to part-time students.

The Transportation Program is housed within the Department of Civil and Environmental Engineering, which also provides a program in highway engineering as part of the master's degree in civil engineering.

Students and continuing professionals from a variety of disciplines undertake studies in transportation to lead to careers in transportation operations, design, planning, or management. Some may choose to pursue this in a dual degree program which can also lead to a Master of Urban Planning or a Master of Public Administration at New York University.

For those oriented to planning or engineering careers, the Polytechnic transportation programs have a strong foundation in traffic engineering, transportation planning, and public transportation. Students may structure degree programs to build on this, emphasizing transportation infrastructure, computer aided engineering, or facility design and operations.

For those oriented to management careers, Polytechnic transportation programs have strong foundations in trans-

portation principles, economics and finance, and transportation policy and management. Students may concentrate in public or private sector management, and emphasize transit maintenance, logistics, or productivity management.

The primary goal of the academic program is to educate transportation planners, engineers and managers who are able to plan, functionally design and control facilities and systems which satisfy the demand for both passenger and freight transportation services.

The program stresses multi-modal approaches to transportation and maintains strong course offerings in:

- Highway and Traffic Engineering
- Public Transportation
- Transportation Planning
- Transportation Safety
- Freight Transportation
- Transportation Management, and
- Economics

Students are exposed to an atmosphere that provides a meaningful integration of practical and theoretical approaches. Classroom presentations, laboratory experiences, and practical problem solutions strengthen the overall education.

GENERAL REQUIREMENTS

ADMISSION REQUIREMENTS

To be eligible for admission as graduate students, applicants must hold at least a baccalaureate degree from an acceptable institution. Students pursuing the "transportation planning and engineering" degrees are expected to have the stronger quantitative background, usually with prior degrees in engineering, mathematics, or the physical sciences.

Students are expected to have basic skills in English adequate for the prepa-

ration of reports and papers. Such skills are evaluated in appropriate courses together with technical material. All foreign students admitted to the transportation programs are required to take an examination in English before registration. Based upon evaluation of that examination, they may be required to take one (in rare cases, two) additional courses in English as a second language for which no graduate credit is given.

GRADE REQUIREMENTS

To earn graduate degrees or certificates, Polytechnic requires that students have 3.0 grade point averages or better in all graduate courses and in all guided studies (readings, projects, theses, dissertations). Averages are separately computed for courses and guided studies. Transfer credits from other institutions are not included in these averages.

In addition to Polytechnic grade requirements, the transportation programs require overall averages of B or better in all required courses taken toward all degrees. Students may not repeat a course toward any of the transportation degrees more than once.

ANALYTIC BACKGROUND

All applicants for Master of Science degrees must show evidence of analytic ability, generally including two years of college mathematics and some exposure to statistics.

All applicants for certificate programs must meet the same entrance requirements as Master of Science applicants.

All applicants for the Engineer and Ph.D. degrees are expected to have a solid analytic background. They must take at least one course in graduate level statistics, regression analysis, or design of experiments as part of their studies.

COMPUTER LITERACY

Students will be exposed to uses of computers and computer packages in transportation integrated into the curricula. Emphasis is on personal and micro-computers. Students will use packages in highway capacity, traffic signal timing and coordination, and transportation assignment (MINUTP, TRANSPLAN, TRANSCAD, and MAPINFO) in required coursework. The Department has its own computer laboratory, using IBM and IBM compatible micro-computers. Students also have access to Polytechnic's CAD/CAM system and personal computer laboratories.

ADVISING

In all graduate programs, the relationship between the student and the academic advisor is important. The academic advisor assists students in selecting courses, and gives guidance in all academic matters. The academic advisor maintains checks on student's progress, and makes recommendations when problems arise. The department head assigns academic advisors.

Students should meet with their academic advisor prior to each registration, and at any other time they need advice or consultation. The student must have a detailed Program of Study formally approved by the academic advisor prior to registration. Advisors also handle requests for waivers of certain degree requirements, such as required courses. Such waivers must be approved in writing by advisors and instructors of required courses, and must be entered into students' departmental files. When such waivers are granted, students may be required to take other specific courses in their place, or to select additional electives.

Students registering for any guided studies (readings, project, thesis, dissertation) are assigned project advisors for each such activity. These are generally not the same as academic advisors, depending upon the subjects being studied. To register for guided studies, students must submit written proposals of the topics to appropriate project advisors and have academic advisors' written approval.

Doctoral students are not permitted to register for dissertation until they have passed the Ph.D. qualifying examination.

Students studying under research fellowships are assigned research advisors, normally the principal investigators of the projects which fund the fellowships.

While academic advisors consult with and give advice to students, students must ensure that requirements are fulfilled and submit all proper forms and applications when necessary.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREES

The Transportation Program has M.S. degrees in transportation planning and engineering, and transportation management each require 36 units, of which 27 must be taken in Polytechnic graduate courses.

Twelve units are in a common core shared by the two M.S. degrees. Each M.S. degree has an additional twelve units of required courses, suited to the orientation of the degree. The remaining twelve units is completed by electives approved by the assigned academic advisors.

Full-time students, particularly those studying under research fellowships, may be required to do a project for which they receive three or more units as part of their electives.

Common Core		Units
TR 600	Characteristics of Transportation Demand and Systems	3
TR 629	Transportation Workshop	3
TR 750	Transportation Economics and Finance	3
TR 759	Transportation Policy and Decision Making	3
		12

Other M.S. (TP&E) Requirements

TR 601	Travel Demand Forecasting	3
TR 701	Traffic Engineering I	3
TR 702	Traffic Engineering II	3
TR 710	Design of Traffic Facilities	3
		12

Other M.S. (TM) Requirements

TR 660	Public Transportation	3
TR 760	Management of Transit Maintenance and Operations	3
CE 828	Project Planning and Control	3
IE 645	Productivity Management	3
		12

Electives

All electives require approval of the assigned academic advisor, and are identified in two groups for each degree:

Elective Group A:

Students in each degree program must take at least three courses from this group, based upon electives shown below.

Depending upon transfer credits and the particular needs and backgrounds of students, Group A requirements may be modified by the concurrence of the academic advisor and the student.

Elective Group B:

Remaining electives may be taken from any courses shown below, from core courses for the "other" transportation M.S. degree, or from any other courses selected by the student and the academic advisor. These may include courses in other departments, or at other institutions suited to individual educational needs.

TRANSFER CREDITS

A total of 36 units is required for M.S. degrees in TP&E and in TM.

The residency requirement for M.S. degrees is 27 units, which means that a minimum of 27 units must be taken at Polytechnic. Students may transfer up to 9 units of acceptable courses from other institutions subject to the department's approval. Students may apply for transfer credits after they complete 12 units of appropriate graduate courses at Polytechnic. To be eligible for transfer credits, the courses in question must be relevant to the transportation program, and students must have received B's or better. Courses graded on a pass-fail basis are not considered for transfer credits unless detailed course evaluations from the instructors are provided. All transfer requests must be accompanied

ENGINEERING

by an official transcript from transferring institutions. Transfer credits are not included in computing grade point average. Validation credits by examination may not be used for any transportation degrees.

ELECTIVES FOR THE TRANSPORTATION M.S. DEGREES

Transportation Facility Design and Operation

		TP&E	TM
TR 660	Urban Public Transportation	x	
TR 670	Planning and Design of Terminals	x	
TR 665	Design of Rail Facilities	x	
TR 671	Airport Planning and Design	x	
TR 672	Port Planning and Design	x	
TR 722	Highway Pavement Design	x	
TR 723	Design and Management of Highway Structures and Materials	x	

Transportation Planning and Urban Planning

TR 602	Urban Transportation Planning	x	x
TR 603	Computer Applications and Analytic Techniques in Transportation	x	

Traffic Safety

TR 865	Traffic Safety Engineering	x	

Transportation Management - Private and Public Sectors

TR 754	Logistics Analysis	x	x
MG 601	Organizational Behavior	x	x
MG 613	Industrial Relations	x	x
MG 614	Collective Bargaining	x	x
CE 781	Analysis of Public Works	x	x
CE 830	Information Systems in Project Management	x	x

NOTE: THE "X" DENOTES A GROUP A ELECTIVE FOR THE PROGRAM.

DUAL DEGREE PROGRAM WITH NYU

The transportation program at the Polytechnic has a dual degree program with the Robert F. Wagner Graduate School of Public Service at New York University. Students may pursue an M.S. (transportation planning and engineering) or an M.S. (transportation management) at Polytechnic, and a Master of Urban Planning (MUP) or a Master of Public Administration (MPA) at NYU. Because of course waivers or advanced standing where appropriate, the two degrees may be obtained with some efficiencies in total units of study and in total time for two distinct degrees.

The two institutions also have an option in which students registered in any of the cited degree programs may take one or more courses from the pool of courses offered by the two cooperating institutions. Such registration is subject to prior approval by the academic advisor for the specific degree program in which students are enrolled.

Those interested in the Dual Degree Program must apply to that program specifically, by indicating this in a letter to the Polytechnic Transportation Program or to the NYU Robert F. Wagner Graduate School of Public Service, accompanied by application forms to both institutions. To aid in program planning, students are encouraged to apply initially, rather than to convert later to the Dual Degree Programs. Those already enrolled in one of the degrees cited, and interested in the Dual Degree Program, should consult their academic advisors.

REQUIREMENTS FOR THE ENGINEER DEGREE IN TRANSPORTATION ENGINEERING

Engineer degrees in transportation engineering are intended to be terminal degrees for those students wishing advanced practical education beyond the M.S. level. It requires 36 units of study beyond the M.S. (Transportation Planning and Engineering).

Engineer degree programs require all of the following prerequisites for admission:

1. An undergraduate degree in an engineering discipline from an accredited institution;
2. All required courses for the master of science in transportation planning and engineering, or their equivalent;
3. A master of science in transportation planning and engineering, or equivalent.

Students lacking any of these must fulfill the prerequisites in addition to the degree requirements listed below. Studies for Engineer's Degree must include at least one graduate level course in statistics, regression analysis, or design of experiments.

All students must complete the following courses:

No.	Class	Units
TR 602	Urban Transportation Planning	3
TR 670	Planning and Design of Terminals	3
CE 825	Project Planning and Control	3
TR 998	Engineering Project in Transportation	6
		15

In certain cases, an appropriate M.S. thesis (not project) or evidence of professional experience may be substituted for the engineering project, in which case 6 additional units of course work are required. Students must select 15 units of electives from among the following

courses and choose an additional 6 units approved by the academic advisors.

TR 603	<i>Computer Applications and Analytic Techniques in Transportation</i>	
TR 660	<i>Urban Public Transportation</i>	
TR 665	<i>Design of Rail Facilities</i>	
TR 671	<i>Airport Planning and Design</i>	
TR 672	<i>Port Planning and Design</i>	
TR 710	<i>Design of Traffic Facilities</i>	
TR 715	<i>Urban Goods Movement</i>	
TR 720	<i>Flexible Pavements: Design and Evaluation</i>	
TR 721	<i>Rigid Pavement: Design and Evaluation</i>	
TR 865	<i>Traffic Safety Engineering</i>	

<i>Central Electives</i>	<u>15</u>
<i>Additional Electives</i>	<u>6</u>
<i>Total beyond M.S.</i>	<u>36</u>

If any courses listed above are taken as part of a prior M.S. program, additional electives are chosen to achieve the required total of 36 units beyond the M.S. degree. All electives are subject to the approval of the student's academic advisor.

Residency requirements for the engineer degree are 27 units of study at Polytechnic beyond the M.S. degree. No more than 9 units of transfer credits may be awarded toward this degree.

DOCTOR OF PHILOSOPHY DEGREE IN TRANSPORTATION PLANNING AND ENGINEERING

The Ph.D. in transportation planning and engineering 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 including all courses required for the M.S. degree.
2. Two 15-unit minors in related areas, one of which is generally in quantitative methods. The second often focuses on a specific transportation area, such as transportation facility design, transportation management, or transportation infrastructure. The minors should support the dissertation topic.

3. A 30-unit dissertation, which must be an original piece of research which meaningfully advances an area of transportation study.

It must be stressed that these are minimum requirements. Many students, particularly those entering with advanced degrees in other fields, may require additional courses to support their dissertation development and to aid completion of the Ph.D. qualifying examination. Applicants to the Ph.D. program are urged to make appointments with Ph.D. program academic advisors for individual consultations and recommendations.

Before being permitted to register for dissertation units, candidates must pass a comprehensive Ph.D. qualifying examination. Given twice a year, usually in January and June, it consists of written and oral portions. Copies of previous examinations are available on request from the Program Office to aid the students in preparation for this examination.

Students normally take the qualifying examination after their first year of full-time coursework (or their part-time equivalent) is completed. All students who wish to take the examination are permitted to do so once they have discussed their interest with the academic advisor. Subsequent attempts are at the discretion of the Department; in no case are more than three attempts permitted.

There is no foreign language requirement.

The residency requirement for the Ph.D. is 30 units, which must include the dissertation. Candidates are, thus, only required to complete their dissertations at Polytechnic to earn degrees here. Any and all graduate courses taken at other approved institutions which are appropriate for either majors or minors may be transferred, provided they are of graduate level and that grades of B or better were achieved.

In support of dissertation research, a doctoral committee is formed to advise each student. Because of the interdisciplinary nature of transportation research, advisory committees often include faculty members from other departments. Outside committee members with suitable backgrounds are permitted, from other universities or from industry.

Once students register for dissertation units, they must meet several requirements. Dissertation registration

must be continuous (excluding summers) until work is completed. Leaves of absence must be formally requested from the Graduate Office. Students must submit and orally defend dissertation proposals before registering for a second full-time semester of dissertation work, or before going beyond 9 units of combined full-time/part-time dissertation study. At the end of each semester of registration, students must submit written progress reports to their dissertation advisors. Upon completion, dissertations must be presented and orally defended before the faculty.

CERTIFICATE PROGRAMS

The Transportation Program offers graduate certificates to students completing 15 units in concentrated subareas of transportation planning, engineering, or management. Certificate programs are geared to students who do not wish to commit themselves to full advanced degree programs. These may be students with bachelor's degrees who wish to specialize in other aspects of transportation, or those already holding advanced degrees who wish to develop additional specialties and receive formal certification for it. Students who enroll in certificate programs may apply for transfer to degree programs without loss of credits, assuming they are admitted to degree studies and that the courses taken are appropriate to the degree.

The Transportation Program offers the following certificates:

Traffic Engineering Certificate

Required: 15 Units

TR 701	<i>Traffic Engineering I</i>
TR 702	<i>Traffic Engineering II Plus three of:</i>
TR 603	<i>Computer Applications and Analytic Techniques in</i>
	<i>Traffic and Transportation</i>
TR 670	<i>Planning and Design of</i>
	<i>Terminals</i>
TR 710	<i>Design of Traffic Facilities</i>
TR 865	<i>Traffic Safety Engineering</i>

Transportation Planning Certificate

Required: 15 Units

TR 600	<i>Characteristics of Transportation Demands and Systems</i>
TR 601	<i>Travel Demand Forecasting</i>
TR 602	<i>Urban Transportation Planning</i>
TR 701	<i>Traffic Engineering I</i>
TR 603	<i>Computer Applications and Analytic Techniques in Transportation</i>

Transportation Facility Design and Operation Certificate

Required: 15 Units

TR 670	<i>Planning and Design of Terminals</i>
TR 701	<i>Traffic Engineering I</i>
TR 710	<i>Design of Traffic Facilities</i>

Plus two of:

TR 660	<i>Urban Public Transportation</i>
TR 665	<i>Design of Rail Facilities</i>
TR 671	<i>Airport Planning and Design</i>
TR 672	<i>Port Planning and Design</i>
TR 722	<i>Highway Pavement Design</i>
TR 723	<i>Design and Management of Highway Structures and Materials</i>

Public Transportation Certificate

Required: 15 Units

TR 660	<i>Urban Public Transportation</i>
TR 759	<i>Transportation Policy</i>
TR 760	<i>Management of Transit Maintenance and Operations</i>

Plus two of:

TR 600	<i>Characteristics of Transportation Demands and Systems</i>
TR 670	<i>Planning and Design of Terminals</i>
TR 750	<i>Transportation Economics and Finance</i>

Transportation Management and Economics Certificate

Required: 15 Units

TR 660	<i>Public Transportation</i>
TR 750	<i>Transportation Economics and Finance</i>
TR 759	<i>Transportation Policy</i>
TR 760	<i>Management of Transit Maintenance and Operations</i>

Plus one of:

TR 754	<i>Logistics Analysis</i>
MG 613	<i>Industrial Relations</i>
MG 614	<i>Collective Bargaining</i>

Units earned toward certificate programs are transferable to degree programs if applicable. No course, however, may be credited toward more than one certificate program.

Course substitution in certificate programs are permitted with the written approval of the assigned academic advisor.

UNDERGRADUATE COURSES

The Program offers an undergraduate course in traffic engineering, which is required for the BS(CE) and may be used as a technical elective where approved by advisors, or as a free elective. Students with suitable undergraduate records may also take graduate transportation courses in their senior year, if approved by their advisors. Graduate students may not take undergraduate courses for credit.

TR 360 Traffic Engineering 3:0:3

Development and use of traffic engineering techniques to aid in planning, functional design and control of highway and street systems. Traffic studies, accident analysis, capacity analysis, sign and coordination, etc. Practical applications. *Prerequisite: junior status.* Also listed as CE 352

GRADUATE COURSES

Refer to Table 1 for identification of elective courses by specialty area. These groupings are intended to aid students in course selection, subject to approval of academic advisors.

TR 600 Introduction to Transportation Analysis 2½:0:3

Introduction to the analysis of data in transportation problems. Basic statistics is covered; means, variances, histo-

grams, applications of normal, t, and chi square distributions, statistical tests, and sampling procedures; applications to transportation data collection, such as, spot speed studies, travel time and delay studies, observance studies. Basic concepts in probability are introduced: probability of events, random variables, with applications to transportation decision-making problems. Discussion of other types of traffic studies, including parking studies, O-D studies, accident studies. Also listed under CE834.

TR 601 Travel Demand Forecasting 2½:0:3

Theory and application of travel forecasting methods to predict the amount and nature of travel on transportation systems. *Corequisite: TR 600 or equivalent.* Also listed under CE834.

TR 602 Urban Transportation Planning 2½:0:3

Transportation system planning from regional to local scales. Problem identification, issues and needs. Planning, design and operation of transportation systems. Evaluation of transportation system performance and impact. *Prerequisite: TR 601 or equivalent.* Also listed under CE835.

TR 603 Computer Applications and Analytic Techniques in Traffic and Transportation 2½:0:3

Model-building in transportation by use of analytic techniques and computer tools such as spreadsheets, statistical analysis, and existing transportation and traffic engineering packages. Emphasis in computer applications is on personal computers and existing software packages. Analytic techniques are addressed on three levels: (1) basic concepts; (2) case studies; and (3) review of literature. Modeling of trip generation, transportation safety, and other topics by deterministic analysis. Sensitivity analysis. Cost-utility analysis. Surveys and errors in surveys. Transportation packages including NETSIM, TRANSYT, TRAF, and Assignment packages. *Prerequisites: TR 702 and TR 600.* Also listed under CE835.

TR 629 Transportation Workshop
0:5:3

Comprehensive projects designed to assure student's understanding of basic principles and their applications, drawing on knowledge from the M.S. requirements. Typically, two to four design or evaluation projects are completed, some of which are group projects. Written reports and oral presentations required. Projects or sub-assignments are based upon the degree the student is pursuing. *Prerequisite for M.S. (TP&E) students: TR 601 and TR 701. Co-requisite: TR 702. Pre- or Co-requisites for M.S. (TM) students: IE 620, TR 750, TR 660. Also listed under CE836.*

TR 660 Public Transportation
2½:0:3

Needs for public transportation in urban areas. Characteristics of public transportation services: commuter rail, rail transit, light rail transit, express and local buses, commuter paratransit modes, taxi and other paratransit services. Planning and operations of transit routes and systems. Transit service performance measures. Functional design of transit stations, park and ride facilities, and transit rights-of-way. Also listed under CE837.

TR 665 Design of Rail Facilities
2½:0:3

Design of systems for moving passengers and freight on rails. Roadbeds, alignment, yard, stations, signal communications, and protection devices. Design of light-rail transit facilities. Also listed under CE838.

TR 670 Planning and Design of Terminals
2½:0:3

Passenger and freight terminals, with emphasis on system descriptions of these facilities. Land, marine, and air terminals. Methods for determining levels of service for pedestrians flow, TOFC and truck terminals are also covered. Also listed under CE 840.

TR 671 Airport Planning and Design
2½:0:3

Techniques for forecasting air passenger traffic and aircraft operations at commercial and general aviation facilities. Principles and practices for planning and design of terminal facilities, ground transportation systems, parking facilities, runways and navigational aids. Airport site selections, configuration and economics. Also listed under CE 841.

TR 672 Port Planning and Design
2½:0:3

Planning of marine terminal facilities for freight and passengers. Harbor and port capacity analysis. Functional design and control of ports. U.S. port terminal needs for containers and bulk freight. Port operations. Also listed under CE839.

TR 701 Traffic Engineering I 1:3:3

First course in a two-semester sequence covering the basic aspects of traffic engineering. Driver, roadway, vehicle, and traffic stream characteristics, and their influence on operations, controls, and design. Traffic studies and data analysis: volume, speed, delay, density, accidents, etc. Concept of traffic capacity and level of service analysis. Capacity and level of service analysis of limited access facilities: freeways, freeway components, two-lane rural highways, multilane highways. Laboratories emphasize the use of spreadsheets in data analysis and the use of computer packages for capacity and level of service analysis. *Corequisite: TR 600 or equivalent. Also listed under CE 805.*

TR 702 Traffic Engineering II 1:3:3

Second course in a two-semester sequence covering the basis of traffic engineering. Traffic control operations, and management. Characteristics of signs, signals, and markings. The "Manual on Uniform Traffic Control Devices" and its use. Intersection control. Signal systems and coordination. Pretimed and actuated control. Design of street hardware. Traffic flow regulations and their implementation. Intersection and arterial analysis. *Prerequisite: TR 701 or equivalent. Also listed under CE 807*

TR 710 Design of Traffic Facilities
2½:0:3

Functional and preliminary design principles and analyses for freeways and arterials. Interchange design for freeway facilities and design of at-grade intersections, using principles of channelization. Design of parking garages and parking lots. Also listed under CE 821.

TR 722 Fundamentals of Pavement Design
2½:0:3

Pavement types, design factors, traffic load analysis, pavement materials, stresses in flexible and rigid pavements, economic factors, pavement strategies and design of flexible and rigid pavements. Also listed as CE 796.

TR 723 Flexible and Rigid Pavements
2½:0:3

Advanced course in the design and evaluation of flexible and rigid pavements for highways and airports: System approach, stochastic process, pavement condition and performance, advanced traffic load analysis, subgrade investigation, properties of subbase, base, asphaltic, and concrete courses, climatic and environmental effects, design strategies, design of highways and airport pavements and pavement evaluation. Also listed under CE 797

TR 724 Pavement Materials Laboratory
1:3:3

Practical course on testing of pavement materials: Physical and indicative tests, soil classifications, CBR test, tests on asphalts, Marshall test, Hveem tests, Fatigue testing, application of results in a design problem. *Prerequisite: TR722. Also listed under CE 814.*

TR 725 Advanced Pavement Technologies
2½:0:3

Advanced course on evolution and innovative recent paving technologies: AASHTO road test, pavement management system, concrete block pavements, pavement recycling, geotextiles in pavements, pavement rehabilitations, bituminous materials, modern materials. *Prerequisites: TR723, TR724. Also listed under CE 814.*

TR 750 Transportation Economics and Finance 2½:0:3

Basic principles of present worth, single payment and uniform series, sinking funds, annualized costs. Differences in the public and private sectors of transportation: profit, depreciation, return on capital. Benefit-cost analysis. Rate of return. Bond issues. Formulation and use of unit costs in highways, transit, and other modes. History of financing of road systems, transit, and trucking. Privatization. Balance sheets, financial control, cash flow. Preparing a private venture business plan. Also listed under CE 812.

TR 754 Logistics 2½:0:3

Basic principles of logistics costs and analysis; interactions to physical distribution aspects of the shipper (packaging, plant and warehouse location) and related logistical analysis approaches. Also listed under IE754.

TR 759 Transportation Policy 2½:0:3

Analysis of the major policies, regulations, and controls established or imposed by government at all levels-federal, state, local-which currently impact on the transportation industry. (All modes considered). Case studies used extensively. Also listed under CE843.

TR 760 Management of Transit Maintenance and Operations 2½:0:3

Management of functional transit systems aspects, including design and monitoring of maintenance functions to provide viable operating fleets and right-of-way, and management of daily operations, including scheduling, run-cutting, dispatching, and street management. Also listed under 844.

TR 860-861 Selected Topic in Transportation I,II each 2½:0:3

Periodic presentation of topical materials of current interest. Possible topics presented are: site development and site impact; decision-making in transporta-

tion; computer packages in transportation; transportation systems safety. *Prerequisite: academic advisor's approval.* Also listed under CE845-846.

TR 865 Traffic Safety Engineering 2½:0:3

Applications of system-safety engineering principles to the driver-vehicle-environment system to achieve higher levels of human safety (reduced accident occurrence and reduced severities of injuries). Proven, practical approaches are applied in the removal hazards and hazardous conditions in every stage of the highway system activity cycle, including planning, engineering, design, operation, maintenance. Also listed under CE847.

TR 901-902 Readings in Transportation I, II 2½:0:3

Special problems in transportation under the direct supervision of faculty members. *Prerequisite: academic advisors' approval.* Also listed under CE903-904.

TR 951-952 Transportation Seminar I, II

Relevant topics in transportation by guest speakers. Presentations and discussions of on-going research by course participants and faculty. Required of all full-time degree students in the program. *Prerequisite: academic advisors' approval.* Also listed under CE954-955.

TR 962 Master's Project in Transportation Planning and Engineering each 3 units

An independent project leading to a comprehensive report demonstrating professional competence. Reports must be orally defended and be submitted in acceptable (unbound) written form. *Prerequisites: degree status and academic advisors' approval.* Also listed under CE957.

TR 963 Master's Internship in Transportation each 3 units

Internships with relevant transportation organizations, leading to report demonstrating students' professional compe-

tence. Students are examined orally and must be orally defended and be submitted in acceptable (unbound) written form. *Prerequisites: degree status and academic advisors' approval.* Also listed under CE958.

TR 966 Master's Project in Transportation Management each 3 units

An independent project leading to comprehensive report demonstrating professional competence. Projects must be orally defended and be submitted in (unbound) written form. *Prerequisites: degree status and academic advisors' approval.* Also listed under CE959.

TR 997 Thesis for the Degree of Master of Science each 3 units

Continuation of project work, initiated in TR 962, or original research of sufficient comprehensiveness for motivated students. Bound written report required. *Prerequisite: degree status and academic advisors' approval.* Also listed under CE960.

TR 998 Engineering Project each 3 units

A comprehensive individual project, usually in the form of a comprehensive engineering and analysis, a functional design project or control/operations system design. *Prerequisites: degree status and academic advisor's approval.* Also listed under CE962.

TR 999 Dissertation for the Degree of Doctor of Philosophy each 3 units

An original investigation embodying the results of comprehensive research in a specific area of transportation worthy of publication in recognized scientific or engineering journals. Students are required to take an oral examination of the subject of the dissertation and related topics. *Prerequisites: degree status, passage of Ph.D. qualifying examination and academic advisor's approval.* Also listed under CE999.

FACULTY

Ilan Juran, Professor of Civil Engineering, Head of the Department of Civil and Environmental Engineering.
B.Sc. Technion, Israel; PhD, D.Sc. Paris XI, Ecole Nationale des Ponts et Chaussees.

Geotechnical engineering, soil improvement technologies, geosynthesis engineering, in-situ soil testing

John C. Falcocchio, P.E., Professor of Transportation Engineering; Program Coordinator, Transportation
B.C.E., M.S., Ph.D., Polytechnic Institute of Brooklyn; Certificate in Highway Traffic Engineering, Yale University.
Transportation planning; public transportation; travel demand; traffic engineering; transportation system evaluation; transportation systems management

Walter Helly, Professor of Operations Research
B.S., Cornell University; M.S., University of Illinois; Ph.D., Massachusetts Institute of Technology
Queues and routing in networks; land use models; stochastic mode choice models

Herbert S. Levinson, P.E., Research Professor of Transportation
B.S.C.E., Illinois Institute of Technology; Certificate in Highway Traffic Engineering, Yale University
Traffic operations, traffic engineering and capacity, highway engineering, transportation policy

William R. McShane, P.E., Professor of Industrial and Systems Engineering; Director, Transportation Training and Research Center.

B.E.E., Manhattan College; M.S., Ph.D., Polytechnic Institute of Brooklyn
Traffic engineering, highway capacity, expert systems in transportation, PC applications and models, economics and finance

Roger P. Roess, Professor of Transportation Engineering and Dean of Engineering, Associate Provost for Academic Affairs
B.S., M.S., Ph.D., Polytechnic Institute of Brooklyn
Traffic capacity and design; traffic engineering; public transportation; transportation economics

Elena S. Prassas, Instructor in Transportation; Deputy Program Coordinator, Transportation Program
B.A., State University of New York, Oneonta; M.S. Polytechnic Institute of New York
Traffic engineering; transit and economics; AI applications; software systems for transportation applications.

Jose M. Ulerio, EIT, Instructor in Transportation
B.S., M.S., Polytechnic Institute of New York
Highway engineering; highway capacity; transportation assignment; transportation demand estimation; CAD and CAE applications.

ADJUNCT FACULTY

Paul Cohen, Lecturer
B.A., City College of New York; M.S., University of Illinois.

Philip A. Habib, P.E., Adjunct Professor
B.E., City College of New York; M.S., Ph.D., Polytechnic Institute of Brooklyn.

Michael Horodniceanu, P.E., Adjunct Professor
B.S., Technion Israel Institute of Technology; M.S., Columbia University; Ph.D., Polytechnic Institute of New York.

Gennaro E. Sansone, Lecturer
B.S.E.E., Kansas State University; M.B.A., Iona College.

David Sampson, Lecturer
B.A., Colby College; M.S., Harvard University

Raymond Schaeffer, Lecturer
B.S.(CE), M.S.(Transportation), Swiss Federal Institute of Technology.

CHEMISTRY

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

Classical divisions of chemistry were organic chemistry, dealing primarily with compounds of carbon; inorganic chemistry, concerned with all other compounds; analytical chemistry, concerned with qualitative determinations of composition; and physical chemistry, which seeks understanding of matter, including chemical bonds and molecular interactions. These classical fields have overlapped increasingly, and several interdisciplinary fields are now of great importance: biochemistry, electrochemistry, photochemistry, polymer chemistry, solid state chemistry, and chemical physics.

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

Staff members conduct and supervise research at undergraduate, graduate and postdoctorate levels. This research is combined with teaching so that courses at all levels are taught by chemists who are highly competent in their respective fields.

Participation of undergraduates in optional research activities provides them with both stimuli and good preparation for graduate school or professional positions.

The department offers programs leading to degrees of bachelor of science, master of science and doctor of philosophy in chemistry.

The department also offers joint programs with the Departments of Physics and Chemical Engineering.

CHEMICAL PHYSICS

Chemical physics is an interdisciplinary program designed to train students for careers in those areas common to chemistry and physics. Administered jointly by the Departments of Chemistry and Physics, it provides, within the scope of a normal graduate program, flexible courses of study in both departments. The program leads to degrees of master of science and doctor of philosophy. (For details see program listing for "Chemical Physics").

POLYMER SCIENCE AND ENGINEERING

Polymer science and engineering is an interdisciplinary program, administered jointly by the Departments of Chemistry and Chemical Engineering, leading to degrees of master of science and doctor of philosophy. (For details see program listing for "Polymer Science & Engineering").

UNDERGRADUATE PROGRAMS

For students majoring in chemistry, the Department of Chemistry provides curricula which go beyond the requirements of the American Chemical Society for professional training. Courses offered are designed to prepare students for graduate studies or work in industry.

Students may elect the thesis option or the no-thesis option in either chemistry or the biochemistry option (see detailed curricula).

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

REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE

	Credits
101, 102, 108, 109, 111, 112, 118-120, 122-125, 161, 162, 175, 501, 504	45
Advanced Chemistry	3
*Thesis Research (CM 390-394)	10
CS 100	2
MA 101-104	14
PH 104-106, 115-116	10

The minimum of 128 credits required for the degree of bachelor of science in chemistry includes a minimum of 30 credits in humanities and social sciences.

At least two semesters of a foreign language (French, German or Russian) are strongly recommended.

* Students electing thesis research are required to submit a written thesis prior to graduation. Students may elect a no-thesis option and select ten credits of advanced chemistry courses in consultation with an advisor.

Curriculum for the Bachelor of Science Degree in Chemistry

FRESHMAN YEAR

No.	Subject	Hours/Week	Cl.	Lab.	Cr.
First Semester					
CM 101	Gen. Chemistry I	2½	0	2½	
CM 111	Gen. Chem. Lab I	0	1½	½	
CS 100	Intro. to Computer-Programming				
	Hum./Soc.Sci. electives	6	0	6	
MA 101	Calculus I or MA 100	4	0	4	
SL 101	Freshman Seminar	1	1	0	
					15

Second Semester

CM 102	Gen. Chem. II	2½	0	2½	
CM 112	Gen. Chem. Lab II	0	1½	½	
	Hum./Soc.Sci. elective	6	0	6	
MA 102	Calculus II or MA 110	4	0	4	
PH 104	Intro. Physics I	3	0	3	
					16

SOPHOMORE YEAR

First Semester

CM 122	Organic Chem. I	3	0	3	
CM 124	Orgn. Chem. Lab. I	3½	5	2	
	Hum./Soc.Sci. electives	6	0	6	
MA 103	Calculus III	3	0	3	
PH 105	Introductory Physics II	3½	0	3½	
PH 115	Physics Lab I	0	1½	½	

Second Semester

CM 123	Organic Chem. II	3	0	3	
CM 125	Organic Chem. Lab II	3½	5	2	
	Hum./Soc.Sci. electives	3	0	3	
CM 161	Physical Chem. I	3	0	3	
MA 104	Appl. Diff. Equations	3	0	3	
PH 106	Intro. Physics III	2½	0	2½	
PH 116	Physics Lab II	0	1½	½	
					17

JUNIOR YEAR

First Semester

CM 118	Chem. Equilibria	2½	5	4	
CM 162	Physical Chem. II	3	0	3	
CM 504	Chemical Lab Safety	1	0	3	
	Hum./Soc.Sci. electives	3	0	3	
	Technical elective			3	
	Elective			3	
					19

Second Semester

CM 108	Inorganic Chem.	3	0	3	
CM 119	Analytical Chem.	3	0	3	
CM 120	Analytical Chem. Lab	0	6	2	
CM 177	Physical Chem. Lab	3½	5	2	
CM 501	Chemical Literature	1	0	1	
	Hum./Soc.Sci. electives	3	0	3	
					17

SENIOR YEAR

First Semester

CM 109	Inorganic Chem. Lab	0	3	1	
	Hum./Soc.Sci. electives	6	0	6	
CM 390-	Bachelor's Thesis			4	
391	Electives			3	
					14

Second Semester

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

Total Credits for Graduation 128

* Placement into MA 101 and MA 102 or MA 100 and MA 110 is based on an entrance examination.

BIOCHEMISTRY OPTION

Freshman and Sophomore courses as above

JUNIOR YEAR

First Semester

LS 105	Biology I	3	0	3	
LS 115	Gen. Biology Lab I	1	3	2	
CM 118	Chemical Equilibria	2½	5	4	
CM 162	Physical Chem. II	3	0	3	
CM 201	Biochemistry I	3	0	3	
CM 504	Chemical Lab Safety	1	0	1	
					16

Second Semester

LS 106	Biology II	3	0	3	
LS 116	Gen. Biology Lab II	1	3	2	
CM 177	Physical Chem. Lab	3½	5	2	
CM 202	Biochemistry II	3	0	3	
CM 204	Biochemistry Lab	3½	5	2	
CM 501	Chemical Literature	1	0	1	
CM 108	Inorganic Chemistry	3	0	3	
					16

SENIOR YEAR

First Semester

CM 109	Inorganic Chem. Lab	0	3	1	
	Hum./Soc.Sci. electives	6	0	6	
CM 390-	Bachelor's Thesis			4	
391	Electives			3	
					14

Second Semester

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

Total Credits for Graduation 128

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

Students are strongly urged to select areas of concentration (such as literature, communications, the arts or philosophy in the Department of Humanities, or political science, economics, history, anthropology or psychology in the Department of Social Sciences) and to elect two or three courses in these concentrations in consultation with departmental advisors. Modern languages are recommended as suitable concentrations, but students without prior knowledge of languages must plan to devote at least 12 credit hours to each one. A minimum of two semesters of French, German or Russian is recommended.

For remaining humanities/social sciences requirements, students should select courses in areas other than that of

their concentrations. Additional courses in humanities and social sciences may be taken as free electives.

Students are strongly encouraged to take technical writing courses prior to their senior year.

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

Students with special interests in biochemistry may eliminate CM 175 and the technical elective but must include the following: LS 105-106, LS 115-116, CM 201-202 and CM 204. It is recommended that LS 105-106, LS 115-116 be taken in the junior year by deferring the necessary credits of humanities/social sciences. Requirements for advanced chemistry courses are waived for students taking the biochemistry thesis option.

All laboratory courses in chemistry require a breakage deposit.

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

Curriculum for the Degree of Bachelor of Science in Engineering Chemistry

Engineering Chemistry is a degree program in Chemistry with a concentration in Engineering Principles and Techniques associated with Chemical Processes. This degree allows students to enter industrial employment with advantages over a pure science degree and at the same time allows pursuit of M.S. or Ph.D. degrees in Chemistry or Chemical Engineering.

Chemistry Curriculum Engineering Chemistry Options

Advanced Chemistry courses are selected from the following list, which appears in the catalog under appropriate interest areas.

FRESHMAN YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.
First Semester				
CM 101	Gen. Chemistry I	2½	0	2½
CM 111	Gen. Chem. Lab I	0	1½	½
	Hum./Soc.Sci. electives*	9	0	9
MA 101	Calculus I or MA 100**	4	0	4
CS 100	Intro. to Computer- Programming	2	0	2
SL 101	Freshman Seminar	1	1	0
				18

Second Semester				
CM 102	Gen. Chemistry II	2½	0	2½
CM 112	Gen. Chem. Lab II	0	1½	½
	Hum./Soc.Sci. electives*	3	0	3
MA 102	Calculus II or MA 110**	4	0	4
MA 104	Intro. Physics I	3	0	3
	Technical elective	3	0	3
				16

SOPHOMORE YEAR

First Semester				
CH 123	Chemical Process Analysis I	2	0	2
CM 122	Organic Chemistry I	3	0	3
CM 124	Organic Chem. Lab I	½/10	5	2
	Hum./Soc.Sci. elective*	3	0	3
MA 103	Calculus III	3	0	3
PH 105	Intra. Physics II	3½	0	3½
PH 115	Physics Lab. I	0	1½	½
				17

Second Semester				
CH 124	Chemical Process Analysis II	2	0	2
MA 104	Appl. Diff. Equations	3	0	3
CM 123	Organic Chem. II	3	0	3
CM 125	Orgn. Chem. Lab II	½/10	5	2
	Hum./Soc.Sci. electives*	3	0	3
CM 161	Physical Chem. I	3	0	3
PH 106	Intro. Physics III	2½	0	2½
PH 116	Physics Lab. II	0	1½	½
				19

JUNIOR YEAR

First Semester				
CH 220	Transfer Operations	4	0	4
CH 220	Therm. Eng. Therm.	4	0	4
CM 118	Chem. Equilibria	2½/10	5	4

CM 162	Physical Chem. II	3	0	3
	Hum./Soc.Sci. elective*	3	0	3
				18

Second Semester

CH 221	Transfer Oper. II	4	0	4
CH 271	Eng. Materials	3	0	3
CM 119	Analytical Chemistry	3	0	3
CM 120	Analytical Chem. Lab	0	6	2
	Hum./Soc.Sci. elective*	3	0	3
	Elective***			3
				18

SENIOR YEAR

First Semester

CM 175	Physical Chem. III	4	0	4
	Bachelor's Thesis			4
CM 108	Inorganic Chemistry	3	0	3
	Hum./Soc.Sci. electives*	3	0	3
	Elective***			3
				17

Second Semester

CH 241	Multistage Separation Processes	3	0	3
	Engineering elective			3
	Bachelor's Thesis			6
	Hum./Soc.Sci. electives*	3	0	3
				15

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

* A minimum of two semesters of a foreign language (German, French or Russian) is strongly recommended. The corresponding courses should be chosen in consultation with advisors.

** Placement into MA 101 and MA 102 or MA 100 and MA 101 is based on an entrance examination.

*** Engineering courses should total at least 6 credits between junior and senior years. Engineering options must be selected from the following list. Students planning studies in Chemical Engineering should be certain to include the following courses:

CH 322	Chemical Reactor Engineering	3	0	3
CH 351	Process Dynamics and Controls	3	0	3
CH 361	Process Design I	3	0	3
CH 362	Process Design II	3	0	3

HONORS CURRICULA IN CHEMISTRY FOR B.S. AND PH.D. DEGREES

Honors Curricula are designed for the talented and motivated student with good scholastic preparation and a serious interest in Chemistry. Students can complete B.S. and Ph.D. degrees in only six years. These accelerated curricula satisfy the normal requirements for both degrees.

While rewarding careers in Chemistry can certainly begin with B.S. degrees, Ph.D. Chemists have more opportunities, more responsibilities, higher salaries and greater potential for advancement in industry, government, or academia. Many Chemistry students begin college with the B.S. as their goal, only to realize in their junior year that they should apply for graduate school.

Graduate school in Chemistry seems distant, forbidding and expensive to high school juniors and seniors, but need not be. This program enables students to complete requirements for Bachelor of Science degrees (certified by the American Chemical Society) after three years, at which time they also have begun graduate level courses. In the fourth year, students hold full graduate status, are no longer required to pay tuition, and are paid graduate Teaching Assistant stipends. Support as a Teaching or Research Assistant continues until the Ph.D. is completed.

Besides the equivalency credits required before matriculation, a B average must be maintained throughout the program, and a minimum B grade is required in Chemistry courses. Applications should be made to Polytechnic, and the student interested in this program should contact the Chemistry Department advisors. Formal application to the graduate program is made in the Fall of the third year. The B.S. degree is awarded at the first regularly scheduled commencement after the third summer, and the Ph.D. degree is conferred after the doctoral dissertation is defended and deposited.

Equivalency work required prior to matriculation:*

CM 101	Gen. Chem. Lecture I	2½
CM 111	Gen. Chem. Lab.	½
CM 102	Gen. Chem. Lecture II	2½
CM 112	Gen. Chem. Lab II	½
PH 104	Intro. Physics I	3
MA 101	Calculus I	4
	Hum./Soc.Sci. elective**	
	(e.g. Language, History)	
	Two courses	6
Total		19

* Equivalency certification may vary from department to department. Please check with individual departments or Chemistry advisors for details.

** A second language in addition to English is strongly recommended, e.g. French, German or Russian; courses can be selected with the aid of advisors, or equivalency credits may be established. A Technical Writing course is also strongly recommended.

Honors Curricula in Chemistry for B.S. and Ph.D. Degrees

FIRST YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.
<i>First Semester</i>				
CM 122	<i>Organic Chemistry</i>	3	0	3
CM 124	<i>Orgn. Chem. Lab I</i>	$\frac{3}{10}$	5	2
PH 105	<i>Intro. Physics II</i>	3½	0	3½
PH 115	<i>Physics Lab I</i>	0	1½	½
MA 102	<i>Calculus II</i>	4	0	4
SL 101	<i>Freshman Seminar</i>	1	1	0
CM 504	<i>Chemical Laboratory</i>			
	<i>Safety</i>	1	0	1
	<i>Humanities/Social</i>			
	<i>Science elective**</i>	3	0	<u>3</u>
				17

Second Semester

CM 123	Organic Chem. II	3	0	3
CM 125	Orgn. Chem. Lab II	3/10	5	2
CS 100	Intro. to Computer Programming	2	0	2
PH 106	Intro. Physics III	2½	0	2½
PH 116	Physics Lab II	0	1½	½
MA 103	Calculus III	3	0	3
	Hum./Soc.Sci. electives**	3	0	3
				16

SUMMER SESSION

First Semester

CM 161	Physical Chem. I	3	0	3
	Hum./Soc.Sci. electives**	3	0	3
				6

Second Semester

CM 162	Physical Chem. II	3	0	3
	Hum./Soc.Sci. electives**	3	0	3
				6

Total Credits 45

SECOND YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.
First Semester				
CM 118	<i>Chemical Equilibria</i>	2½/10	5	4
CM 175	<i>Adv. Physical Chem.</i>	4	0	4
	<i>Technical elective</i>			3
	<i>Electives (two)</i>			<u>6</u>
				17

Second Semester

CM 108	Inorganic Chemistry	3	0	3
CM 119	Analytical Chemistry			
	Lecture	3	0	3
CM 120	Analytical Chemistry			
	Laboratory	0	6	2
CM 177	Physical Chemistry			
	Laboratory	3/10	5	2
CM 501	Chem. Literature	1	0	1
CM 871	Guided Studies	TBA	TBA	3
	Elective			3
				17

SUMMER SESSION

First Semester

	Hum./Soc.Sci. elective (two)	6	0	6

Second Semester

	Hum./Soc.Sci. electives (two)	6	0	6

Total Credits 46

THIRD YEAR

First Semester

CM 109	Inorganic Chem. Lab	0	3	1
CM 703	Advanced Physical Chemistry I	3½	0	4½
CM 903	Advanced Organic Chemistry I	3½	0	4½
CM 971	Colloquium in Chem.	0	0	0
CM 973	Seminars in Chem. and either†	1	0	1½
CM 907	Spectroscopy of Organic Molecules	3½	0	4½
CM 872	Guided Studies	TBA	TBA	4½
				16

Second Semester

CM 704	Advanced Physical Chemistry II	3½	0	4½
CM 904	Advanced Organic Chemistry II	3½	0	4½
CM 972	Colloquium in Chem.	0	0	0
CM 974	Seminar in Chemistry Elective and either†			
CM 872	Guided Studies	TBA	TBA	4½
CM 802	Applied Spectroscopy	3½	0	4½
				18

During the Fall Semester, the student shall make formal application to the Graduate Program in Chemistry.

At this point, the student has completed all requirements for the B.S. Degree in Chemistry, and amassed 21 credits toward the Ph.D./B.S. Degrees are conferred at the next scheduled commencement. In the fourth year, students are considered full-fledged graduate students, and are supported by teaching or research assistantships.

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

Total Credits 40

† For these two options, students choose either the first in both semesters, or the second in both semesters, depending upon interests.

FOURTH YEAR

First Semester

CM 601	Adv. Inorganic Chem.	3½	0	4½
CM 971	Colloquium in Chem.	0	0	0
CM 975	Seminar in Chemistry	1	0	1½
CM 991	Special Experimental Techniques	TBA	TBA	3
	Advanced Chemistry			12

Second Semester

CM 972	Colloquium in Chem.	0	0	0
CM 976	Seminar in Chem.	1	0	1½
CM 992	Special Experimental Techniques	TBA	TBA	3
CM 998	Research in Chem. Advanced Chemistry Courses (Two)	TBA	TBA	7
				6
				17½

Total Credits 29½

FIFTH YEAR

First Semester

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

Second Semester

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

Total Credits 36

SIXTH YEAR

First Semester

CM 971	Colloquium in Chem.	0
CM 999	Research in Chem.	18
		18

Second Semester

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

Total Credits: 36

INORGANIC CHEMISTRY

CM 614-619 Special Topics in Inorganic Chemistry

PHYSICAL CHEMISTRY

CM 715-717 Advanced Topics in Physical Chemistry: Kinetics of Chemical Reactions, Valence and Molecular Structures, Electrochemistry

CM 721 Quantum Mechanics for Chemists

CM 722 Statistical Mechanics for Chemists

CM 730-731 Group Theory and Applications I & II

CM 750 Special Topics in Physical Chemistry

CM 760 Minicomputer Instrumentation for Scientific Research

POLYMER CHEMISTRY

CM 771 Introductory Polymer Chemistry

CM 772 Synthesis of High Polymers

CM 781 Solution Properties of High Polymers

CM 782 Macromolecule in the Solid State

CM 783 Laboratory Methods in Polymer Chemistry

CM 785 Special Topics in Polymer Chemistry

CM 790 Biopolymer

ORGANIC CHEMISTRY

CM 915 Topics in Physical Organic Chemistry

CM 920 Current Aspects of Organic Synthesis

CM 921-933 Advanced Topics Inorganic Chemistry

CM 940 Special Topics Inorganic Chemistry

BIOCHEMISTRY

CM 941-942 Biochemistry I & II

CM 943-946 Advanced Topics in Biochemistry

CM 947 Biochemical Techniques

With advisor's approval, courses in other departments may be taken instead of the advanced chemistry courses, such as courses in Physics, Metallurgy, Computer Sciences, Chemical Engineering and Bioengineering.

There are five major areas in chemistry for the Ph.D. Degree, and there are individual requirements in each area:

BIOCHEMISTRY

CM 601, CM 704, CM 802, CM 903, and at least 9 credits selected from the following: CM 781, CM 790, CM 941-7, CH 672.

INORGANIC CHEMISTRY

CM 601; CM 703; CM 802 or CM 907; CM 903 or CM 904; at least 6 units of advanced topics in inorganic chemistry (CM 614-619).

ORGANIC CHEMISTRY

CM 601; CM 703 or CM 704; CM 903; CM 904; CM 907; and CM 920

PHYSICAL CHEMISTRY

CM 601; CM 703; CM 704; CM 802; CM 903 or CM 904; either CM 721 and CM 722 or 9 units selected from PH 663, PH 664, PH 667 or PH 668; and CM 995 (Seminar in Chemical Physics).

POLYMER CHEMISTRY

CM 601; CM 703 or CM 704; CM 903 or CM 904; CM 802 or CM 907; CM 771; CM 772; CM 781; CM 782; CM 783.

There are also minor requirements. The Chemistry Department offers minors in biochemistry, inorganic chemistry, organic chemistry, physical chemistry and polymer chemistry. A faculty advisor in the minor area will advise students in selecting two courses to satisfy minor requirements.

By the end of the second year, students have earned 110 credits (including equivalency credit) towards the B.S. degree. In the third year, the student accumulates 19 credits toward the B.S. degree, e.g., CM 109 (1 credit), either CM 704 or CM 904 (4½ credits, as an advanced chemistry course), CM 872 (4½ credits, guided studies, reading), and a total of three electives (3 credits each, for a total of 9) in the second semester and in summer sessions. Total credits earned towards the B.S. degree by the end of the third year are 129; by this time the student has earned 21 credits towards the Ph.D. (remaining credits for the third year). If a student decides not to continue, he/she would receive a B.S. degree at the next regularly scheduled commencement. Formal application is made to Graduate School in the third year.

During the fourth, fifth and sixth years, students take advanced chemistry courses, colloquia, seminars, and research credits. At the end of the sixth year, students accumulated 46½ credits of advanced degree work (including core courses, major requirements, minor

requirements, seminars and colloquium registration) and 69 credits of research to be presented in a dissertation, which is in excess of the credits of research required for Ph.D. degrees (45).

Major differences between the Honors Curriculum and the standard one, aside from the acceleration of course work, are: advanced preparation and equivalency credit for more than a semester's course work; substitution of courses for bachelor's thesis (since the student prepares a doctoral dissertation); and the combination of lower level and upper level courses in the third year.

In the fourth year, the student begins duties as a teaching assistant, supervising undergraduate laboratories and grading exams. Then, the student is supported financially by the department as a Teaching Fellow. Depending upon these duties and the availability of necessary advanced courses, course loads may be redistributed slightly, and the student may take courses in a semester different from those described above.

Selection of an advisor and a dissertation committee and the scheduling of examinations are described under the graduate program.

Academic policy for the graduate program in chemistry requires that a B average be maintained. Similarly, a B average exclusive of research or guided studies is required for a student to remain in the Honors Program. B minimum grades in chemistry courses must be maintained during the first two years of study.

GRADUATE PROGRAMS

Admission to graduate studies in chemistry requires a sound foundation in mathematics, physics and chemistry. College preparation should include at least four semesters of mathematics, two semesters of physics, and all basic chemistry courses (analytical, inorganic, organic and physical). In addition, it is desirable for students to have had differential equations, atomic and nuclear physics, and two years of German, Russian or French. All applicants are required to take the Graduate Record Examination (General and Chemistry). Applicants whose native language is other than English must score at least

550 on the TOEFL. All teaching assistants must pass HU 521 or an oral examination given by the Chemistry Department. Chemistry graduate students cannot take CM 500 level courses for graduate credit.

REQUIREMENTS FOR THE MASTERS OF SCIENCE DEGREE

Chemistry

A total of 36 units past the bachelor's degree is required with an overall grade point average of B(3.0) or better in all courses (exclusive of thesis research or guided studies) submitted for a master's degree. Programs must include the following core courses:

No.	Subject	Units
CM 601	<i>Inorganic Chemistry</i>	4½
CM 703	<i>Chemical Physics I</i>	4½
	or	
CM 704	<i>Chemical Physics II</i>	
CM 802	<i>Applied Spectroscopy</i>	4½
	or	
CM 907	<i>Organic Spectroscopy</i>	
CM 903	<i>Advanced Organic Chem. I</i>	4½
	or	
CM 904	<i>Advanced Organic Chem. II</i>	

Students may elect research and a thesis (12 units). The oral defense of the thesis is held after the typed thesis has been submitted. A grade of A or B in thesis research is required.

Students not electing theses are required to take 3-6 units of guided studies (CM 871-872) with the submission of a written report.

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

Students must be in continuous attendance at departmental colloquia.

All master's students must take CM 504, Chemical Laboratory Safety. Students are strongly encouraged to take CM 501, Chemical Literature.

REQUIREMENTS FOR THE DOCTOR'S OF PHILOSOPHY DEGREE

The student selects a research advisor or after interviewing a minimum of five faculty members. The student must take the Written Preliminary Examination during the second year. Two attempts are allowed. (After a second failure, the student is dropped from the doctoral program). The student then selects a dissertation committee including the research advisor, major advisors, a minor advisor and at least one other faculty member who monitors the progress of the student through the rest of the program. Approximately six months after the Written Preliminary Examination, an Oral Preliminary Examination is scheduled, where students will present plans and possibly results from specific areas of thesis research for evaluation by the committee. When all thesis research is completed, the student schedules an Oral Defense of the Thesis. Final judgement on awarding a Ph.D. is made by the dissertation committee.

A total of 90 units past the baccalaureate degree level is required. A grade point average of B or better is mandatory in all courses (not including dissertation research) submitted for the Ph.D. degree and a grade of A or B is required for the dissertation.

Currently the Chemistry Department offers the Ph.D. degree with majors in biochemistry, inorganic, organic, physical or polymer chemistry. Minors are also required and may be in any of these areas other than the major and, additionally, in other departments or areas such as polymer science and engineering. The program includes the following courses, for which students must maintain at least a B average.

1. Required Courses

In the doctoral curriculum, required courses are listed below:

Course	Title	Units
CM 601	<i>Inorganic Chemistry</i>	4½
CM 703	<i>Chemical Physics I</i>	
	or	
CM 704	<i>Chemical Physics II</i>	4½
CM 802	<i>Applied Spectroscopy</i>	
	or	
CM 907	<i>Organic Spectroscopy</i>	4½

CM 903	<i>Organic Chemistry I</i>	
	or	
CM 904	<i>Organic Chemistry II</i>	4½

These courses are offered in two consecutive terms so that full time students entering in the fall term can complete the sequence in two terms. In addition to the 18 credits of required courses listed, Ph.D. students must take a one credit course in laboratory safety, CM 504, and fulfill the seminar and other requirements described in the catalog. Course requirements are explicitly defined below.

2. Required Courses for Chemistry Majors

Listed below are required courses for the five major areas in chemistry, i.e., biochemistry, inorganic, organic, physical and polymer.

BIOCHEMISTRY:

CM 601, CM 704, CM 802, CM 903, and at least 9 credits selected from the following: CM 781, CM 790, CM 941-7, CH 672.

INORGANIC CHEMISTRY:

CM 601, CM 903 or CM 904, CM 802 or CM 907, CM 703 and at least six units of advanced topics in inorganic chemistry (CM 614-619).

ORGANIC CHEMISTRY:

CM 601, CM 703 or CM 704, CM 903, CM 904, CM 907 and CM 920.

PHYSICAL CHEMISTRY:

CM 601; CM 703, CM 704, CM 802; CM 903 or CM 904; either CM 721 and CM 722 or 9 credits selected from PH 663, PH 664, PH 667 or PH 668; and CM 995.

POLYMER CHEMISTRY:

CM 601, CM 703 or CM 704, CM 802 or CM 907, CM 903 or CM 904, CM 771, CM 772, CM 781, CM 782 and CM 783.

3. Minor Requirements

The Chemistry Department offers a minor concentration in biochemistry, inorganic, organic, physical and

polymer chemistry. Students may elect a minor in areas of concentration offered by other departments. In all cases a faculty advisor from the minor area will be a member of the guidance committee. The student shall select courses to fulfill minors in consultation with the minor advisor.

4. Seminar

Participation in seminar for four semesters, twice as a lecturer.

5. Research

Research presented in a dissertation.

6. Laboratory Safety

All doctoral students must take CM 504, Chemical Laboratory Safety, prior to registering for thesis research.

7. Chemical Literature

Students are strongly encouraged to take CM 501, Chemical Literature.

8. Colloquia

Students must be in continuous attendance at department colloquia for the duration of research.

9. Oral Examination

The final oral examination will take place after members of the guidance committee have read the dissertation in typed, unbound form.

All students in the doctoral program are granted master of science degrees upon satisfactory completion with a B average of course requirements and 12 units of research toward doctoral dissertations, as certified by the chairman of the guidance committee. On application to the Office of Research and Graduate Studies and after completion of preliminary examinations, the student is certified as having earned a master of science degree.

All students should consult the current departmental bulletin, Information for Chemistry Graduate Students, for most recent guidelines for Ph.D. students.

UNDERGRADUATE COURSES

CM 101 General Chemistry I

1/2:0:2 1/2

Chemical equations; chemical conservation laws; stoichiometry; thermochemistry; properties of gases; atomic structure; periodic table; chemical bonding and molecular structure. This class meets four hours per week for lectures, recitations, tutorials and examinations. *Co-requisite: MA 101 or MA 100.*

CM 102 General Chemistry II

2 1/2:0:2 1/2

States of matter; chemical thermodynamics and chemical equilibria; kinetics; acid-base chemistry; descriptive inorganic chemistry; introduction to organic chemistry. This class meets four hours per week for lectures, recitation, tutorials and examinations. Not open to students who take CM 103. *Prerequisites: CM 101; CM 111; MA 101, or MA 100. Co-requisites: MA 102 or MA 110; CM 112.*

CM 103 Chemistry for Engineers

1 1/2:0:1 1/2

States of matter; chemical thermodynamics and chemical equilibria; kinetics; electrochemistry; organic molecules; polymers; types of materials; electronic and magnetic materials. This class meets three hours per week for lectures, recitations, tutorials and examinations. Not open to students who take CM 102. *Prerequisites: CM 101, CM 111; MA 101 or MA 100. Co-requisites: MA 102 or 110; CM 113. Open only to EE undergraduates.*

CM 108 Inorganic Chemistry 3:0:3

Atomic structures of elements as basis for periodic classification. Descriptive chemistry of elements and their compounds. Theories of chemical bonds and introduction to coordination chemistry. *Prerequisites: CM 102, CM 112 and CM 161.*

CM 109 Inorganic Chemistry Laboratory

0:3:1

Laboratory experiments introducing techniques employed in preparation and characterization of inorganic substances. Lab fee required. *Prerequisite: CM 102, CM 112 and CM 161.*

CM 111 General Chemistry Laboratory I

0:1 1/2:1/2

Introduction to chemical laboratory procedures. Laboratory associated with lecture course CM 101. Lab fee required.

CM 112 General Chemistry Laboratory II

0:1 1/2:1/2

Laboratory experiments are coordinated with CM 102. Lab fee required. *Prerequisites: CM 101, CM 111.*

CM 113 Chemistry for Engineers Laboratory

0:1 1/2:1/2

Laboratory experiments in the chemistry of materials, taken in conjunction with CM 103. Not open to students who take CM 112. *Prerequisites: CM 101, CM 111. Co-requisite: CM 103. Open only to EE undergraduates.*

CM 118 Chemical Equilibria

2 1/2:5:4

Equilibria in homogeneous and heterogeneous chemical processes. Applications of equilibrium concepts and data to analytical and physical chemistry. Theory of titration 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

Theories and applications of instrumental techniques in modern analytical chemistry, including chromatography, spectroscopy (absorption, fluorescence, infrared, Raman, nuclear magnetic resonance, electron spin resonance, atomic absorption, and emission); x-ray absorption, fluorescence and diffraction; mass spectrometry; thermal methods, etc. *Prerequisites: CM 161-162.*

CM 120 Analytical Chemistry Laboratory

0:6:2

Techniques described in CM 119 applied to various chemical problems stressing physicochemical interpretation of data obtained. Lab fee required. *Prerequisites: CM 118 and CM 161-162. Co/Prerequisite: CM 119.*

CM 122 Organic Chemistry I 3:0:3

Chemistry of organic molecules: structure, nomenclature, properties and reactions of carbon compounds with emphasis on aliphatic compounds. Introduction to reaction, mechanisms, and stereochemistry. *Prerequisites: CM 102 and CM 112.*

CM 123 Organic Chemistry II

3:0:3

Continuation of CM 122 with emphasis on spectroscopic methods, aromatic chemistry, condensation reactions, carbohydrates, amino acids, and synthetic polymers. *Prerequisite: CM 122.*

CM 124 Organic Chemistry Laboratory I

1/2:5:2

Laboratory methods for preparation, isolation and purification of typical organic compounds. Experiments chosen to illustrate basic techniques. Lab fee required. *Co/Prerequisite: CM 122.*

CM 125 Organic Chemistry Laboratory II

1/2:5:2

Laboratory methods for preparation, purification, characterization and identification of organic compounds by chemical and physical means. Introduction to instrumental methods of analysis and identification. Lab fee required. *Prerequisite: CM 124. Co/Prerequisite: CM 123.*

CM 161 Physical Chemistry I

3:0:3

Chemical thermodynamics (macroscopic and molecular approach) with applications to solutions, phase and chemical equilibria. Kinetic theory. *Prerequisites: CM 102, CM 112, MA 103 and PH 103.*

CM 162 Physical Chemistry II 3:0:3

Electrochemistry; ionic solutions. Solids, liquids, surfaces, high polymers. Chemical kinetics. Relation of bulk properties of matter to atomic and molecular properties. *Prerequisite:* CM 161.

CM 175 Physical Chemistry III 4:0:4

Atomic and molecular aspects of physical chemistry. Quantum chemical statistical description of matter with applications to molecular spectroscopy, binding and structure. *Prerequisite:* MA 104, *Co/Prerequisite:* CM 162.

CM 177 Physical Chemistry Laboratory ½:5:2

Experimental methods of physical chemistry. Chemical kinetics; thermodynamics, electrochemistry, molecular spectroscopy, high vacuum, instrumental techniques. Computer analysis of experimental data. Report writing. Lab fee required. *Prerequisites:* CM 118 and CM 162.

CM 201 Biochemistry I 3:0:3

Survey of modern biochemistry with emphasis on current areas of research. Structure-function relationships in proteins. Enzymes and their mechanisms of action. Bioenergetics principles and energy production. Biochemical theories and techniques. *Prerequisites:* CM 123, CM 125 and CM 161, or instructor's permission.

CM 202 Biochemistry II 3:0:3

Continuation of Biochemistry I. Principles of intermediary metabolism, energetics, membrane structure and transport; structure and function of DNA and RNA, principles of molecular biology, the immune system, hormonal regulation, cancer. *Prerequisites:* CM 201 and CM 162, or instructor's permission.

CM 204 Biochemistry Laboratory ½:5:2

Laboratory experiments illustrating techniques for isolating and characterizing

biological macromolecule, analyzing enzyme kinetics and elucidating metabolic pathways. Lab fee required. *Co/Prerequisite:* CM 201.

CM 390-394 Bachelor's Thesis in Chemistry each 2 credits

Original investigations by student under guidance of staff members. Careful literature search required before inception of laboratory work; continued reference to chemical literature expected, and active participation in conferences and seminars scheduled as work progresses. A written thesis must be approved by at least two members of the department.

Full-time students are expected to register for 10 credits of thesis during senior year. Research (lab) fee required. *Co/Prerequisites:* CM 501 and CM 504.

**GRADUATE COURSES
(Special Listing)**

CM 501 Chemical Literature 1:0:1

Programs of lectures, exercises and discussion designed to familiarize students with the chemical literature. Undergraduate students may emphasize topics related to the bachelor's thesis. *Prerequisites:* CM 123, CM 125 and CM 162.

CM 502 Environmental Chemistry 3:0:3

Chemical properties of pollutants in air, water, soil and hazardous wastes. Effects of chemical pollutants on health. *Prerequisites:* CM 122, CM 124 and CM 161 or CM 164 or instructor's permission. This course does not fulfill requirements for the regular M.S. or Ph.D. degrees in chemistry. M.S. candidates in Industrial Chemistry may select this course to meet degree requirements.

CM 504 Chemical Laboratory Safety 1:0:1

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 undergradu-

ate chemistry students before they undertake laboratory research.

CM 515 Polymer Organic Chemistry 2½:0:3

Review of basic organic chemistry. Synthesis, characterization and applications to polymeric materials. May not be taken for credit by undergraduates to substitute for CM 122-123. May not be taken for graduate credit by graduate students in Chemistry or Polymer Science and Engineering. *Prerequisite:* CM 101, 102 or consent of instructor.

GRADUATE COURSES

INORGANIC CHEMISTRY

CM 601 Inorganic Chemistry 3¼:0:4½

Theories of bonding in inorganic compounds. Introduction to group theory as applied to molecular orbital and ligand field theories. Spectra of inorganic compounds. Nonaqueous solvents. Introduction to transition metal chemistry. Required of all candidates for Ph.D. degree in chemistry.

CM 614-619 Advanced Topics in Inorganic Chemistry each 2½:0:3

Selections from following topics may be offered: physical and synthetic methods in inorganic chemistry, organometallic chemistry, chemistry of the solid state, chemistry of coordination compounds, mechanisms of inorganic reactions, chemistry of non-metals, inorganic polymers, chemistry of representative elements, bonding theories. *Prerequisite:* CM 601 and advisor's approval.

PHYSICAL CHEMISTRY

CM 703 Chemical Physics I 3¼:0:4½

Quantum structures of molecules. Fundamental ideas of quantum mechanics. Applications to atomic and molecular structures and bonding. Approximation methods. Interactions of light and matter. *Prerequisites:* undergraduate physical chemistry and physics.

CM 704 Chemical Physics II

3 1/2:0:4 1/2

Chemical kinetics and thermodynamics. Fundamental ideas of statistical mechanics. Development of relationships of various bulk properties of matter to molecular structures and interactions. Applications to solutions, polymers. *Prerequisites:* Undergraduate physical chemistry and physics.

CM 715-717 Advanced Topics in Physical Chemistry

2 1/2:0:3

Selections from the following topics may be offered at irregular intervals: Kinetics of Chemical Reactions, Valence and Molecular Structure, Electrochemistry.

CM 721 Quantum Mechanics for Chemists

3 1/2:0:4 1/2

Principles of quantum mechanics quantitatively developed. Comparison of various approaches. Most important approximation methods useful for applications of theory to many problems in chemistry and physics. Detailed discussions of several applications to some basic problems. Required of all Ph.D. candidates with major in physical chemistry. *Prerequisites:* CM 704, PH 601 and PH 602. May be offered at irregular intervals.

CM 722 Statistical Mechanics for Chemists

3 1/2:0:4 1/2

Classical and quantum statistical mechanics systematically developed and applied to calculations of thermodynamic properties of various states of matter from knowledge of structure of atoms and molecules and their forces of interaction. Required of all Ph.D. candidates with major in physical chemistry. *Prerequisite:* CM 721. May be offered at irregular intervals.

CM 730-731 Group Theory and its Applications I,II

each 2 1/2:0:3

Group theory and its application to various problems in chemistry and physics. Abstract group theory; group representations; finite and continuous groups. Applications to crystallography; valence theory; interpretation of atomic and molecular spectra; crystal field theories; energy band theories of solids; crystal symmetry and physical properties. CM 730

Prerequisite: instructor's permission. CM 731 *Prerequisite:* CM 730. May be offered at irregular intervals.

CM 750 Special Topics in Physical Chemistry

2 1/2:0:3

Advanced or specialized topics in physical chemistry presented at irregular intervals.

CM 760 Minicomputer Instrumentation for Scientific Research

1 1/2:2:3

Fundamentals of digital electronics and minicomputers; computer-automated laboratory instrumentation; programming and interfacing required for data acquisition and control in scientific research. Experiments with minicomputers and with laboratory apparatus interfaced directly to minicomputers. Lab fee required. *Prerequisite:* instructor's permission. Offered in alternate years. Also listed under PH 612 and BE 623.

POLYMER CHEMISTRY

CM 771 Introductory Polymer Chemistry

2 1/2:0:3

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

2 1/2:0:3

Organic aspects. Chemistry of monomer and polymer formations. Modern mechanistic analyses of reactions. Stereochemistry of polymer structures and forces of stereoregulation. Condensation; free radical (bulk, suspension, emulsion, solution); ionic, ring-opening and non-classical polymerization reactions.

CM 781 Solution Properties of High Polymers

2 1/2:0:3

Application of osmometry, light scattering, equilibrium ultracentrifugation, electrophoresis, viscosity, diffusion, ultracentrifugal sedimentation, flow

birefringence, polarimetry, spectroscopy, and other techniques to the characterization of dissolved macromolecule. Properties of polyelectrolyte, association in solutions containing macromolecule and reaction kinetics in macromolecular solutions also are discussed. The course is designed to cover both synthetic and biological macromolecule. *Prerequisites:* CM 161, CM 162 & CM 772 or CM 783

CM 782 Macromolecule in Solid States

2 1/2:0:3

Crystalline-amorphous systems, thermodynamics of crystallization, defect structures, morphology of polymer crystals, characterization of polymeric solids by X-ray and electron diffraction, potential energy calculations, electron microscopy, absorption spectroscopy, and nuclear magnetic resonance. Electrical and optical properties of polymer solids. *Prerequisite:* CM 771.

CM 783 Laboratory Methods in Polymer Chemistry

0:4:3

Experiments on free radical and ionic polymerization, copolymerization; UV/VIS and NMR spectroscopy, intrinsic viscosity, light scattering, gel permeation chromatography, X-ray diffraction, thermogravimetric analysis, differential scanning calorimetry, dilatometry, concentrated solution viscosity, and other aspects of polymer synthesis and characterization. Lab fee required. *Prerequisite:* CM 771.

CM 785 Special Topics in Polymer Chemistry

2 1/2:0:3

Presentation at intervals of various advanced or specialized topics in polymer chemistry.

CM 790 Biopolymer

2 1/2:0:3

Structure and properties of important biological macromolecule including proteins, nucleic acids and polysaccharides, membranes and macromolecular complexes, applications of X-ray diffraction, NMR, vibrational and CD spectroscopy to the analysis of structure. Biopolymer may be used to satisfy major field requirements in polymers or minor field requirements in biochemistry. Offered in alternate years. *Pre/Corequisite:* CM 941 or consent of instructor.

ANALYTICAL CHEMISTRY

CM 802 Applied Spectroscopy 3 1/4:0:4 1/2

Solving chemical problems using spectroscopic methods. Vibrational, electronic, nuclear magnetic resonance spectroscopy and mass spectrometry. Discussion of physical principles, instrumentation, interpretation of spectra, applications to molecular and physical problems. *Prerequisite:* CM 703 or consent of instructor.

ORGANIC CHEMISTRY

CM 903 Organic Chemistry I 3 1/4:0:4 1/2

Molecular structure and bonding. Stereochemical and conformational principles. Theories of bonding and the physical parameters of stable and reactive molecular states. Applications in biochemistry and polymer chemistry. *Prerequisites:* undergraduate physical chemistry and organic chemistry.

CM 904 Organic Chemistry II 3 1/4:0:4 1/2

Reactivity of molecules. The methods of mechanistic study of reaction pathways. Important reactions of organic and organometallic chemistry. Introduction to synthesis and applications in living systems and in polymer reactions. *Suggested prerequisite:* CM 903 or consent of instructor.

CM 907 Organic Spectroscopy 3 1/4:0:4 1/2

Structure elucidation by joint applications of spectroscopic techniques such as proton and carbon-13 magnetic resonance, infrared and mass spectroscopy, and other methods. *Prerequisite:* CM 903 or CM 904 or consent of instructor.

CM 915 Topics in Physical Organic Chemistry 2 1/2:0:3

Quantitative aspects of structural, electronic and medium effects in organic reactions; theoretical approaches to organic mechanisms; stereochemistry. *Prerequisite:* CM 903 or CM 904. May be offered at irregular intervals.

CM 920 Current Aspects of Organic Synthesis 2 1/2:0:3

Approaches to syntheses of organic molecules. Stereoselective and stereospecific reactions. Examples drawn from naturally occurring and theoretically interesting molecules. *Prerequisite:* CM 903 or CM 904. May be offered at irregular intervals.

CM 921-933 Advanced Topics in Organic Chemistry 2 1/2:0:3

Selections from the following topics will be offered at irregular intervals: organometallic chemistry, photochemistry, heteroatom chemistry, and natural products. *Prerequisite:* CM 903 or CM 904.

CM 940 Special Topics in Organic Chemistry 2 1/2:0:3

Topics selected from current research or literature, and approaches to problem solving. *Co/Prerequisite:* CM 903 or CM 904.

BIOCHEMISTRY

CM 941-942 Biochemistry I,II each 2 1/2:0:3

In depth studies of biochemistry. Structure and function of biological macromolecule: proteins, nucleic acids, polysaccharides. Enzyme kinetics, mechanism and control. Membrane structure and function. Energy production, transformation and utilization. Regulation of biochemical systems. Replication, transcription and translation of DNA. Mutagenesis and carcinogenesis. Immune system. *Prerequisite:* consent of instructor.

CM 943-946 Advanced Topics in Biochemistry 2 1/2:0:3

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 1 1/2:5:3 1/2

Laboratory procedures illustrating new techniques for isolation, fractionation and characterization of biological macromolecule. Enzyme kinetics. Lab fee required. *Prerequisites:* CM 123, CM 125, CM 202, CM 162, LS 106, LS 116. *Co/Prerequisites:* CM 941-942.

GENERAL COURSES

CM 871-872 Guided Studies in Chemistry as arranged

Directed studies or supervised readings in advanced areas of chemistry. Registration by consent of department head.

CM 971-972 Chemical Colloquium 0

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

CM 973-976 Seminar in Chemistry each 1 1/2 units

Chemical topics of current interest presented by participating students, staff, outside lecturers. Two semesters required of all master's candidates and four semesters of all doctoral candidates.

CM 991-992 Special Techniques in Experimental Chemistry I,II each 0:6:3

Specialized techniques and processes of modern experimental chemistry. Depending upon requirements of thesis students and recommendations of advisors, advanced laboratory skills in X-ray diffraction, solid state synthesis, measurements of magnetic moments and susceptibilities, spectroscopic techniques, chromatographic techniques, thermal analyses, relaxation kinetics, electrochemistry, etc. Emphasis on intensive training in students' research activities. May be taken for a maximum of two semesters. *Prerequisite:* Concurrent

thesis registration and permission of advisor and course director.

CM 995-996 Seminar in Chemical Physics *each 1½ units*

Topical subjects, problems, current research in chemical physics presented by participants, staff, outside lecturers. Required of all master's and doctoral candidates in chemical physics.

CM 998 Research in Chemistry *3 units*

Original research, which serves as basis for master's degrees. To be taken by Ph.D. candidates before completion of Ph.D. preliminary examinations in chemistry. Minimum research registration requirements for the master's degree: 12 units. Registration for research required each semester consecutively until students have completed adequate research projects and acceptable theses and passed required oral examinations. Research credits registered for each semester reflect realistically time devoted to research. A maximum of 6 units may be counted towards a Ph.D. in chemistry. Research charge. *Prerequisites:* for M.S. candidates, degree status and consent of graduate advisor and thesis director and CM 504.

CM 999 Research in Chemistry *3 units*

Original experimental or theoretical research (undertaken under guidance of a chemistry faculty member), which may serve as basis for degree of doctor of philosophy. Chemical physics majors with thesis advisors in Department of Physics should register for PH 791-796 and PH 981-993. Minimum research registration requirements for degree for holders of M.S. based on research and thesis acceptable to department, 33 units; for other students, 45 units. Registration for research required each semester consecutively until students have completed adequate research projects and acceptable theses and passed required oral examinations. Number of research credits registered for each semester must reflect realistically time devoted to research. Research fees required. *Prerequisites:* completion of Ph.D. preliminary examination in chemistry, consent of thesis director and CM 504.

LIFE SCIENCES COURSES

In recent years, Polytechnic has developed life sciences courses which complement those in its teaching and research programs in engineering and physical sciences. Undergraduate students with specific interests in the areas of biology, biochemistry, environmental sciences, bioengineering, premedicine and laboratory techniques may elect life science courses to fulfill specific B.S. program requirements or to serve as technical or free electives.

Biology is concerned with the study of life in all manifestations—from the simple to the complex, from the invisible to the macroscopic, from the virus to the human. To move beyond definitions of life to understanding life's fundamental nature, characteristics of living systems must be examined, including growth, heredity and reproduction, metabolism, energy production and utilization, responsiveness, and locomotion. Structures and function of living matter at the molecular, cellular and organismal levels must be probed. Biology, chemistry and physics contribute to understanding of living systems.

Undergraduate Courses

LS 105-106 General Biology I, II *each 3:0:3*

Fundamentals of biology. Physical, chemical, biochemical bases of life on various organizational levels. Cellular morphology, complementarity of form and function. Reproduction, development, genetics. Homeostasis, regulation, integration, coordination. *LS 105 prerequisite:* high school chemistry. *LS 106 prerequisite:* LS 105 or instructor's consent.

LS 115-116 General Biology Laboratory I, II *1:3:2*

Recitations in relationship to laboratory experiments include discussions of such topics as: cell structure and function; chemical and physical characteristics of living things; unity and diversity of living things; genetics, development, homeostasis, integration and coordination; adaption, evolution, ecology and the biological bases of behavior. Lab fee required. *LS 115 Co/Prerequisite:* LS 105. *LS 116 Co/Prerequisite:* LS 106.

LS 103-200 Topics in Biology Credit as arranged

From time to time courses may be offered in the following areas: Developmental Biology, Fundamentals of Genetics, Microbiology, Physiology, Cell Physiology, Cell Biology, Techniques and Instrumentation, Histological Techniques, and others.

LS 305-307 Projects in Life Sciences *each 2 credits*

Investigations of problems in biology under supervision of faculty members. Library research, experimental studies, written reports required. Lab fee required. *Prerequisite:* senior status or advisor's consent.

LS 308 Life Science Internship *2 credits*

Supervised projects carried out in hospital, community or industrial settings. Evaluated on basis of written and oral reports present to faculty and outside project co-sponsors. Faculty conferences and visits required. Open to senior students on approval of departmental advisor. Preplanned experiences provide students with significant exposure to relationships between theoretical information and practical applications. *Prerequisite:* senior status or advisor's consent.

LS 310 Seminar in Biology *1 credit*

Selected topics of current interest presented by participating students, staff and outside lecturers. *Prerequisites:* LS 105 and LS 106.

Graduate Courses

LS 561-702 Advanced Topics in Biology *credit arranged*

From time to time, graduate level courses may be offered in Bioethics, Electron Microscopy, Environmental Biology, Neurophysiology, Topics in Neurophysiology, Topics in Neuroscience, and Cytology.

LS 900 Selected Topics in Biology
2½:0:3

Presentation of significant topics in biology or related interdisciplinary areas. Topics may vary from year to year.

FACULTY

Donald M. Schleich, Professor of Inorganic Chemistry and Head, Department of Chemistry
B.S., SUNY (Fredonia); Ph.D., Brown University; *Materials, chemistry, solid state chemistry*

Mary K. Cowman, Associate Professor of Biochemistry; B.S., M.S., Ohio University; Ph.D., Case Western Reserve
Solution conformation and interactions of complex carbohydrate polymers; circular dichroism and nuclear magnetic resonance spectroscopy; biochemistry of extracellular matrix components

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

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

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

T.K. Kwei, Professor of Polymer Chemistry
M.S., National Chiao-Tung University (China); M.S., University of Toronto; Ph.D., Polytechnic Institute of Brooklyn
Polymer-polymer miscibility, segmented polyurethanes and unsaturated polyesters, phase relationships in polymer blends, interactions in composites

Kalle Levon, Assistant Professor of Polymer Chemistry
Phase separation in polymer blends and solutions, gelation, conductive polymers

Shirley M. Motzkin, Professor of Biology
B.S., Brooklyn College; A.M., Columbia University; Ph.D., New York University
Development mechanisms, teratology and skeletal development, radiation effects

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

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

Norman C. Peterson, Professor of Physical Chemistry
B.S., Massachusetts Institute of Technology; Ph.D., Iowa State University
Molecular beam scattering, laser chemistry, reaction kinetics

Sergio Petrucci, Professor of Physical Chemistry; Ph.D., University of Rome
Relaxation kinetics, ligand substitution in non-aqueous media, microwave and diffusional rotational relaxation

Arnost Reiser, Professor of Chemistry
Dr. Ing. (Prague); D.Sc. (London)
Polymer photochemistry, photoresists, image science

Wayne F.K. Schnatter, Assistant Professor of Organic Chemistry
B.S. (Chemistry) B.S. (Biology), Rennselaer Polytechnic Institute; M.A., Ph.D., Princeton University
Organotransition metal chemistry; synthesis of enantiomerically pure compounds; molecular design; catalyst development

Guiliana Tesoro, Research Professor of Polymer Chemistry
Ph.D., Yale University
Applied polymer science, fiber science, thermal dehydration and flammability of polymers, composites, and polymers for electronics applications

Nancy M. Tooney, Associate Professor of Biochemistry and Assistant Provost for Academic Affairs
B.S., M.S., SUNY (Albany); Ph.D., Brandeis University
Structure and function of proteins and other biopolymer, blood clotting system, fibronectin structure and function, environmental chemistry

**EMERITUS
FACULTY**

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

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

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

Ernest Loeb, Professor Emeritus of Physical Chemistry
M.S., Hebrew University, Ph.D., Columbia University
Theoretical Chemistry, Quantum Statistical Mechanics

CHEMICAL PHYSICS

GRADUATE DEGREE PROGRAMS

The chemical physics program at Polytechnic is designed to train students for careers in areas common to chemistry and physics. It provides, within the scope of a normal graduate program, an unusual overlap of students in both departments, emphasizing aspects that are closely related to both fields.

Faculty members participating in the chemical physics program are currently engaged in research in the following areas:

- Atomic and molecular dynamics
- Imaging sciences
- Laser chemistry and spectroscopy
- Medical physics
- Microparticle photophysics
- Nonlinear optics
- Polymer photochemistry and photophysics
- Solid state chemistry
- Statistical mechanics
- Surface and condensed matter physics
- X-ray crystallography

Doctoral research in chemical physics involves working closely with a faculty member on a research project in areas such as those listed above.

Students normally enter the program with undergraduate degrees in chemistry, physics and mathematics. Students spend the first year in the program developing competence in those areas of chemistry, physics and mathematics that are outside their undergraduate training. Guided by the graduate advisor, students select a plan of study suited to their individual needs and interests; thus there are no formal specific course requirements for a master's or doctor's degree. Representative first-year programs for students entering graduate study in chemical physics are:

REPRESENTATIVE PROGRAM FOR FIRST YEAR STUDENTS

No	Subject	Units
CM 703	<i>Chemical Physics I</i>	4½
CM 704	<i>Chemical Physics II</i>	4½
MA 630	<i>Complex Variables</i>	3
MA 839	<i>Introduction to Functional Analysis</i>	3

CM/PH		
995-996	<i>Seminar in Chem. Physics</i>	3
CM 971-972	<i>Chemistry Colloquium</i>	
	<i>Zero or</i>	
PH 901-902	<i>Physics Colloquium Zero</i>	

Students with baccalaureate degrees in chemistry:

MA 260	<i>Vector Analysis and Partial Differential Eqns.</i>	4
PH 373-374	<i>Introduction to Theoretical Physics</i>	6

Students with baccalaureate degrees in physics:

CM 161-162	<i>Physical Chemistry I, II</i>	6
CM 601	<i>Inorganic Chemistry</i>	4½

Thesis, project and/or electives chosen from chemistry, physics and mathematics 8-11

REQUIREMENTS FOR THE MASTER'S DEGREE

The program of study for the degree of master of science in chemical physics offers three options, each requiring 36 units. One option, including early formal research, consists of a 12-unit thesis and 24 units of required and elective courses. In another option, candidates with suitable experience may substitute a six-unit project and six additional electives for the 12-unit thesis. The project

requires a literate and critical discussion of the current status of a specialized area of research and demonstration of the student's professional maturity. The project is completed by the submission of an acceptable written report and by its satisfactory defense in an examination.

The third option emphasizes a strong formal training in courses and is acceptable as well as advised only for students planning to proceed to the doctorate. The Ph.D. qualifying examination will generally serve as the M.S. final examination. A satisfactory pass is required.

No.	Required Subjects	Units

CM 971-972	<i>Chemistry Colloquium Zero</i>	
	<i>or</i>	
PH 901-902	<i>Physics Colloquium Zero</i>	
CM/PH 995-996	<i>Seminar in Chemical Physics</i>	
	<i>or</i>	
	<i>Chemistry or Physics</i>	
	<i>(to be taken with either colloquium)</i>	3

and one of the following:

CM/PH 998-999	<i>Thesis in Chemical Physics</i>	12
	<i>Electives*</i>	at least 21
	<i>or†</i>	
CM/PH 998-999	<i>Project in Chemical Physics</i>	6
	<i>Electives*</i>	at least 27
	<i>or†</i>	
	<i>Electives*</i>	at least 33
		at least 36

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

† Advised and allowed only for students intending to proceed to the doctorate.

**REQUIREMENTS FOR
THE DOCTOR'S
DEGREE**

The requirements for the doctorate conform to the general regulations given elsewhere in this catalog. Both the major and minor fields are generally chosen from the areas of chemical physics, chemistry, physics and mathematics. Students are expected to pass examinations which form part of those regularly given to graduated students in the Departments of Chemistry and Physics.

The most important requirement is the preparation of a dissertation embodying a substantial research contribution in chemical physics.

Students may apply for admission to the chemical physics program either when applying for admission to graduate school or later. Application forms, as well as additional information, are available from the Office of Research and Graduate Studies.

**FACULTY
(Interdepartmental
Committee)**

Bruce A. Garetz, Associate Professor of Chemistry;
Chairman, Chemical Physics Committee

Donald M. Schleich, Professor and
Head of Chemistry

Edward L. Wolf, Professor and Head of
Physics

Peter Riseborough, Professor of Physics

**PARTICIPATING
FACULTY**

Stephen Arnold, Professor of Physics

Ephraim Banks, Professor Emeritus of
Chemistry

Patrick T. Cahill, Professor of Physics

Lorcan Folan, Assistant Professor of
Physics

Hellmut J. Juretschke, Professor of
Physics

Kalle Levon, Assistant Professor of
Chemistry

Alla Margolina, Assistant Professor of
Physics

Norman C. Peterson, Professor of
Chemistry

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

Carol Thompson, Assistant Professor of
Physics

PHYSICS

Physics is the basic science of the natural world — the science of matter, energy and motion. It is indispensable for any engineering or scientific career.

The training of physics majors, at both undergraduate and graduate levels, is basic and general. This broad preparation makes graduates less subject to the risks of obsolescence produced by the rapidity of technological change in modern life. Curricula are designed as back-grounds for careers in industry, government and education. Others go into science teaching at many different levels. Physics graduates at all levels are employed in private industry, government agencies and research foundations for fundamental research and engineering. Training in physics serves as a valuable preparation for any science-based or science-connected careers.

Besides the very active fields of solid-state and nuclear physics, other general areas in which physicists are now employed are the radio/television and electronics, the chemical industry and biophysics, space science and medical physics.

The Department of Physics grants the degrees of bachelor of science, master of science, and the doctor of philosophy in physics.

UNDERGRADUATE PROGRAM

The aim of the four-year undergraduate program in physics is to prepare students thoroughly for any one of the many careers for which a concentration in physics forms the base. For some students, this means preparation for graduate school and further study leading to the master's or doctor's degree. For many others, it means professional work in industry, government or in high school teaching. Some students use their major in physics as preparation for work in mathematics, chemistry, biology,

medicine, engineering, law, history of science, writing, or business.

The program's emphasis on fundamental knowledge, on thorough analytic training and on the universal logic of science enables physics students to take these different paths.

The structure of the undergraduate program is four-fold: formal instruction in the sciences; instruction in the humanities and the social sciences; informal instruction; and additional activities.

Formal instruction in the sciences is described by its program of courses. This program includes — after the freshman year with its beginning courses in physics, chemistry and mathematics — a spiraling sequence of courses in the three broad areas of mechanics, electromagnetic theory and modern physics, matched at each level to the student's increasing mathematical maturity. With this background, a senior is ready for theoretical physics and electives in solid-state, x-ray, nuclear physics or quantum theory. Specialized courses such as optics, thermodynamics, computing and electronics are required, and additional courses in mathematics, chemistry or life sciences may be elected.

Instruction in the humanities and social sciences is built around the 32 credit hours of courses in the humanities and the social sciences required of all physics majors. This department urges students to choose additional courses in these areas. It believes that the natural curiosity which brought students to choose physics as a major should also be stimulated in other areas of intellectual activity such as literature, psychology, poetry, music, economics and history.

Informal instruction accompanying the formal course work takes a variety of forms. All students meet regularly with members of the physics faculty for normal conferences to discuss their work, review problems or talk physics.

All physics freshmen take a seminar on current advances in physics; all seniors participate in another seminar. In both, students prepare talks on aspects of

advanced topics in physics and present them to the critical audiences of their peers and professors.

Many students spend some time in research, either assisting in the various research programs performed by the faculty or working on relatively independent research projects assigned after consultation with their adviser. Undergraduate participation in research with graduate students and professors is becoming so important that it will probably soon enter the department's formal education structure. A number of juniors and seniors in the physics department now spend ten weeks each summer in such full-time research activity. Opportunities for guided research during the academic year also exist.

The department offers opportunities for individual reading and advanced study under professional guidance and accepts satisfactory performance in regular course examinations as fulfillment of course requirements.

Physics students have a common study area in which they meet with other students for shop talk, for problem-solving and for the exchange of ideas.

Information about advanced placement of freshmen is included in the section of this catalog on Admissions.

Additional activities, in which all physics students are urged participate, include the programs organized by the Physics-Math Society, by the chapter of Sigma Pi Sigma (the physics honor society) and by the local student chapter of the American Physical Society. Here the students listen to and meet speakers on various topics and participate in trips to industrial and government laboratories. Undergraduates are encouraged to come to the regular research colloquia where invited scientists discuss the latest advances in physics. They also attend meetings of the American Physical Society and other professional societies associated with the American Institute of Physics.

By means of these activities and through the structure of the department, students have a wide range of opportunities for interacting with their professors, their fellow students and with the world of physics. Such interaction is the most valuable preparation for any careers in physics. This blending of experiences leads to appreciation of the intellectual impact of physics and to understanding why so many important thinkers have been attracted to physics and have added to its achievements.

REQUIREMENTS FOR THE BACHELOR OF SCIENCE DEGREE IN PHYSICS

The program requires 128 credits, including 56 credits of required courses in physics. The remaining credits are distributed among required technical courses, required humanities, social sciences courses, a foreign language requirement and restricted electives.

(See Typical Course of Study on the following page.) The distribution is as follows:

	Credits
PH 104, 105, 106, 113, 115, 116, 210, 234, 236, 250, 302, 311, 323, 324, 335, 336, 340, 347, 360, 373, 374, 390	56
CM 101, 102, 111, 112, MA 101, 102, 103, 104, 153, 260, 217, CS 112	33
HU 101, HU 200; SS 104	9
Language (or equivalent)	12
Electives	18
(6 PH, 12 Hum./Soc. Sci.)	128

Required Physics Courses

The course format of the required courses may be lectures, recitations or guided reading. Any substitutions require the permission of the undergraduate adviser.

Electives

Elective courses are chosen in consultation with the departmental adviser.

Typical Course of Study for the Bachelor of Science Degree in Physics

FRESHMAN YEAR

		Hours/Week		
No.	Subject	Cl.	Lab.	Cr.
<i>First Semester</i>				
CS 112	Programming in Pascal	3	0	3
CM 101	Gen. Chemistry	2½	0	2½
CM 111	Gen. Chem. Lab I	0	1½	½
MA 101	Calculus I or MA 100	4	0	4
PH 113	Seminar in Current Physics	2	0	2
	Hum./Soc.Sci. elective ¹	6	0	6
SL 101	Freshman Seminar	1	1	0
PE 10x	Physical Education	0	2	0
				18

Second Semester				
CM 102	Gen. Chemistry I	2½	0	½
CM 112	Gen. Chem. Lab.	0	1½	½
MA 102	Calculus II	4	0	4
PH 104	Intro. to Physics I	3	0	3
	Hum./Soc.Sci. elective ¹	6	0	6
PE 102	Physical Education	0	2	0
				16

SOPHOMORE YEAR

First Semester				
MA 103	Calculus III	3	0	3
MA 104	Appl. Diff. Equations	3	0	3
PH 105	Intro. to Physics II	3½	0	3½
PH 115	Physics Lab. I	0	1½	½
PH 210	Analyt. Mechanics	3	0	3
	Hum./Soc.Sci. elective ¹	3	0	3
PE 10x	Physical Education	0	2	0
				16

Second Semester				
MA 153	Elem. Linear Alg.	3	0	3
PH 106	Intro. to Physics III	2½	0	2½
PH 116	Physics Lab. II	0	1½	½
PH 234	Intro. to Modern Physics	2	0	2
PH 236	Physics Lab. III	½	1½	1
PH 250	Electronics for Physical Scientists	3	3	4
	Hum./Soc.Sci. elective ¹	3	0	3
PE 10x	Physical Education	0	2	0
				16

JUNIOR YEAR

First Semester

PH 311	Thermodynamics	3	0	3
PH 323	Elect. & Magnetism I	2	0	2
PH 335	Quantum Phys. II	4	0	4
MA 260	Vector Anal. & PDE	4	0	4
	Hum./Soc.Sci. elective ¹	3	0	3
				15

Second Semester

PH 302	Advanced Lab.	1	3	2
PH 324	Elect. & Magnet. II	2	0	2
PH 336	Quantum Mechanics	3	0	3
PH 340	Special Topics	3	3	4
PH 360	Special Topics	3	0	3
	Hum./Soc.Sci. elective ¹	3	0	3
				17

SENIOR YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.
<i>First Semester</i>				
MA 217	Complex Variables	3	0	3
PH 347	Modern Optics	3	3	4
PH 373	Intro. Theo. Phys. I	3	0	3
PH 663	Stat. Mech. I ²			
	or			
PH 667	Quantum Mech. ² I	3	0	3
	Hum./Soc.Sci. elective ¹	3	0	<u>3</u>
				16

Second Semester

PH 374	Intro. Theo. Phys. II	3	0	3
PH 390	Senior Seminar	2	0	2
PH 664	Stat. Mech. II ²			
	or			
PH 668	Quantum Mech. II ²	3	0	3
	Hum./Soc.Sci. elective ²	6	0	6
				14

¹ Humanities and Social Sciences: Required courses (21 credits), include HU 101 and either HU 200, SS 104 or IS 140, 141 (9 credits); and ML 1x1 through 1x2 (12 credits). The modern language requirement must be satisfied in German, French, or Russian. Based on performances in prior language studies, the language requirement may, with approval of the Department of Physics, be replaced by other humanities or social sciences electives. Elective courses (11 credits): The student is strongly urged to select two or three courses from an area of concentration such as literature, communications, the arts, philosophy,

comparative religion, political science, economics, history, anthropology, or psychology.

Electives are chosen with the adviser's approval.

¹ Advanced electives strongly recommended for students intending to pursue graduate studies in physics. Other possible electives include Advanced Lab II (PH 303), X-ray Diffraction (PH 372) Readings in Physics (PH 381-2), courses in PH 6xx sequence.

REQUIREMENTS FOR THE BACHELOR OF SCIENCE DEGREE IN PHYSICS WITH OPTIONS IN MATHEMATICS, ELECTRONICS, MATERIALS, AND BIOLOGY

These programs offer the student an opportunity to gain competence in two different and substantial fields of science, to such an extent that upon earning a Bachelor's degree he or she may be able to qualify for industrial positions in two distinct areas, or to go on to graduate studies in either of the two subjects.

The option in Mathematics provides a strong training in both Physics and Mathematics, approaching the requirements for separate degrees in each subject. The options in Electronics, Materials, and Biology may be viewed as similar to Applied Physics programs with concentrations in the respective areas. In all cases the student benefits from the strong basic training in Physics and positions himself for further training or direct employment in the area of his option.

Electronics, Materials Sciences, and Biology are areas of immense importance in today's technology, providing a wide range of employment opportunities in addition to those available in Physics. As examples, in the active technology areas of Microelectronics and High Temperature Superconductivity, combined knowledge of Physics and Electronics or Materials opens many opportunities for employment. A student with a strong basic training in Physics, in addition to that in his option, may enjoy in his career more flexibility and greater ability to adjust to changing requirements in technology.

The changes in course requirements for each Option from that of the B.S. in Physics are listed below.

MATHEMATICS OPTION

Require:

MA 101(4:0:4), MA 102(4:0:4), MA 103(3:0:3), MA 104(3:0:3), MA 153(3:0:3), MA 201 (3:0:3), MA 202(3:0:3), MA 224(3:0:3), MA 333(3:0:3), MA 358.

Drop:

PH 113(2:0:0), PH 250(3:3:4), PH 340(2:2:4), PH 360(3:0:3), Sr. Electives (6:0:6)

ELECTRONICS OPTION

Require:

EE 101(3:0:3), EE 102(3:0:3), EE 109(4:0:4), EE 110(3:0:3), EE 103(4:0:4), EE 193(0.5:1.5:1), EE 194(0.5,1.5,1), EE 195(1:3:2) --- 21 credits

Elect:

EE 395(0.5:1.5:1), and EE xxx Senior Lab/Project (3 cr.) or other technical electives ---- 4 to 7 cr.

Drop:

PH 250(3:3:4), PH 360(3:0:3), Sr. electives (6:0:6), PH 373-4 (6:0:6), PH 340 (3:3:4).

MATERIALS OPTION

Require:

MT 401(3:0:3), MT 403(3:0:3), MT 404(0:6:2), MT 408(0:6:2) --- 10 credits

Elect:

PH 372 MT 412(2:3:3) or MT 375(3:0:3) or MT 603/4 (4.5:2:6) --- 3 or 6 cr.

Drop up to the same number of total credits from the following lists:
PH 360(3:0:3), Sr. electives (6:0:6), PH 373 - 4(6:0:6).

BIOLOGY OPTION

Require:

LS 105-6 (6:0:6), LS 115-6 (2:6:4) --- 10 credits

Drop up to the same number of total credits from the following lists:
PH 360(3:0:3), Sr. electives (6:0:6), PH 373-4(6:0:6).

Typical Course of Study for the Bachelor of Science Degree in Physics (Mathematics Option)

FRESHMAN YEAR

		Hours/Week		
No.	Subject	Cl.	Lab.	Cr.
First Semester				
CS 112	Programming in Pascal	3	0	3
CM 101	Gen. Chemistry I	2½	0	2½
CM 111	Gen. Chem. Lab I	0	1½	½
MA 101	Calculus I	4	0	4
	Hum./Soc.Sci. elective	6	0	6
SL 101	Freshman Seminar	1	1	0
PE 10x	Physical Education	0	2	0
				16

Second Semester

CM 102	Gen. Chemistry II	2½	0	2½
CM 112	Gen. Chem. Lab II	0	1½	½
MA 102	Calculus II	4	0	4
PH 104	Intro. to Physics I	3	0	3
	Hum./Soc.Sci. elective	6	0	6
PE 10x	Physical Education	0	2	0
				16

SOPHOMORE YEAR

First Semester

MA 223	Probability	3	0	3
PH 105	Intro. to Physics II	3½	0	3½
PH 115	Physics Lab I	0	1½	½
PH 210	Analyt. Mechanics	3	0	3
	Hum./Soc.Sci. elective	3	0	3
				16

Second Semester

MA 104	Appl. Diff. Eqns.	3	0	9
MA 153	Elem. Lin. Algebra	3	0	3
PH 106	Intro. to Physics III	2½	0	2½
PH 116	Physics Lab II	0	1½	½
PH 234	Intro. to Mod. Phys.	2	0	2
PH 236	Physics Lab III	½	1½	1
	Hum./Soc.Sci.			
	elective	3	0	3
PE 10x	Physical Education	0	2	0
				15

JUNIOR YEAR

First Semester

MA 201	Appl. Analysis I	3	0	3
MA 333	Partial Diff. Eqns.	3	0	3
MA 224	Statistics	3	0	3
PH 323	Elect. & Magnetism I	2	0	2
PH 335	Quantum Physics	3	0	3
	Hum./Soc.Sci.			
	elective	3	0	3
				17

Second Semester

MA 202	Appl. Analysis II	3	0	3
MA 358	Numerical Analysis	3	0	3
PH 302	Advance Lab	1	3	2
PH 324	Elect. & Magnet. II	2	0	2
PH 336	Quantum Mechanics	3	0	3
	Hum./Soc.Sci.			
	elective	3	0	3
				16

SENIOR YEAR

First Semester

MA 217	Complex Variables	3	0	3
PH 311	Thermodynamics	3	0	3
PH 373	Intro. Theo. Phys. I	3	0	3
PH 347	Modern Optics	3	3	4
	Hum./Soc.Sci.			
	elective	3	0	3
				16

First Semester

PH 347	Intro. Theo. Phys. II	3	0	3
PH 390	Senior Seminar	2	0	2
	Hum./Soc.Sci.			
	elective	3	0	3
	Free elective	8	0	8
				16

**Typical Course of Study
for the Bachelor of Science
Degree in Physics
(Electronics Option)**

FRESHMAN YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.

First Semester

CS 112	Prog. in Pascal	3	0	3
CM 101	Gen. Chemistry I	2½	0	2½
CM 111	Gen. Chem. Lab I	0	1½	½
MA 101	Calculus I			
	(or MA 100)	4	0	4
PH 113	Seminar in Current Physics	2	0	2
	Hum./Social Science			
	Elective ¹	6	0	6
SL 101	Freshman Seminar	1	1	0
PE 10x	Physical Education	0	2	0
				18

Second Semester

CM 102	Gen. Chemistry II	2½	0	2½
CM 112	Gen. Chem. Lab II	0	1½	½
MA 102	Calculus II			
	(or MA 110)	4	0	4
PH 104	Intro. to Physics I	3	0	3
	Hum./Social Science			
	Elective ¹	6	0	6
PE 10x	Physical Education	0	2	0
				16

SOPHOMORE YEAR

First Semester

MA 103	Calculus III	3	0	3
MA 104	Appl. Diff. Equations	3	0	3
PH 105	Intro. to Physics II	3½	0	3½
PH 115	Physics Lab I	0	1½	½
PH 210	Analyt. Mech.	3	0	3
EE 101	Electric Circuits I	3	0	3
EE 193	Sophomore EE Lab I	½	1½	1
PE 10x	Physical Education	0	2	0
				17

Second Semester

MA 153	Elem. Linear Algebra	3	0	3
PH 106	Intro. to Physics III	2½	0	2½
PH 116	Physics Lab II	0	1½	½
PH 234	Intro. to Modern Physics	2	0	2
PH 236	Physics Lab III	½	1½	1
EE 102	Electric Circuits II	3	0	3

EE 194	Sophomore EE Lab II	½	1½	1
	Hum./Social Science			
	Elective ¹	3	0	3
PE 10x	Physical Education	0	2	0
				16

JUNIOR YEAR

First Semester

EE 109	Solid State Dev. & Ccts I	4	0	4
EE 195	Junior EE Lab I	1	3	2
PH 311	Thermodynamics	3	0	3
PH 323	Elect. & Magnetism I	2	0	2
MA 260	Vector Anal. & PD	4	0	4
	Hum./Social Science			
	Elective ¹	3	0	3
				18

Second Semester

EE 110	Solid State Dev. & Ccts II	3	0	3
PH 302	Advanced Lab	1	3	2
MA 217	Complex Variables	3	0	3
EE 103	Signals & Transforms	4	0	4
PH 324	Elect. & Magtism. II	2	0	2
	Hum./Social Science			
	Elective ¹	3	0	3
				14

SENIOR YEAR

First Semester

PH 335	Quantum Physics	3	0	3
PH 347	Modern Optics	3	3	4
EE 395	Intro. to Project ²	½	1½	1
	Hum./Social Science			
	Elective ¹	6	0	6
				17

Second Semester

EE xxx	Senior EE Lab/Proj. ²	x	x	3
PH 336	Quantum Mechanics	3	0	3
PH 390	Senior Seminar	2	0	2
	Hum./Social Science			
	Elective ¹	6	0	6
				14

¹ Humanities and Social Sciences: Required Courses (21 credits), include HU 101 and either HU 200, SS 104 or IS 140, 141 (9 credits); and ML 1x1 through 1x4 (12 credits). The modern language requirements must be satisfied in German, French or Russian. Based on performance in prior language studies, the language requirement may, with approval of the Department of Physics, be replaced by other Humanities or Social Science electives. Elective courses (11 credits): The student is strongly urged to select two or three courses from an area of concentration

such as literature, communications, the arts, philosophy, comparative religion, political science, economics, history, anthropology, or psychology.

Electives are chosen with the adviser's approval.

- 2 EE 395 - EE xxx is an elective sequences of 4 to 7 credits. Specific electives may be chosen with the help/approval of the departmental adviser. For a strong semiconductor device concentration, the sequence EE 395 - EE 206 is desirable. (EE 206 is currently offered on the Long Island Campus, and has EE 119 as a prerequisite.) Please consult the Departmental Standards section in the EE catalog listing for minimum grades required for various EE courses.

Typical Course of Study for the Bachelor of Science Degree in Physics (Materials Option)

FRESHMAN YEAR

		Hours/Week		
No.	Subject	Cl.	Lab.	Cr.
<i>First Semester</i>				
CS 112	Prog. in Pascal	3	0	3
CM 101	Gen. Chemistry I	2½	0	2½
CM 111	Gen. Chem. Lab I	0	1½	½
MA 101	Calculus I			
	(or MA 100)	4	0	4
PH 113	Seminar in Current			
	Physics	2	0	2
	Hum./Social Science			
	Elective¹	6	0	6
SL 101	Freshman Seminar	1	1	0
PE 10x	Physical Education	0	2	0
				18

First Semester				
CM 102	Gen. Chemistry II	2½	0	2½
CM 112	Gen. Chem. Lab II	0	1½	½
MA 102	Calculus II (or MA 110)	4	0	4
PH 104	Intro. to Physics I	3	0	3
	Hum./Social Science Elective ¹	6	0	6
PE 10x	Physical Education	0	2	0
				16

SOPHOMORE YEAR

First Semester				
MA 103	Calculus III	3	0	3
MA 104	Appl. Diff. Equations	3	0	3
PH 105	Intro. to Physics II	3½	0	3½
PH 115	Physics Lab I	0	1½	½
PH 210	Analyt. Mechanics	3	0	3
	Hum./Social Science			

	Elective ¹	3	0	3
PE 10x	Physical Education	0	2	0
				16

Second Semester

MA 153	Elem. Linear Algebra	3	0	3
PH 116	Physics Lab II	0	1½	½
PH 234	Intro. to Modern Physics	2	0	2
PH 236	Physics Lab III	½	1½	1
PH 250	Electronics for Physical Scientists	3	3	4
	Hum./Social Science Elective ¹	3	0	3
PE 10x	Physical Education	0	2	0
				16

JUNIOR YEAR

First Semester

PH 311	Thermodynamics	3	0	3
PH 323	Elect. & Magnetism I	2	0	2
MT 401	Physical Metallurgy I	3	0	3
MT 404	Metallography Lab	0	6	2
MA 260	Vector Anal. & PDE	4	0	4
	Hum./Social Science Elective ¹	3	0	3
				17

Second Semester

PH 302	Advanced Lab	1	3	2
PH 324	Elect. & Magtism II	2	0	2
MT 403	Physical Metallurgy II	3	0	3
MT 408	Phys. Metallurgy Lab	0	6	2
PH 340	Computer Methods in Physics	3	3	4
	Hum./Social Science Elective ¹	3	0	3
				16

SENIOR YEAR

First Semester

MA 217	Complex Variables	3	0	3
PH 335	Quantum Physics	3	0	3
PH 347	Modern Optics	3	3	4
MT 603	Intro. to Electron Microscopy I ²	2½	0	3
	Hum./Social Science Elective ¹	6	0	6
				16

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.

Second Semester

PH 336	Quantum Mechanics	3	0	3
PH 390	Senior Seminar	2	0	2
MT 604	Intro. to Electron Microscopy II ²	2	2	3
	Hum./Social Science Elective ¹	6	0	6
				14

- 1 Humanities and Social Sciences: Required Courses (21 credits), include HU 101 and either HU 200, SS 104 or IS 140, 141 (9 credits); and ML 1x1 through 1x4 (12 credits). The modern language requirement must be satisfied in German, French, or Russian. Based on performance in prior language studies, the language requirement may, with approval of the Department of Physics, be replaced by other Humanities or Social Sciences electives. Elective courses (121 credits): The student is strongly urged to select two or three courses from an area of concentration such as literature, communications, the areas, philosophy, comparative religion, political science, economics, history, anthropology, or psychology. Electives are chosen with the adviser's approval.

- 2 MT603-4 is an elective strongly recommended. Other possible electives include PH 372/MT 412 x-ray Diffraction (2:3:3), MT 423 Introduction to Ceramic Refractory Materials (3:0:3), or others chosen with the advisers approval.

Typical Course of Study for the Bachelor of Science Degree in Physics (Biology Option)

FRESHMAN YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.
<i>First Semester</i>				
CS 112	Prog. in Pascal	3	0	3
CM 101	Gen. Chem. I	2½	0	2½
CM 111	Gen. Chem. Lab I	0	1½	½
MA 101	Calculus I			
	(or MA 100)	4	0	4
PH 113	Seminar in Current			
	Physics	2	0	2
	Hum./Social Science			
	Elective ¹	6	0	6
SL 101	Freshman Seminar	1	1	0
PE 10x	Physical Education	0	2	0
				18

Second Semester				
CM 102	Gen. Chemistry II	2½	0	2½
CM 112	Gen. Chem. Lab II	0	1½	½
MA 102	Calculus II (or MA 110)	4	0	4
PH 104	Intro. to Physics I	3	0	3
	Hum./Social Science Elective ¹	6	0	6
PE 10x	Physical Education	0	2	0
				16

SOPHOMORE YEAR

First Semester

MA 103	Calculus III	3	0	3
MA 104	Appl. Diff. Equations	3	0	3
PH 105	Intro. to Physics II	3½	0	3½
PH 115	Physics Lab I	0	1½	1½
PH 210	Analyt. Mechanics	3	0	3
	Hum./Social Science			
	Elective¹	3	0	3
PE 10x	Physical Education	0	2	0
				16

Second Semester

MA 153	Elem. Linear Algebra	3	0	3
PH 106	Intro. to Physics III	2½	0	2½
PH 116	Physics Lab II	0	1½	1½
PH 234	Intro. to Modern Physics	2	0	2
PH 236	Physics Lab III	½	1½	1
PH 250	Electronics for Physical Scientists	3	3	4
	Hum./Social Science			
	Elective¹	3	0	3
PH 10x	Physical Education	0	2	0
				16

JUNIOR YEAR

First Semester

LS 105	Gen. Biology I	3	0	3
LS 115	Gen. Biology Lab I	1	3	2
PH 311	Thermodynamics	3	0	3
PH 323	Elect. & Magnetism I	2	0	2
MA 260	Vector Anal. & PDE	4	0	4
	Hum./Social Science			
	Elective¹	3	0	3
				17

Second Semester

LS 106	Gen. Biology I	3	0	3
LS 116	Gen. Biology Lab II	1	3	2
PH 302	Advanced Lab	1	3	2
PH 324	Elect. & Magtism. II	2	0	2
PH 340	Computer Methods in Physics	3	3	4
	Hum./Social Science			
	Elective¹	3	0	3
				16

SENIOR YEAR

First Semester

MA 217	Complex Variables	3	0	3
PH 335	Quantum Physics	3	0	3
PH 347	Modern Optics	3	3	4
PH 663	Stat. Mech. I²			
	or			

PH 667	Quantum Mech. I²	3	0	3
	Hum./Social Science			
	Elective¹	3	0	3
				16

Second Semester

PH 336	Quantum Mechanics	3	0	3
PH 390	Senior	2	0	2
PH 664	Stat. Mech. I²			
	or			
PH 668	Quantum Mech. I²	3	0	3
	Hum./Social Science			
	Elective¹	6	0	6
				14

1 Humanities and Social Sciences: Required Courses (21 credits), include HU 101 and either HU 200, SS 104 or IS 140, 141 (9 credits); and ML 1x1 through 1x4 (12 credits). The modern language requirement must be satisfied in German, French, or Russian. Based on performance in prior language studies, the language requirement may, with approval of the Department of Physics, be replaced by other Humanities or Social Sciences elective. Elective courses (11 credits): The student is strongly urged to select two or three courses form an area of concentration such as literature, communications, the areas, philosophy, comparative religion, political science, economics, history, anthropology, psychology. Electives are chosen with the adviser's approval.

2 Advanced electives tryingly recommended for students intending to pursue graduate studies in physics. Other possible electives include Advanced Lab. (PH 303), X-ray Diffraction (PH 372), Readings in Physics (PH 381-2), courses in PH 600 sequence.

GRADUATE PROGRAMS

The Department of Physics offers graduate programs leading to the degrees of master of science and doctor of philosophy in physics. In addition, the Department of Physics cooperates with the Department of Chemistry in offering an interdisciplinary program leading to degrees in chemical physics.

Experimental research programs are offered in solid state physics, low temperature physics, surface physics, x-ray physics, quantum optics, radiation physics, and medical physics in modern well equipped laboratories. The x-ray diffraction laboratory, is equipped for all types of crystal analysis and has unique capabilities in high resolution x-ray interferometry. Surface physics studies are performed both in the department's

extensive surface science laboratories and at various synchrotron radiation facilities (e.g., National Synchrotron Light Source at Brookhaven National Laboratories and Cornell High Energy Synchrotron Source). Areas of current theoretical research are in solid state physics and statistical mechanics within the theoretical condensed matter group, and also field-matter interactions, image restoration, and nuclear theory.

For admission to graduate study in physics, a bachelor's degree in physics is required with preparation equivalent to intermediate courses in mechanics, electromagnetic theory, optics, thermodynamics, quantum mechanics, and atomic physics. Applicants with degrees in physics of different emphasis, or with a degree in another field, may be admitted with undergraduate deficiencies if approved by the department adviser. All applicants are requested to take the Graduate Record Examination.

Applicants can apply for teaching fellowships, research fellowships, or partial tuition remission.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE

The requirements for the master of science degree in physics conform to the general Polytechnic requirements. (see Degree Requirement)

The minimum course requirements for the master's degree are as follows:

No.	Subject	Units
PH 667	Quantum Mechanics I	3
PH 953-954	Graduate Seminar I,II	3
PH 901-902	Physics Colloquium I,II	0
	Elective Courses	30

With the approval of the graduate adviser, up to nine units of equivalent courses taken elsewhere may be used to fulfill individual course requirements. Registration for PH 901-902 Physics Colloquium is required each semester for all full-time graduate students. Elective courses may include a 6-unit project in physics or a 12-unit thesis in physics. Choices of a project or thesis option and of elective courses should be made with the approval of the graduate adviser. No comprehensive examination is required for the master's degree in physics.

REQUIREMENTS FOR THE DOCTOR OF PHILOSOPHY DEGREE

Requirements for the Ph.D. degree in physics conform to general Polytechnic requirements. Entrance into the doctoral program of study and research is contingent upon passing the department qualifying examination. The student entering with a bachelor's degree normally takes the qualifying examination after one year of study. The examination, given once a year at the beginning of the fall semester, consists of written questions in classical mechanics, electromagnetic theory, statistical mechanics, and quantum mechanics followed by an oral examination. Sample examination questions are available in the departmental office.

After passing the qualifying examination, the candidate suggests a guidance committee consisting of a prospective research director, a minor adviser, and at least one additional member of the physics faculty. The guidance committee must approve the candidate's choice of courses, conducts the dissertation, precis examination and the final dissertation oral examination, and must approve the dissertation, before the degree can be awarded.

The minimum course requirement for the Ph.D. degree in physics are:

No.	Subject.	Units
PH 669-670	Quantum Mechanics III,IV	6
PH 953-954	Graduate Seminar I,II	3
PH 901-902	Physics Colloquium I,II	0
PH 999	Research in Physics	24
	Additional Physics courses	33
	Minor Courses	12
	Elective Courses or	
	Additional Research in Physics	12
	Total	90

With the approval of the graduate adviser, equivalent courses taken elsewhere may be used to fulfill individual course requirements, although a minimum of 30 units including the dissertation units must be taken at Polytechnic. General knowledge of more than one area of physics is expected of all Ph.D. candidates. There is no foreign language requirement for the Ph.D. in physics. Registration for PH 901-902 Physics Colloquium is required each semester for

all full-time graduate students. Registration for PH 999 Research in Physics, once begun, is required each semester consecutively until the completion of the thesis unless leave is formally granted. Until the appointment of the guidance committee, the choice of physics courses, minor courses, and elective courses should be made with the approval of the graduate adviser.

Approximately three months before completion of the dissertation, a precis of the proposed work is circulated to the physics faculty and a precis examination held. Upon completion of the dissertation, an oral thesis defense is held.

CHEMICAL PHYSICS PROGRAM

Chemical physics is an interdisciplinary program designed to train students for careers in those areas common to chemistry and physics. Jointly administered by the Departments of Chemistry and Physics, it provides, within the scope of a normal graduate program, an unusual overlap of studies, emphasizing those aspects which are closely related to both fields.

UNDERGRADUATE COURSES

PH 091-092 Concepts of Contemporary Physics I,II

each 3:3:4

Topics in both classical and modern physics. Development of physics as a dynamic cumulative process through the interplay of experiment and theory. Co/Prerequisites: MA 091-091.

PH 104 Introductory Physics I

3:0:3

Development of the dynamics of particles and systems of particles within the general principles of symmetry and the conservation laws of physics. This class meets six hours per week for lectures, recitation, tutorials, and examinations. Prerequisites: MA 101 (or 100). Corequisite MA 102 (or 110). [In addition,

EE's must have a grade of C- or better in MA 101 (or 100)].

PH 105 Introductory Physics II

3½:0:3½

Continuation of PH 104. Electromagnetic fields and forces, and their interactions with particles. Thermodynamics and kinetic theory of gases. This class meets five hours per week for lectures, recitations tutorials, and examinations. Prerequisites: PH 104 (or 101) and MA 102 (or 110). Corequisite: Students who register for PH 105 must coregister for PH 115, unless excused in writing by the Director of the Introductory Physics Program; if they withdraw from one, they must also withdraw from the other. [In addition, EE's must have grades of C- or better in MA 101 (or MA 100), MA 102 (or MA 110), and PH 104 (or 101). MA 104 is a preferable corequisite.]

PH 106 Introductory Physics III

2½:0:2½

Continuation of PH 105. Propagation of waves, particularly as illustrated through studies of physical and geometric optics. Sound. This class meets three hours per week for lectures, tutorials, and examinations. Prerequisites: PH 105 and 115, (or PH 102); MA 102 (or 110). Corequisite: Students who register for PH 106 must coregister for PH 116 unless excused in writing by the Director of the Introductory Physics Program; if they withdraw from one, they must also withdraw from the other. [In addition, EE's must have grades of C- or better in MA 101 (or 100), MA 102 (or 110), and PH 105 (or 102), MA 104 is a preferable prerequisite, and MA 103 a preferable corequisite.]

PH 115 Physics Laboratory I

0:1½:0:¼

Principles of physical measurements in electric, magnetic, and thermodynamic experiments. Lab fee required. Prerequisite: PH 104. Corequisite: Students who register for PH 115 must coregister for PH 105 unless excused in writing by the Director of the Introductory Physics Program; if they withdraw from one, they must withdraw from the other.

PH 116 Physics Laboratory II
0:1½:0:½

Continuation of PH 115. Experiments in optics and sound. Lab fee required. *Prerequisite:* PH 105 and PH 115. *Corequisite:* Students who register for PH 116 must register for PH 106 unless excused in writing by the Director of the Introductory Physics Program; if they withdraw from one, they must also withdraw from the other.

PH 113 Seminar in Current Physics
2:0:2

Analyses, lectures, readings and discussions of selected topics of current interest in physics emphasizing concepts and the underlying framework of physical understanding. Topics include astrophysics, atomic and nuclear physics, the solid state and biophysics. Visiting scientists.

PH 210 Analytical Mechanics 3:0:3

Statistics by virtual work and potential energy methods. Stability of equilibrium. Particle dynamics, harmonic oscillator and planetary motion. Plane rigid body dynamics. *Prerequisite:* MA 103 and PH 104 (or 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 106 (or 103).

PH 234 Introduction to Modern Physics 2:0:2

Relativity; quantization of electricity, light, and energy; the nuclear atom and electron spin; electron waves; the Schrodinger equation; some properties of solids; atomic physics; nuclear physics and elementary particles. Lectures and discussion sessions. *Prerequisites:* PH 105 and PH 115. *Corequisite or prerequisite:* PH 106 and PH 116; if students withdraw from PH 116 while coregistered in PH 234, they must also withdraw from PH 234. [In addition, EE's must have grades of C- or better in MA 101 (or 100), MA 102 (or 110), PH 104 (or

101), and PH 105 (or 102). MA 104 is a preferable prerequisite, and MA 103 a preferable corequisite.]

PH 236 Physics Laboratory III
0:½:1½:1

Basic experiments in modern physics. Lab fee required. *Prerequisite:* PH 116. *Corequisite or prerequisite:* PH 230 or PH 234. [Experiments have included such topics as (1) Measurement of e/m for the electron; (2) Spectrometer and atomic spectra; (3) Frank-Hertz Experiment; (4) Geiger-Muller tube and Statistics; (5) Gamma-ray spectroscopy; (6) X-ray emission, absorption, Moseley's law, and Planck's constant.]

PH 250 Electronics for Physical Scientists 3:3:4

Lectures and laboratory on electrical measurements as currently applied in scientific research. Behavior and applications of discrete and integrated solid-state devices in electronic instrumentation. Introduction to measurements of small signals, noise and shielding problems, synchronous detection, and counting techniques. Outlines of digital electronics and descriptions and applications of several interface standards commonly employed for minicomputers in laboratory settings. *Prerequisite:* PH 106 (or 103) and MA 103.

PH 281 Astronomy and Astrophysics* 3:0:3

Historical development. Traditional and modern observational techniques. Theories of planets, stars, galaxies. Current advances in astrophysics and cosmology. Given on demand. *Prerequisite:* PH 106 (or 103).

PH 302-303 Advanced Lab I,II*
1:3:2

Precision measurements in mechanics, heat, electricity, optics, modern physics. Lab fee required. Given alternate years. *PH 302 co/prerequisite:* PH 334, 335. *PH 303 co/prerequisite:* PH 302, 336.

PH 331 Thermodynamics 3:0:3

Experimental bases of fundamental laws of macroscopic thermodynamics. Operational definitions of heat, internal energy, entropy, absolute temperature and other thermodynamic functions. Techniques of deriving and using thermodynamics relations. *Prerequisite:* PH 234.

PH 323-324 Electricity and Magnetism 2:0:2 each

Properties of the electrostatic, magnetostatic and electromagnetic field in vacuum and in material media. Maxwell's equations with applications to elementary problems. *Prerequisite:* MA 104.

PH 335 Quantum Physics II 3:0:3

Electrons and nuclear structures of the atom. Relativity, wave mechanics, natural and artificial radioactivity, fission, cosmic rays. Fundamental experiments and postulates of wave and particle physics. *Prerequisite:* PH 230, PH 234, or PH 334.

PH 336 Quantum Mechanics 3:0:3

Introduction to the calculation methods of quantum mechanics ---- with examples and applications. *Prerequisite:* PH 335.

PH 340 Computer Methods in Physics 2:2:4

Computer methods for solutions and simulations of a wide variety of problems in physics. Numerical methods applicable to problems in mechanics, electromagnetism, optics, statistical mechanics, elementary quantum mechanics and the interpretation of experimental data will be discussed. Strategies to determine if computer results are physically reasonable. Numerical simulation techniques for experimental and theoretical problems. Students have access to microcomputers. *Prerequisites:* CS 111, PH 210, and PH 323.

PH 347 Modern Optics 3:3:4

The physics of contemporary optics. Reflections and refractions of rays, matrix optics of optical instruments. Interferences and diffractions of waves and wave packets, Fourier transform optics. Coherence and quantum aspects

of light. The laboratory includes computer simulations of optical phenomena, and emphasizes lasers, holography, crystal optics, and nonlinear phenomena. *Prerequisites:* PH 324, PH 336 or equivalents.

PH 360 Special Topics in Physics

3:0:3

Lectures in some specialized area, such as acoustics, biophysics, or relativity. Topics reflect student and faculty interests, and vary from year to year. The course may be taken for credit more than once, for different subject offerings. *Prerequisites:* PH 106 (or 103), PH 334.

PH 372 X-ray Diffraction

2:3:3

Production and properties of x-rays. Elements of crystallography. Stereographic projections. Powder and single crystal diffraction techniques. Structures and crystal orientations. Stress analyses and phase and quantitative chemical analysis by x-ray techniques. *Prerequisite:* MA 104 and PH 106 (or 103). Also listed under MT 412.

PH 373-374 Introduction to Theoretical Physics I,II

3:0:3

Mathematical methods used in classical theoretical physics. Lagrange's equations, vibrating strings and membranes, flow of fluids, flow of heat, electrostatics, electrodynamics, Maxwell's equations. PH 373 *Prerequisites:* PH 210 and PH 324. PH 374 *prerequisite:* PH 373.

PH 381-382 Reading Course in Physics I,II

each 2 credits

Special topics in physics, supervised by staff member. *Prerequisites:* Physics major, junior standing and departmental approval.

PH 390 Senior Seminar

2:0:2

Topics of general interest prepared, reported and discussed by students. *Prerequisite:* PH 336

PH 391-394 Bachelor's Thesis in Physics

each 2 credits

An individual investigation involving theoretical, experimental and bibliographic studies of some problem of

interest to physicists. Students may register for thesis in parts as noted. Total credits determined in consultation with advisers.

PH 339 Senior Honors Work in Physics*

credit to be arranged

Independent work undertaken by qualified honor students. Course material arranged by a faculty steering committee.

GRADUATE COURSES

PH 605-606† Special Techniques in Experimental Physics I,II

each 0:3:1½

A range of specialized techniques and processes of modern experimental physics, depending on requirements of thesis students and recommendations of advisers. Vacuum techniques, thin-films, preparation of samples for solid-state studies, crystal growing, cryogenics and instrument design. Intensive training in those particular skills required in student research endeavors. Permission of advisers and director of the course required. May be taken no more than two semesters. *Prerequisite:* concurrent thesis registration.

PH 615 Theoretical Mechanics I

2½:0:3

Principles of particle and rigid body dynamics. Lagrange's equations. Small vibrations of coupled systems, normal modes of oscillation. *Prerequisite:* PH 313 or equivalent.

PH 616 Theoretical Mechanics II

2½:0:3

Hamiltonian mechanics. Transformation theories of mechanics including the Hamilton-Jacobi and Poisson bracket formulation, Lagrangian formulation of mechanics of continuous media. *Prerequisite:* PH 615.

PH 624 Electromagnetic Theory I

2½:0:3

Maxwell's equations. Plane waves. Relativistic covariance of electromagnetic field. Motions of charges in fields. Fields of moving charges. Hertz and Lienard-Wiechert potentials. Radiation from charges, dipoles and quadrupoles. *Prerequisite:* PH 321.

PH 625 Electromagnetic Theory II

2½:0:3

Interaction of electromagnetic fields with material media from classical viewpoint. Macroscopic description of dielectric, magnetic and conducting materials, energy relations, dispersion, and attenuation in dielectrics and ionized media. Wave propagation in anisotropic crystals and ferrites; waves in inhomogeneous media. *Prerequisite:* PH 623. Also listed under EL 673

PH 633-634† Introduction to Nuclear and Elementary Particles Physics I,II*

each 2½:0:3

Fundamental properties of atomic nucleus and its constituents. Two-body problems at low energies and the theory of nuclear forces. Nuclear radioactivities such as alpha-, gamma-, and beta-decay. General features of nuclear reactions and of the various nuclear models. Basic properties of elementary particles, their modes of decay, interactions, classifications and invariance laws. PH 663 *Prerequisite:* PH 336. PH 634 *prerequisite:* PH 633.

PH 638 Quantum Mechanics with Applications

2½:0:3

Wave mechanics with applications to atomic and nuclear systems. Use of Schrodinger wave equation with perturbation theory for eigenvalue/eigenfunctions of harmonic oscillator and collision and applications to atomic nuclei. This course can be used by medical physics students to satisfy the prerequisites of PH 667 for a master's degree in physics. *Prerequisite:* PH 335 and PH 336 or equivalents.

PH 651-652† Introduction to Solid State Physics I,II each 2½:0:3

Phenomena and theory of physics of crystalline solids. Topics from thermal, magnetic, electrical and optical properties of metals, insulators and semiconductors. *PH 651 prerequisite: PH 336. PH 652 prerequisite: PH 651.*

PH 663 Statistical Mechanics I 2½:0:3

Equilibrium distributions. Relationships to laws of thermodynamics. Quantum effects. Maxwell-Boltzmann, Fermi-Dirac, Bose-Einstein distributions. Applications to bulk properties of phenomena using Boltzmann transport equation. *Prerequisite: graduate status.* Also listed under EL 651

PH 664 Statistical Mechanics II 2½:0:3

Micro-, macro-, and grand-canonical ensembles and principles of classical statistical mechanics. Condensation phenomena. Treatment of fluctuation and transport phenomena. Density matrix formalism of quantum statistical mechanics. Many-body problems. *Prerequisites: PH 663 and PH 667, or equivalents.* Also listed under EL 652

PH 667-668 Quantum Mechanics I,II each 2½:0:3

Quantum mechanics with applications to atomic systems. The use of Schrodinger's equations. Angular momentum and spin. Problems and approximation methods. Semiclassical theory of field-matter interaction. Also listed under EL 655-656

PH 669-670 Quantum Mechanics III,IV each 2½:0:3

Theory of measurement and connection with classical dynamics. The Dirac formulation, transformation theory, scattering theory and introduction to the theory of radiation. *PH 669 prerequisites: PH 616, PH 624 and PH 667-668. PH 670 prerequisite: PH 669.*

PH 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 determined each year by students and faculty. May be given in more than one section. Consult department office for current offerings.

PH 901-902 Physics Colloquium I,II each 2:0:0

Topical subjects of experimental and theoretical physics by the staff and outside lectures. Fee required. Required of all master's and doctoral candidates.

PH 953-954 Graduate Seminar I,II each 1½ units

Presentations by participating students and discussion of topics in physics of current interest and from the literature.

PH 955-956 Reading in Physics I,II each 2½:0:3

Selected papers and current literature in a specialized field of physics guided by a faculty member. *Prerequisite: graduate adviser's and supervising faculty member's permission.*

PH 999 Research in Physics each 3 units

An original investigation in some branch of physics or chemical physics, which may serve as basis for the degree of master of science or doctor of philosophy, to be performed under the direction of a member of the department. Chemical physics majors should register for appropriate CM courses. The number of research credits registered for each semester should reflect realistically the time devoted to research. *Prerequisites: degree status and graduate adviser's and research director's consent.*

The following graduate course are offered irregularly in response to student demand:

- PH 601,602 Physics for Chemists I,II
- PH 603 Graduate Laboratories
- PH 604 Physics of Stars
- PH 607,608 Mathematical Methods of Physics I,II
- PH 612 Microcomputer Methods of Physics I,II
- PH 635,636 Biophysics I,II

PH 637 Radiation Physics with Biological and Medical Applications

- PH 671,672 X-ray Diffraction I,II
- PH 673,674 X-ray Diffraction Techniques I,II
- PH 676 Methods of Crystal Structure Determination

- PH 751,752 Theory of Solids I,II
- PH 753,754 Crystal Dynamics I,II
- PH 761,762 Relativistic Quantum Mechanics & Field Theory I,II
- PH 763,764 Nuclear Theory I,II
- PH 765,766 High Energy Physics & Elementary Particle Theory I,II
- PH 780 Special and General Theory of Relativity

FACULTY

Edward L. Wolf, Professor of Physics and Head of Department
B.A., Swarthmore College;
Ph. D., Cornell University
Experimental physics, superconductivity, scanning tunnel microscopy, and electron tunneling spectroscopy.

Stephen Arnold, Thomas Potts
Professor of Physics
B.S., University of Toledo;
M.A., Queens College; Ph.D., CUNY
Organic solid-state and microparticle photo-physics

Raphael Aronson, Professor of Physics
B.S., University of Minnesota;
M.A., Ph.D., Harvard University
Transport Theory

Patrick T. Cahill, Professor of Physics
B.S., M.S., University of New Hampshire; Ph.D., Harvard University
Medical physics, magnetic resonance imaging, atomic physics

Deo C. Choudhury, Professor of Physics
B.S., M.Sc., University of Calcutta (India);
Ph.D., University of California
Theoretical nuclear physics

Hellmut J. Juretschke, Professor of Physics
B.S., M.A., Ph.D., Harvard University
Surface and condensed matter physics

ADJUNCT FACULTY

Erich E. Kunhardt, Professor of Electrophysics (Electrical Engineering), Professor of Physics, and Director of the Weber Research Institute B.S. and M.S., New York University, Ph.D. Polytechnic Institute of New York *Plasma Physics, Non-equilibrium properties*

K. Ming Leung, Professor of Physics B.S., University of Missouri, Ph.D., University of Wisconsin *Theoretical condensed matter and surface physics*

Peter S. Riseborough, Professor of Physics; B.S. and Ph.D., Imperial College, London *Theoretical condensed matter*

Donald B. Scarf, Professor of Physics B.A., Leigh University; Ph.D., Princeton University *Quantum optics; atomic physics*

Meir Menes, Associate Professor of Physics; B.S., Cooper Union; Ph.D., New York University *Experimental solid-state physics; gaseous electronics*

Lorcan Folan, Assistant Professor of Physics; B.Sc. Trinity College, Dublin; Ph.D. Polytechnic University *Energy transfer in condensed matter, aerosols*

Alla Margolina, Assistant Professor of Physics; B.S. and M.S. Odessa (USSR); Ph.D., Boston University. *Mathematical modeling, fractals, teaching of physics*

Sarath C. Meepagala, Assistant Professor of Physics B.Sc., University of Colombo; M.S., Ph.D., Wayne State. *Scanning Tunneling Microscopy, Superconducting Devices*

Carol Thompson, Assistant Professor of Physics; B.S. Cal Tech; M.S. Stanford; Ph.D. Univ. Houston *Experimental Condensed Matter, Materials, X-ray Scattering*

Benjamin Bloch, Adjunct Professor of Physics; B.A. Columbia University; Ph.D., Polytechnic Institute of Brooklyn

Aleksandr Izmailov, Adjunct Assistant Professor of Physics B.S. and M.S. Kazan (USSR); Ph.D. Kazan (USSR). *Theoretical Physics, nuclear, condensed matter.*

Walter Kiszenick, Adjunct Professor of Physics; B.S. Brooklyn College; M.S., Ph.D., Polytechnic Institute of Brooklyn *Experimental Physics, X-ray Scattering, Teaching Physics.*

Carl Henry Leyh, Adjunct Associate Professor of Physics B.S., Drexel; M.S. and Ph.D., University of Virginia *Experimental Physics, Gravitation*

Jack A. Lowenthal, Adjunct Professor of Physics B.S. Polytechnic Institute of New York; M.S. and Ph.D. Penn State; *Electro-optics; teaching of physics.*

Rajiv S. Ravi, Adjunct Assistant Professor of Physics B.Sc. and M.Sc., University of Mysore

EMERITUS FACULTY

Hilda Bass, Emeritus Associate Professor of Physics B.A., Hunter College; M.A., Smith College *Atomic and nuclear physics; physics education*

John J. Dropkin, Professor Emeritus B.A., Columbia University; M.S., Ph.D., Polytechnic Institute of Brooklyn *Solid-state physics*

Terje Kjeldaas, Jr., Professor Emeritus of Physics B.S., Polytechnic Institute of Brooklyn; M.A., Columbia University; Ph.D., University of Pittsburgh *Theoretical solid state and atomic physics*

Benjamin Post, Professor Emeritus, Research Professor; B.S., CCNY; M.S., Ph.D., Polytechnic Institute of Brooklyn *X-ray physics, crystallography, solidstate chemistry*

H. William Schleuning, Professor Emeritus; M.A. New York University *Vacuum and thin films*

RESEARCH FACULTY

Walter Egan, Research Professor of Physics; B.E.E., City College; M.A., Columbia; Ph.D. Polytechnic Institute of Brooklyn. *Polarimetry, Remote Sensing, Optical Properties*

Peter Hanggi, Research Professor of Physics; B.S., College of Mathematics and Natural Sciences, Basel; M.S., Ph.D., University of Basel (Switzerland) *Statistical mechanics, quantum tunneling*

Yuli M. Ivanchenko, Research Professor of Physics M.S., Kharkov (USSR), Ph.D., Donetsk (USSR) *Condensed Matter Theory, Superconductivity, Tunneling*

MATHEMATICS AND STATISTICS

Mathematics is devoted to the solution of problems by the use of symbolic language and formal logical operations. It serves as a foundation for other scientific disciplines and is an indispensable tool for engineering. Today mathematicians find employment not only in schools and colleges but in every branch of industry and government.

A complete spectrum of mathematics courses is offered at Polytechnic, ranging from first-year courses to the doctoral level and covering all branches of abstract and applied mathematics.

In addition, a sequence of elective courses is available in theoretical and applied statistics which enable students to prepare themselves for careers in statistics or in a field utilizing statistical theories and techniques. The graduate curriculum is more specialized. Courses, thesis work and informal departmental activities are designed to familiarize students with mathematics in general while they become specialists in their particular areas of choice.

UNDERGRADUATE PROGRAMS

The undergraduate program in mathematics provides both a background for advanced study or subsequent research in abstract or applied mathematics and training for those students who expect to terminate their formal education with a bachelor's degree. In addition, a sequence of elective courses in theoretical and applied statistics prepares students for careers in statistics or in fields utilizing statistical theories and techniques.

For science and engineering majors, mathematics provides the theory and methods essential for comprehension of the mathematical aspects of their respective fields.

With these objectives, the Department of Mathematics offers courses in

abstract and applied mathematics and, for the mathematics major, specific programs leading to the degree of Bachelor of Science.

Students wishing to pursue the bachelor's degree in mathematics may elect to follow one of three courses of study. Students wishing to focus their studies within mathematics itself may elect course of study I, emphasizing abstract mathematics. Students particularly interested in applying mathematics to other fields may elect course of study II, emphasizing applied mathematics. Students wishing to incorporate computer science into their mathematical training may elect course of study III, the computer science option. All three programs provide basic grounding in mathematical knowledge. Details of each follow.

REQUIREMENTS FOR THE BACHELOR OF SCIENCE DEGREE IN MATHEMATICS

MA 101** - 104, 153, 154, 217, 223, 260	29
CS 200; PH 104-106, 115, 116;	
CM 101, 102, 111, 112	19
HU 101, HU 200 and SS 104, or IS 140 and IS 141	9
Two years (or equivalent) of French, German, Russian or Spanish*	12
Major specialty†	18
Minor specialty‡	12
Humanities/Social Sciences electives	9
Free electives	20
	128

* If less than 12 credits are needed, the remaining credits should be taken in the humanities/social sciences areas.

** MA 100-110 is an alternative to MA 101-102 with advisor's approval.

† Major specialty. Students must elect coherent courses of study in their major field. Three typical selections follow.***

Course of Study I

MA 570
MA 211, 212
Math electives - nine credits

Course of Study II

MA 224
MA 201, 202
MA 358
IE 327, 328

Course of Study III

Course of study II plus
CS 201, 205, 212, 236, 275, 337

NOTE: IF COURSE OF STUDY III IS ELECTED, THE MINOR SPECIALTY IS ELIMINATED.

‡ Minor specialty: at least twelve credits beyond required courses in any single area of study outside the Department of Mathematics, except for statistics, which may include mathematical statistics courses. The sequence must be well integrated and consistent, thereby enabling the student to gain knowledge in an area outside the Department of Mathematics. The faculty advisor of the department of interest should be consulted.

*** In addition, a program of studies leading to the bachelor of science degree in mathematics (actuarial science) appears in the section titled actuarial science section.

Minor Specialties - To achieve depth of understanding in a field other than mathematics, students are asked to choose a 12-credit sequence from other disciplines. This work must be in addition to courses taken under other categories of the programs, e.g., required courses in physics do not count toward a minor in physics nor do French courses in fulfillment of language requirements count toward a minor in French. With the exception of applied statistics and computing courses, all minor courses must be completed outside the department. Education courses are not accepted to-

ward a minor specialty, nor are the first two years of a second foreign language.

Courses of minor specialties are chosen in consultation with advisors. In appropriate cases, advisors for minor sequences may be from departments other than mathematics. The following are possible minor concentrations:

Aerospace	ME 111, 112; AE 311, 312
Statistics	MA 232, 555, 556, 557
Biology	LS 103, 105, 106, 115, 116
Chemistry	CM 122, 123, 161, 162
Computers	CS 201, 205, 236, 237
Industrial Engineering	IE 300, 306, 327, and one of IE 311, 319, 321
Operations Research	IE 300, 327, 328, and one of IE 319, 346, 380
Management	MG 300, SS 299, MG 304 and one of SS 251, 252
Physics	PH 210, 323, 324, 373, 374
Psychology	SS 189, 204, 208, 209, 215, 216
Economics	SS 251, 252, 264; IE 300
Electrical Engineering	
Systems	EE 101, 102, 103, 104
English Literature	HU 211, 212, 222, 251, 258, 262, 272, 295
French	ML 135, 235, 236, 237, 238
Transportation	TR 360, 362, 600, 601, 603

Advanced Placement - Advanced placement credits may be given for the first year of calculus. Students receiving grades of 4 or 5 on advanced placement examinations in calculus, conducted by the College Entrance Examination Board, may be granted a maximum of eight credits to be applied toward the 128-credit requirement for bachelor's degrees in mathematics.

REQUIREMENTS FOR THE BACHELOR OF SCIENCE DEGREE IN MATHEMATICS (ACTUARIAL SCIENCE)

The actuarial profession has always been a lucrative field for those at ease with numbers and mathematical theories. Actuarial science combines mathematics, statistics, and business economics. It provides the educational background for a range of careers in business, industry, and government. Typical areas include: insurance, human resources and benefit planning, and contract negotiation.

Actuaries are responsible for calculating premiums on life insurance, casualty insurance, retirement and pension plans. Their duties cover deciding how much money must be set aside periodically

to provide future payment of benefits; analyzing sources of earnings under policy contracts to determine proper rates of dividends, and investigating factors related to payments of various types of policies. In life insurance, they consider effects on mortality of physical impairments, hazardous occupations, and other unusual risks; in pension and casualty fields, they are concerned with changing life styles and demographic effects on policy incomes and payments. Actuaries usually play important roles in developing executive policies of companies. Although these actuaries cannot operate without thorough knowledge of the mathematical bases of finance, they are more business men and women than mathematicians. They explain complicated problems to colleagues and policyholders in clear language.

The development of health, pension, and accident insurance has posed many new problems in mathematical and statistical theory and practical administration. It is largely actuaries who solve these problems. Though not restricted to insurance, many actuaries are found in insurance companies. Business and industry provide opportunities for consulting actuaries. Actuaries are also employed by federal and state governments.

The profession is not crowded. Large companies, particularly those engaged in writing industrial insurance, group insurance, and pension plans, need large staffs of actuaries. Many people initially trained as actuaries move on to other spheres, particularly the investment, administration, underwriting, accounting, and other executive positions.

In actuarial careers, adequate salaries are paid even during training periods. Later, salaries depend upon responsibilities assumed; average salaries are high.

Qualification is attained by passing examinations required for membership in the Actuarial Society of American or the American Institute of Actuaries. Salaries for actuarial trainees depend on the number of examinations passed. It is anticipated that students in this program are able to take and pass three or four of these examinations before graduating. For this reason, these studies are well-suited to the Cooperative Education Program, especially if students plan to work the year between their junior and senior year.

The program is similar to others in the mathematics department. Course requirements, typical courses of study, and course descriptions for actuarial science follow.

	Credit
MA 101*-104, 153, 217, 223	23
CS 111; PH 104-106, 115, 116;	
CM 101, 102, 111, 112	19
HU 101, 200; SS 104, 251, 252	15
Two years* (or equivalent) of French, German, Russian or Spanish	12
Major specialty: MA 201, 202, 224, 358; AC 301, 302, 401, 402, 501, 503; IE 300, 327, 328	38
Humanities/Social Sciences elective	3
Free electives	18†
	128

* If less than 12 credits are needed, remaining credits should be taken in the HU/SS areas.

** MA 100-110 is an alternative to MA 101-102 with advisor's approval.

† It is suggested that some of these be CS courses.

REQUIREMENTS FOR THE JOINT BACHELOR OF SCIENCE DEGREE IN MATHEMATICS AND PHYSICS

A joint major for the BS degree in Mathematics and Physics is offered at the Polytechnic.

The purpose of the Joint Major is to offer a student an opportunity to gain competence in two different and substantial fields of science, to such an extent that upon earning a Bachelor's degree, they are able to qualify for industrial positions in two distinct areas, or to go on to graduate studies in either of the two subjects.

	Credit
MA 101*-104, 153, 201, 202, 217, 223, 224, 260, 358	38
PH 104-106, 115-116, 210, 234, 236, 302, 311, 323-324, 335-336, 347, 373-375, 390	43
CM 101-102, 111-112; CS 112	9
HU 101, 200; SS 104	9
Language (or equivalent)	12
Humanities/Social Sciences electives	9
Free electives	8‡
	128

** MA 100-110 is an alternative to MA 101-102 with advisor's approval.

‡ It is suggested that some of these be CS courses.

TYPICAL COURSE OF STUDY FOR THE BACHELOR OF SCIENCE DEGREE IN MATHEMATICS (ABSTRACT)*

FRESHMAN YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.
<i>First Semester</i>				
MA 101	Calculus I			4
PH 104	Introductory Physics I			3
CS 200	Programming in Pascal			3
HU 101	Writing and the Humanities I			3
	Language course			3
SL 101	Freshman Seminar			0
				16

Second Semester				
MA 102	Calculus II			4
PH 105	Introductory Physics II			3½
PH 115	Physics Lab I			½
HU 200	Writing and the Humanities II			3
	Language			3
MA 153	Elem. Linear Algebra			3
				17

SOPHOMORE YEAR

First Semester				
MA 103	Calculus III			3
MA 154	Elem. Abstract Algebra			3
PH 106	Introductory Physics III			2½
PH 116	Physics Lab II			½
	Language course			3
CM 101	General Chemistry I			2½
CM 111	General Chemistry Lab I			½
				15

Second Semester				
MA 104	Differential Equations			3
MA 570	Intro. Geometry			3
CM 102	General Chemistry II			2½
CM 112	General Chemistry Lab. II			½
	Language course			3
	Electives*			3
				15

JUNIOR YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.
<i>First Semester</i>				
MA 211	Analysis			3
MA 217	Complex Variables			3
MA 223	Intro. to Probability			3
SS 104	Contemp. World History			3
	Minor specialty			3
	Electives*			<u>2</u>
				17

Second Semester				
MA 212	Analysis II			3
MA 260	Partial Diff. Equations			3
	Minor specialty†			3
	Electives*			7
				16

SENIOR YEAR

First Semester				
	Minor specialty			3
	Electives			13
				16

Second Semester				
	Minor Specialty†			3
	Electives*			13

Total Credits for Graduation: 128

* Electives total 45 credits, of which nine must be in the courses with MA labels and at least nine in courses with HU, SS or ML labels. Remaining electives may be freely chosen from the catalog.

† See minor specialty.

‡ This is a sample program. Students should consult with an advisor before embarking on a specific course of study.

TYPICAL COURSE OF STUDY II FOR THE BACHELOR OF SCIENCE DEGREE IN MATHEMATICS (APPLIED)*

FRESHMAN YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.
<i>First Semester</i>				
MA 101	Calculus I**			4
PH 104	Introductory Physics I			3
CS 200	Programming in Pascal			3
HU 101	Writing and the Humanities I			3
	Language course			3
SL 101	Freshman Seminar			0
				16

Second Semester				
MA 101	Calculus II**			4
PH 105	Introductory Physics II			3½
PH 115	Physics Lab I			½
HU 101	Writing and the Humanities II			3
SS 104	Contemp. World History			3
	Language course			3
				17

SOPHOMORE YEAR

First Semester				
MA 103	Calculus III			3
PH 106	Introductory Physics III			2½
PH 116	Physics Lab II			½
MA 223	Intro. Probability			3
	Language course			3
CM 101	General Chemistry I			2½
CM 111	General Chemistry Lab I			½
				15

Second Semester				
MA 104	Differential Equations			3
MA 224	Intro. to Math Stat.			3
MA 153	Elem. of Linear Algebra			3
	Language course			3
CM 102	General Chemistry II			2½
CM 112	General Chemistry Lab II			½
				15

JUNIOR YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.
<i>First Semester</i>				
MA 201	Applied Analysis I			3
MA 217	Complex Variables			3
MA 260	Partial Diff. Equations			3
IE 327	Operations Res. Models I			3
	Minor specialty*			3
	Electives*			<u>2</u>
				17

Second Semester

MA 202	Applied Analysis II			3
MA 358	Intro. Numerical Anal.			3
IE 328	Operations Res. Models II			3
	Minor specialty			3
	Electives*			<u>4</u>
				16

SENIOR YEAR

First Semester

MA 154	Elem. of Abstract Algebra			3
	Minor specialty*			3
	Electives			<u>10</u>
				16

Second Semester

	Minor Specialty†			3
	Electives*			<u>13</u>

Total Credits for Graduation: 128

* See minor specialty.

** MA 100-110 is an alternative to MA 101-102 with advisor's approval. This is a sample program. Students should consult with an advisor before embarking on a specific course of study.

‡ This is a sample program. Students should consult with an advisor before embarking on a specific course of study.

TYPICAL COURSE OF STUDY III FOR THE BACHELOR OF SCIENCE DEGREE IN MATHEMATICS (COMPUTER SCIENCE)‡

FRESHMAN YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.
<i>First Semester</i>				
MA 101	Calculus I**			4
PH 104	Introductory Physics I			3
CS 200	Programming in Pascal			3
HU 101	Writing and the Humanities I			3
	Language course			3
SL 101	Freshman Seminar			<u>0</u>
				16

Second Semester

MA 101	Calculus II**			4
PH 105	Introductory Physics II			3½
PH 115	Physics Lab I			½
HU 101	Writing and the Humanities II			3
CS 201	Data Structures and Algorithms			3
	Language course			<u>3</u>
				17

SOPHOMORE YEAR

First Semester

MA 103	Calculus III			3
PH 106	Introductory Physics III			2½
PH 116	Physics Lab II			½
MA 223	Intro. Probability			3
	Language course			3
CS 236	Theory and Logic Design			<u>3</u>
				15

Second Semester

MA 104	Differential Equations			3
MA 224	Intro. to Math Stat.			3
MA 153	Elem. of Linear Algebra			3
	Language course			3
SS 104	Contemporary World History			<u>3</u>
				15

JUNIOR YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.
<i>First Semester</i>				
MA 201	Applied Analysis I			3
MA 217	Complex Variables			3
CS 212	C, UNIX, and Software Dev.			3
IE 327	Operations Res. Models I			3
CM 101	General Chemistry I			2½
CM 111	General Chemistry Lab I			½
				15

Second Semester

MA 202	Applied Analysis II			3
MA 358	Intro. Numerical Anal.			3
IE 328	Operations Res. Models II			3
CS 205	Assembly Language and Systems Programming			3
CM 102	General Chemistry II			2½
CM 112	General Chemistry Lab II			½
	Elective			<u>3</u>
				18

SENIOR YEAR

First Semester

MA 154	Elem. of Abstract Algebra			3
CS 337	Computer Architecture and Organization			3
MA 260	Vector Analysis and Partial Differential Equations			3
	Electives			<u>7</u>
				16

Second Semester

	Theory of Computation			3
	Electives*			<u>13</u>

Total Credits for Graduation: 128

** MA 100-110 is an alternative to MA 101-102 with advisor's approval.

‡ This is a sample program. Students should consult with an advisor before embarking on a specific course of study.

TYPICAL COURSE OF STUDY FOR THE BACHELOR OF SCIENCE DEGREE IN MATHEMATICS (ACTUARIAL SCIENCE)

FRESHMAN YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.
First Semester				
MA 101	Calculus I**			4
PH 104	Introductory Physics I			3
CS 200	Programming in Pascal			3
HU 101	Writing and the Humanities I			3
	Language course			3
SL 101	Freshman Seminar			0
				16

Second Semester

MA 102	Calculus II**			4
PH 105	Introductory Physics II			3½
PH 115	Physics Lab I			½
HU 200	Writing and the Humanities II			3
CS 104	Main Themes in Contemporary World History			3
	Language course			3
				17

SOPHOMORE YEAR

First Semester

MA 103	Calculus III			3
PH 106	Introductory Physics III			2½
PH 116	Physics Lab II			½
MA 223	Intro. Probability			3
	Language course†			3
CM 101	General Chemistry I			2½
CM 111	General Chemistry Lab I			½
				15

Second Semester

MA 104	Differential Equations			3
MA 224	Intro. to Math Stat.			3
MA 153	Elem. of Linear Algebra			3
	Language course†			3
CM 102	General Chemistry II			2½
CM 112	General Chemistry Lab II			½
				15

JUNIOR YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.
<i>First Semester</i>				
MA 201	Applied Analysis I			3
MA 217	Complex Variables			3
IE 327	Operations Res. Models I			3
AC 301	Actuarial Science Workshop I			2
	Elective			3
IE 300	Engineering Economy			<u>3</u>
				17

Second Semester

MA 202	Applied Analysis II			3
MA 358	Intro. Numerical Anal.			3
IE 328	Operations Res. Models II			3
AC 302	Actuarial Science Workshop II			2
AC 501	Actuarial Science I			3
	Elective			3
				17

SENIOR YEAR

First Semester

AC 401	Actuarial Science Workshop III			2
AC 502	Actuarial Science II			3
SS 251	Microeconomics†			3
	Electives*			9
				17

Second Semester

AC 402	Actuarial Science Workshop IV			2
AC 503	Actuarial Science III			3
SS 252	Microeconomics†			3
	Electives*			6
				14

Total Credits for Graduation: 128

† If only 6 language credits are required because foreign languages were begun in high school, they should be taken in freshman year and SS 251, 252 should be taken in sophomore year. Language requirement in sophomore year may then be replaced by 6 other credits of HU/SS in senior year.

* Electives total 21 credits, of which at least 3 must be in courses with HU/SS labels.

** MA 100-110 is an alternative to MA 101-102 with advisor's approval.

† This is a sample program. Students should consult with an advisor before embarking on a specific course of study.

TYPICAL COURSE OF STUDY FOR THE BACHELOR OF SCIENCE DEGREE WITH A JOINT MAJOR IN MATHEMATICS AND PHYSICS

FRESHMAN YEAR

No.	Subject	Hours/Week		
		Cl.	Lab.	Cr.
<i>First Semester</i>				
CS 200	Programming in Pascal			3
CM 101	General Chemistry I			2½
CM 111	General Chemistry Lab I			½
MA 101	Calculus I**			4
	Hum./Soc. Sci. elective			6
SL 101	Freshman Seminar			0
				16

Second Semester

CM 102	General Chemistry II			2½
CM 112	General Chemistry Lab II			½
MA 102	Calculus II*			4
PH 104	Introductory Physics I			3
	Hum./Soc. Sci. elective			6
				16

SOPHOMORE YEAR

First Semester

MA 103	Calculus III			3
MA 223	Probability			3
PH 105	Intro to Physics II			3½
PH 115	Physics Lab I			½
PH 210	Analyt. Mechanics			3
	Hum./Soc. Sci. elective			3
				16

Second Semester

MA 104	Differential Equations			3
MA 224	Intro. to Math Stat.			3
PH 106	Intro. to Physics III			2½
PH 116	Physics Lab II			½
PH 234	Intro. to Mod. Phys.			2
PH 236	Physics Lab III			1
	Hum./Soc. Sci. elective			3
				15

JUNIOR YEAR

No.	Subject	Hours/Week	Cl. Lab. Cr.
First Semester			
MA 201	Applied Analysis I	3	
MA 217	Complex Variables	3	
MA 153	Elem. Linear Algebra	3	
PH 323	Elect. & Magnetism I	2	
PH 335	Quantum Physics II	3	
	Hum./Soc. Sci.		
	Elective	3	
		17	

Second Semester			
MA 202	Applied Analysis II	3	
MA 358	Intro. Numerical Anal.	3	
PH 302	Advanced Lab	2	
PH 324	Elect./Soc. Magnetism II	2	
PH 336	Quantum Mechanics I	3	
	Hum./Soc. Sci.		
	Electives	3	
		16	

SENIOR YEAR

First Semester			
MA 217	Complex Variables	3	
PH 311	Thermodynamics	3	
PH 373	Intro. Theo. Phys. I	3	
PH 347	Modern Optics	4	
	Hum./Soc. Sci.		
	Electives*	3	
		16	

Second Semester			
PH 374	Intro. Theo. Phys. II	3	
PH 390	Senior Seminar	2	
	Hum./Soc. Sci.		
	Elective	3	
	Free elective	8	
		16	

Total Credits for Graduation: 128

† If only 6 language credits are required because foreign languages were begun in high school, they should be taken in freshman year and SS 251, 252 should be taken in sophomore year. Language requirements in sophomore year may then be replaced by 6 other credits of HU/SS in senior year.

* Electives total 21 credits, of which at least 3 must be in courses with HU/SS labels.

** MA 100-110 is an alternative to MA 101-102 with advisor's approval.

‡ This is a sample program. Students should consult with an advisor before embarking on a specific course of study.

GRADUATE PROGRAMS

The Department of Mathematics offers graduate-level courses in foundations and logic, analysis, geometry and topology, algebra and number theory, applied mathematics, probability and statistics. These courses form a major portion of the work for advanced degrees in mathematics. They may also be taken by students in other departments to satisfy minor and elective requirements and by qualified pre-degree students who desire further study in graduate-level mathematics.

The department offers master's degrees in abstract mathematics, industrial and applied mathematics and applied statistics. Doctor's degrees are offered in abstract mathematics, applied mathematics and applied statistics. Departmental requirements for these degrees are supplemented by certain general requirements for advanced degrees set forth elsewhere in this catalog.

Outstanding students are advised to apply for research fellowships, teaching fellowships or partial tuition remission.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE IN MATHEMATICS

Bachelor's degrees in mathematics are required for admission to this program. Students with degrees in other fields may be admitted, possibly with undergraduate deficiencies, at the discretion of departmental advisors.

Before beginning graduate studies, students are expected to have completed a year's course in advanced calculus. In case of acceptance without these credits, students are asked to take the sequence MA 619-620 at Polytechnic in addition to other requirements listed below for master's degrees.

Thirty-six units are required, including 21 units of required courses. Six units may be devoted to a thesis.

No.	Required Subjects	Units
MA 621-622	Real and Complex Analysis	6
MA 705-706	Linear and Modern Algebra	6
	Elective courses	18
	Additional electives	6
		36

The thesis option includes an examination of the thesis material by faculty advisors and certification that the work is satisfactory. Students offering only course work must pass comprehensive oral examinations before degrees are awarded. Examinations cover the student's program of study and are scheduled toward the end of the semester in which work is completed.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE (INDUSTRIAL AND APPLIED MATHEMATICS)

The industrial and applied mathematics option is offered to students interested in certain areas of applied mathematics rather than in pure mathematics. By selecting appropriate sequences of courses, students can major in mathematical statistics or in mathematical operations research. Departmental advisors aid students in the selection of a program of study. Students who elect this option may continue toward the Ph.D. in mathematics.

Bachelor's degrees in some quantitative field, with at least a minor in mathematics, are required for admission to this program. Students who enter without a year's course in advanced calculus are asked to take the sequence MA 619-620 at Polytechnic for which no graduate credit is given. Students who enter without undergraduate courses in linear algebra or complex variables are asked to take one from the graduate program; for each such course successfully completed, three units are allowed toward the degree.

No.	Required Subjects	Units
MA 813	Linear Programming	3
MA 821	Numerical Analysis	3
MA 853	Probability I	3
MA 861	Principles of Statistical Inference	3
	Applied electives - chosen from MA 812, 814, 815, 817, 822, 823, 854, 855, 862	9
	Other electives	9
	Additional electives or thesis	6
		36

Regulations governing the thesis option or final examination for degrees are the same as for the master's degrees in mathematics.

MATHEMATICS/SCIENCE

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE (STATISTICS)

Bachelor's degrees are required in some quantitative field with at least a minor in mathematics, which should include a six-credit course in probability and statistics equivalent to MA 233-224 or MA 561-562. Students may be admitted with undergraduate deficiencies after consulting with departmental advisors. Such students are required to take the courses necessary to remove deficiencies.

No.	Required Subjects	Units
MA 619-620	<i>Advanced Calculus</i>	6
<i>At least 3 of</i>		9-12
MA 554	<i>Applied Decision Theory</i>	
MA 555	<i>Design of Experiments</i>	
MA 556	<i>Correlation and Multivariate Models</i>	
MA 557	<i>Sampling</i>	
MA 853,854	<i>Probability I, II</i>	6
MA 861,862	<i>Principles of Stat. Inference I,II</i>	6
		27-30
<i>Electives: Project ST 995 (3 units),</i>		
<i>Thesis ST 997 (6 units)</i>		3-9
		36

Regulations governing the thesis option for final examination for this degree are the same as for the master's degrees in mathematics.

The thesis or project option includes an examination of the material by faculty advisors and certification that the work is satisfactory. Students offering only course work must pass comprehensive oral examinations before degrees are awarded. Examinations cover the student's program of study and are scheduled toward the end of the semester in which work is completed.

REQUIREMENTS FOR THE DOCTOR OF PHILOSOPHY DEGREE IN MATHEMATICS

Requirements for the doctor's degrees are primarily qualitative rather than quantitative. All students' programs must have the approval of the guidance committee.

The number of graduate units of course work usually associated with doctoral programs is 72. These are nor-

mally selected to form well-balanced programs in one major and two minor fields. One minor field may be outside the Department of Mathematics, selected from such fields as applied mechanics, electrophysics, circuit theory, physics, industrial engineering, industrial management, etc.

Doctoral candidates must pass a qualifying oral examination which is divided into two parts. Part 1, taken early in the students' careers, covers real and complex variables and algebraic structures. Part 2 covering three elective topics, may be taken only after Part 1 has been passed. Final examinations, which follow the submission of acceptable dissertations, are also oral.

In addition to 72 units of course materials, students must devote at least 24 units to dissertations, reporting original research under the direction of faculty advisors.

Students must satisfy doctoral language requirements in one language (selected from French, German or Russian).

Additional details are contained in brochures which may be obtained from the departmental office.

REQUIREMENTS FOR THE DOCTOR OF PHILOSOPHY DEGREE IN STATISTICS

Within the Department of Mathematics, Polytechnic offers graduate studies in the field of statistics leading to Ph.D. degrees. A full range of courses is offered in the areas of applied and mathematical statistics, supported by a range of elective courses in probability and all areas of abstract and applied mathematics. Students may also take elective courses from other departments, selected under the supervision of graduate advisors.

A bachelor's degree with at least a minor in mathematics, which should include a one-year course in advanced calculus, is required for admission.

No.	Required Subjects	Units
MA 630	<i>Elements of Complex Variables</i>	3
MA 703	<i>Linear Algebra</i>	3
MA 621	<i>Real Analysis</i>	3
MA 853-855	<i>Probability, Stochastic Processes</i>	9
MA 861-862	<i>Principles of Statistical Inference</i>	6
MA 863-864	<i>Multivariate Analysis</i>	6
MA 865-866	<i>Regression and Analysis of Variance</i>	6
		36

<i>At least 3 of</i>		9-12
MA 555	<i>Design of Experiments</i>	
MA 557	<i>Sampling</i>	
MA 867	<i>Nonparametric Methods in Statistics</i>	
MA 881	<i>Statistical Analysis of Time Series</i>	
<i>Electives, approved by departmental advisor</i>		24-27
		Subtotal 72
<i>Dissertation ST 999 (3 units each)</i>		24
		Total 196

Students must satisfy the doctoral language requirements in one language (selected from French, German, or Russian).

REQUIREMENTS FOR THE CERTIFICATE PROGRAMS

The department offers certificate programs in the areas of applied statistics, mathematical statistics, computer mathematics and mathematical programming. Requirements for the certificate program are 15 units.

Applied Statistics

MA 223	<i>Introduction to Probability</i>
MA 224	<i>Introduction to Mathematical Statistics</i>

Choice of three

MA 554	<i>Applied Decision Theory</i>
MA 555	<i>Design of Experiments</i>
MA 556	<i>Correlation and Multivariate Models</i>
MA 557	<i>Sampling</i>

Mathematical Statistics

MA 861, 862	<i>Statistical Inference I, II</i>

Choice of three

MA 863,864	<i>Multivariate Analysis I,II</i>
MA 865,866	<i>Regression and Analysis of Variance I, II</i>
MA 881,882	<i>Statistical Analysis of Time Series I, II</i>
MA 867	<i>Nonparametric Methods in Statistics</i>

Computer Mathematics

MA 821	<i>Numerical Analysis</i>
MA 822	<i>Numerical Solution of Partial Differential Equations</i>

Choice of three

MA 823	<i>Special Topics in Numerical Analysis</i>
MA 825	<i>Numerical Linear Algebra</i>
MA 837	<i>Applied Matrix Theory</i>
MA 838	<i>Linear Algebra and Differential Equations</i>

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*

**UNDERGRADUATE
COURSES**

**MA 091-092 Principles of
Mathematics I, II** 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 100 Introductory Calculus I 4:0:4

Basic algebraic operations, including absolute value. Equations and inequalities. Functions and their graphs. Systems of equations including determinants and Cramer's rule. Trigonometric functions; definitions, graphs, identities; and equations. Law of Sines, law of Cosines. Solution of triangles. Complex numbers. Limits and continuity of functions, including trigonometric functions. Derivatives and differentiation, including trigonometric functions. Emphasis is placed on solving word problems.

**MA 110 Introductory
Calculus II** 4:0:4

Applications of differentiation, including related rates and maximum-minimum problems. Definition of the integral. The fundamental theorem of calculus. Applications of the definite integral, including area and volume. Derivatives and integrals of logarithmic, exponential, inverse trigonometric and hyperbolic functions. Techniques of integration, improper integrals. L'Hospital rule. Sequences, series, and tests for convergence. Polar coordinates and applications. Parametric equations. *Prerequisite: MA 100 or MA 101.*

MA 101 Calculus I 4:0:4

Standard first course in calculus for beginning students. Function concepts, trigonometric functions, limits of algebraic and trigonometric functions, differentiation, maximization, applications to geometry and physics. The integral, elementary techniques of integration of algebraic and trigonometric functions.

MA 102 Calculus II 4:0:4

Applications of integration, logarithmic and exponential functions, advanced techniques of integration, hyperbolic functions, inverse trigonometric and hyperbolic functions, areas in polar coordinates, conic sections, indeterminate forms, infinite series and power series. *Prerequisite: MA 101.*

MA 103 Calculus III 3:0:3

Solid geometry and vectors, partial derivatives. Multiple integrals. Parametric equations. *Prerequisite: MA 102 or equivalent.*

**MA 104 Applied Differential
Equations** 3:0:3

Ordinary differential equations: separable variables, linear equations with constant coefficients, series solutions. Systems of differential equations. *Prerequisite: MA 102 or equivalent.*

**MA 143 Introduction To
Number Theory** 3:0:3

Properties of integers and prime numbers, congruences, theorems of Fermat, Euler, Wilson, quadratic residues, diophantine equations. *Prerequisite: MA 102 or equivalent.*

**MA 153† Elements of Linear
Algebra** 3:0:3

Linear transformations, matrices and determinants, characteristic roots, diagonalization, introduction to vector spaces. *Prerequisite: MA 102 or equivalent.*

**MA 154† Elements of Abstract
Algebra** 3:0:3

Basic properties of groups, rings, fields, ideals, Euclidean rings, modules, field extensions, Galois theory, finite fields. *Prerequisite: MA 153.*

**MA 161 Introduction To Point
Set Topology** 3:0:3

Definitions for general topological space, mappings, compact sets, separation axioms, metric space and completion of a metric space. *Prerequisite: MA 211 or MA 202.*

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 or MA 113 and MA 114.*

MA 211-212 Analysis I, II
each 3:0:3

Careful and rigorous discussion of real numbers. Limits, sequences, series. Functions of one real variable: continuity, derivatives, integral. Series and sequences of functions of one variable. Functions of several variables, transformations. Theorems of Gauss, Green, Stokes. *MA 211 prerequisite: MA 114. MA 212 prerequisite: MA 211.*

MA 217 Complex Variables 3:0:3

Functions of a complex variable, derivatives, Cauchy-Riemann equations, integrals. Cauchy integral theory, power series, residue theory, conformal mapping. Schwarz-Christoffel transformation. *Prerequisites: MA 103 and MA 104 or MA 113 and MA 114.*

MATHEMATICS/SCIENCE

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 3:0:3

Descriptive statistics computed from data; means, variances, histograms. Applications of binomial, normal, t, and chi square distributions. Point estimation. Statistical tests. Confidence intervals. *Prerequisite: MA 102 or equivalent.*

MA 232† Statistical Methods II 3:0:3

Analysis of 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.*

MA 260† Vector Analysis and Partial Differential Equations 3:0:3

Vector algebra and vector calculus. Surface, line, and volume integrals. Theorems of Gauss, Green, Stokes. Curvilinear coordinates. Fourier series. Legendre polynomials and Bessel func-

tions. Dirichlet and Neumann problems. Heat flow, wave motion, vibration problems. *Prerequisites: MA 103 and MA 104.*

MA 341 Discrete Computational Structures I 3:0:3

Basic concepts of discrete mathematics. Logic and proof techniques. Sets, relations and functions. Introductory combinatorics. Directed and undirected graphs. Boolean Algebra. *Prerequisite: MA 101.*

MA 342 Discrete Computational Structures II 3:0:3

Extends graph theory to network algorithms and covers material from finite state machines, computability, and formal languages. Introduces basic concepts of queuing theory. *Prerequisite: MA 101.*

MA 358 Introductory Numerical Analysis 3:0:3

Polynomial interpolation and approximation of functions. Divided differences. Least-squares data fitting, orthogonal polynomials. Numerical differentiation and integration. Solution of nonlinear equations. Gaussian elimination, pivoting, iterative refinement, conditioning of matrices. Numerical solution of ordinary differential equations. *Prerequisites: MA 104 and some experience in computer programming.*

MA 385-386 Reading Seminar In Mathematics I, II each 3:0:3

Reading, study and investigation of selected topics in mathematics. Problem discussions and presentations by participating students. *Prerequisite: departmental advisor's permission.*

Additional offerings in the area of statistics may be found under 500-number courses.

ACTUARIAL SCIENCE

AC 301 Actuarial Science Workshop I 1½:1½:2

Applications of analysis, linear algebra and probability to actuarial science. Review and extension of concepts skimmed in prerequisite courses. *Prerequisites: MA 104 or MA 114, MA 153, MA 223.*

AC 302 Actuarial Science Workshop II 1½:1½:2

Application of statistics, operations research and numerical methods to actuarial science. *Prerequisites: AC 301, MA 224, IE 327. Corequisites: IE 328, MA 358.*

AC 401 Actuarial Science Workshop III 1½:1½:2

Further applications of operations research and numerical methods to actuarial science. Compound interest workshop. *Prerequisites: AC 302, AC 501, IE 328, Corequisite: AC 502.*

AC 402 Actuarial Science Workshop IV 1½:1½:2

Workshop on life contingencies. *Prerequisites: AC 401, AC 502. Corequisite: AC 503.*

AC 501 Actuarial Science I - Mathematics of Compound Interest And Introduction to Life Contingencies 2½:0:3

Measurement of interest; elementary and general annuities; amortization schedules; sinking funds; bonds and other securities; introduction to life contingencies. *Prerequisites: MA 103, MA 104, MA 223.*

AC 502 Actuarial Science II - Single Life Functions 2½:0:3

Life annuities; insurance premiums; reserves; expenses; combined benefits; and population theory. *Prerequisite: AC 501.*

AC 503 Actuarial Science III
- Multi-Life and Multi
- Decrement Functions 2½:0:3

Joint life status; general multi-life status-
es, contingent functions; reversionary
annuities; multiple decrement tables;
secondary decrements; a generalized
model. *Prerequisite: AC 502.*

GRADUATE COURSES

**MA 505-506 Foundations of
Mathematics** each 2½:0:3

Propositional logic, quantification theory,
relations, functions, cardinals, ordinals,
cardinal arithmetic, axiom of choice,
filters, and ultrafilters. Topics to be
chosen from: lattices and Boolean alge-
bra; nonstandard analysis, quantum
logic; multivalued logic; model theory;
ordinal arithmetic; measurable cardinals.
(Acceptable for graduate credit in the
Mathematics Dept.)

**MA 531-532 Applied Mathematics
In Engineering and Science I, II**
each 2½:0:3

Vector algebra and vector analysis.
Determinants and matrices. Jordan nor-
mal forms. Eigenvalues of symmetric
matrices by iteration. Applications to
systems of differential equations, matrix
exponential, Sturm-Liouville problems.
Legendre polynomials and Bessel func-
tions. Applications. Not acceptable for
graduate credit in the Department of
Mathematics. *MA 531 prerequisites: MA
103 and MA 104. MA 532 prerequisites:
MA 531.*

**MA 541-542† Fundamentals of
Discrete Mathematics I, II**
each 2½:0:3

Mathematical models, mathematical
reasoning, primitives of naive set theory,
inductive and recursive procedures,
functions, relations, orderings, introduc-
tion to graph theory, counting and algo-
rithm analysis, introduction to algebraic
structures. *MA 541 prerequisite: permis-
sion of advisor. MA 542 prerequisite:
permission of advisor.*

**MA 551† Applied Statistics I
(Data Analysis)** 2½:0:3

Treatment of statistical methods and
application to analysis of data, fitting of
functions to data. Estimation of popula-
tion parameters, t-tests, chi-square tests,
rank tests. Not accepted for graduate
credit in the Department of Mathematics.
Prerequisite: MA 102.

**MA 552 Correlation-
Regression-Variance Analysis** 2½:0:3

Discussion of models and computational
schemes associated with correlation,
regression coefficients, and variances.
*Prerequisite: MA 224 or MA 562 or MA
231 or MA 551.*

**MA 554† Applied Decision
Theory** 2½:0:3

Principles of statistical decision proce-
dures; 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 experi-
mentation and practice in use of basic
designs for scientific and industrial ex-
periments. Single-factor experiments,
randomized blocks, Latin squares, factor-
ial and fractional experiments, surface
fitting designs. *Prerequisite: MA 224 or
MA 232.*

**MA 556† Correlation and
Multivariate Models** 2½:0:3

Treatment of experimental data involving
several types of measurements per indi-
vidual. Regression and correlation. Sim-
ple, multiple and partial correlations.
Problems of discrimination and classifi-
cation, elements of factor analysis. Ap-
plications to analysis and interpretation
of data. *Prerequisite: MA 224 or MA
232.*

MA 557† Sampling 2½:0:3

Statistical theory and methods applica-
ble to survey sampling. Simple random
sampling, stratified, cluster, double and

systematic sampling, ratio and regression
estimates, purposive sampling. Control
of errors, costs and nonsampling aspects
of survey investigations. *Prerequisite:
MA 224 or MA 232.*

**MA 558-559 Topics in Geometric
Optimization I, II** each 2½:0:3

Topics to be chosen from: search tech-
niques, geometric distributions, packings
and coverings, arrangements and
spreads, curve fittings and pattern recog-
nitions, mathematical stereology and
extremum problems. *MA 558 prerequi-
sites: MA 103 and MA 104. MA 559
prerequisites: MA 103 and MA 104.*

MA 561† Elements of Probability 2½:0:3

Probability of events. Random variables
and expectations, discrete and continuous
distributions, important standard distribu-
tions and applications, moment generat-
ing functions, central limit theorem. Not
acceptable for graduate credit in the
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. Applica-
tions to engineering problems. (Not open
to students who have taken MA 224.)
Not acceptable for graduate credit in the
Department of Mathematics. *Prerequi-
site: MA 561.*

MA 570† Introductory Geometry 2½:0:3

First course in modern geometry. Sur-
face areas, volumes, transformation
groups, convexity, Minkowski spaces,
elementary 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, intro-
duction to transformation groups. Space
curves and ruled surfaces. Tensors and
exterior forms, manifolds and tensor
fields. Theory of surfaces. Introduction
to Riemannian geometry. *Prerequisites:
MA 103 and MA 153 or equivalent.*

LOGIC AND FOUNDATIONS

MA 605-606 Topics in Analysis for Teachers I, II each 3¼:0:4½

Elements of abstract spaces and structures with application to specific modern problems in ordinary and partial differential equations, probability and statistics, linear programming. Credit for these courses granted only to those students in high school teachers' program. *MA 605 prerequisite: calculus. MA 606 prerequisite: MA 605.*

MA 607-608 Fundamentals of Mathematics I, II each 2½:0:3

Introduction to informal axiomatic set theory: relations, functions, the axiom of choice, well ordering, Zorn's lemma, transfinite recursion, cardinal numbers, ordinal numbers, cardinal arithmetic, ordinal arithmetic. Introduction to mathematical logic: propositional calculus, first-order logic, first-order recursive arithmetic. Topics to be chosen from the following: Boolean algebra and lattices, Turing machines, computability, non-standard analysis, model theory. *MA 607 prerequisite: calculus. MA 608 prerequisite: MA 607.*

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 prerequisite: 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 convergence theorems. Radon-Nikodym theorems, Lusin's theorem, product measure, Fubini theorems. *Prerequisite: MA 620 or equivalent.*

MA 622 Real and Complex Analysis II 2½:0:3

Rigorous development of theory of functions of a complex variable. Complex number systems, differentiation and integration, analytic and meromorphic functions, residue theory, introduction to Riemann surfaces, conformal mappings, Blaschke products, Picard theorems. *Prerequisite: MA 621.*

MA 630 Elements of Complex Variables 2½:0:3

Analytic functions of a complex variable. Complex numbers, differentiation and integration. Cauchy theorems, power series. Evaluation of integrals by residues. Conformal mapping, Schwarz-Christoffel transformations. *Prerequisites: MA 103 and MA 104 (not open to students who have taken MA 217.)*

MA 637-638 Topics in Complex Variables each 2½:0:3

Content of course varies. In spring of year prior to one in which course is offered, detailed description posted and mailed to all graduate mathematics students. *Prerequisite: MA 622.*

MA 645 Theory of Ordinary Differential Equations 2½:0:3

Ordinary differential equations. 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, well-posedness. *Prerequisite: MA 645.*

MA 649-650 Topics in Ordinary and Partial Differential Equation 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, 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 to classical analysis. *MA 681 prerequisite: MA 703. MA 682 prerequisite: MA 681.*

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.*

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 canonical form, Hermitian operators, unitary operators, normal operators, spectral theorem. Dual spaces, inner product spaces. *Prerequisite: MA 705.*

MA 715-716 Advanced Topics in Algebra each 2½:0:3

Content of course varies. In spring of year prior to one in which course is offered, detailed description posted and mailed to all graduate mathematics students. *MA 715 prerequisite: MA 705 and MA 706. MA 716 prerequisite: MA 715.*

GEOMETRY AND TOPOLOGY

MA 754 Topological Methods in Analysis 2½:0:3

Aspects of topological methods and applications to existence theorems in analysis. Use of fixed-point theorem and topological degree in study of properties of solutions of ordinary and partial differential equations. No previous courses in topology required. *Prerequisite: MA 212 or 202 or MA 620.*

MA 755-756 Topology I, II each 2½:0:3

Topological spaces, compactness, connectedness, continua, extension theo-

rems, 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 755.*

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 theory. *MA 775 prerequisite: instructor's approval. MA 776 prerequisite: MA 775.*

MA 785 Selected Topics in Geometry 2½:0:3

Integral geometry, combinatorial geometry, transformation groups, Lie groups and algebras, algebraic geometry, convex polytopes and geometry of numbers. *Prerequisite: instructor's approval.*

MA 786 Selected Topics in Topology 2½:0:3

Complex spaces (several complex variables), calculus of variations in the large (Morse theory), global differential geometry. Differential topology, homotopy theory. *Prerequisite: instructor's approval.*

APPLIED MATHEMATICS

MA 801-802 Special Topics in Applied Mathematics I, II each 2½:0:3

Asymptotic expansions of definite integrals and of solutions to differential equations, perturbation theory, variational methods, non-linear vibrations, distributions, spectral representation of linear operators, relaxation methods, boundary-value problems. *MA 801 prerequisites: linear algebra and complex variables. MA 802 prerequisite: MA 801.*

MA 812-817 listed Below under Probability, Statistics, Operations Research

MA 821 Numerical Analysis 2½:0:3

Interpolation. Approximation of functions by polynomials. Fast Fourier transform. Numerical integration. Solution of non-linear equations. Iterative improvement of solutions of linear equations. Eigenvalues of matrices. Numerical solution of ordinary differential equations. *Prerequisite: MA 153 and some experience in computer programming.*

MA 822 Numerical Solution of Partial Differential Equations 2½:0:3

Stability, consistency, and convergence of finite-difference methods for initial-value problems. Implicit and explicit schemes. Method of lines. Alternating direction methods. Direct and iterative solutions of elliptic equations. Finite element methods. *Prerequisite: MA 821 or 358 and 153 and some experience in computer programming.*

MA 823 Special Topics in Numerical Analysis 2½:0:3

Numerical solution of ordinary and linear partial differential equations. Stability, consistency, error estimates, convergence of difference schemes. *MA 821 and MA 153.*

MA 833 Partial Differential Equations of Mathematical Physics 2½:0:3

First-and second-order partial differential equations and systems of equations. Initial and boundary value problems. Fundamental solutions and Green's functions. Theory of characteristics. Eigenvalue problems. Rayleigh-Ritz and Ritz-Galerkin methods. Approximate and asymptotic methods. Nonlinear equations and applications. *Prerequisite: MA 202 or MA 212 or MA 620 or equivalent.*

MA 836 Applied Complex Variables 2½:0:3

Brief review of important characteristics of analytic functions. Use of conjugate functions in solution of two-dimensional

potential problems. Study of conformal mapping with emphasis on Schwarz-Christoffel transformation and its applications. *Prerequisite: MA 630 or MA 622.*

MA 837 Applied Matrix Theory
2½:0:3

In-depth introduction to theory and application of linear operators and matrices in finite-dimensional vector space. Invariant subspaces, elementary divisors, canonical forms, and minimax theorems for eigenvalues of hermitian pencils. *Prerequisites: MA 103 and MA 104.* Also listed under EL 613

MA 838 Linear Algebra and Differential Equations
2½:0:3

Basic theory of linear algebra and its application to systems of ordinary differential equations, method of adjoints, series solutions, equations with periodic coefficients, stability theory, applications to nonlinear systems. *Prerequisites: MA 103 and MA 104.*

MA 844 Optimal Control Theory
2½:0:3

Optimal control problems for deterministic systems with various constraints. Solutions for both continuous and discrete-time systems using maximum principle and dynamic programming. Hamilton-Jacobi theory as applied to synthesis problem. *Prerequisite: EL 723.* Also listed under EL 823

MA 846 Fourier and Laplace Transforms
2½:0:3

Application of transform methods to partial differential equations of mathematical physics. Includes introduction to Wiener-Hopf technique. *Prerequisite: MA 630.*

MA 853-855, 861-874 listed below under Probability, Statistics, Operations Research

PROBABILITY, STATISTICS, OPERATIONS RESEARCH

MA 812 Theory of Games
2½:0:3

Introduction to mathematical analysis of conflict situations. Network and extensive form games, matrix games, solution algorithms, consideration of n-person and non-zero sum games. *Prerequisite: MA 153 and MA 223.*

MA 813 Linear Programming
2½:0:3

Theory and application of linear programming techniques. Simplex and revised simplex algorithms. Duality theory, dual simplex method, post-optimality analysis. Degeneracy. Transportation and assignment problems. Applications, problem formulation, computer solutions. *Prerequisite: MA 153.* Also listed under IE 631

MA 814 Integer Programming
2½:0:3

Solution techniques for integer and mixed-integer linear programming problems. Cutting plane methods, zero-one programming, branch and bound methods. Surrogate constraints. Quadratic programming. Applications to combinatorial analysis. *Prerequisite: MA 813.* Also listed under IE 633

MA 815 Theory of Queues 2½:0:3

Steady-state solutions for single and multiple channels, various arrival and service distributions, queue disciplines. Transient solutions. Emphasis on theory, with solution techniques given for specific classes of queues. *Prerequisite: MA 223.*

MA 816-817 Graph Theory
I, II each 2½:0:3

Graphs and subgraphs, connectivity, trees and girth, planarity, embeddings, n-connectivity and edge-connectivity, Hamilton graphs, matchings, factorization and covering, graphs and groups, graph isomorphism and reconstruction, colorings, map colorings, Ramsey and extremal graph theory, enumeration, connectedness in digraphs. Euler and

Hamilton graphs, tournaments, networks. *MA 816 prerequisites: MA 103 and MA 104. MA 817 prerequisite: MA 816.*

MA 818 Non-Linear Programming
2½:0:3

Optimization of nonlinear functions. Classical methods. Constraints and Lagrangian methods. Kuhn-Tucker theory, duality and economic interpretation. Separable programming, feasible directions, gradient projection. Quadratic and convex programming. Industrial and engineering applications. *Prerequisite: MA 813.* Also listed under IE 632

MA 821-823, 825-833, 835-839, 841-842, 844, 846 listed above under Applied Mathematics.

MA 853 Probability I
2½:0:3

Probability 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 Process 2½:0:3

Normal and stationary processes, Wiener processes, Poisson and renewal processes, Markov Processes. *Prerequisites: MA 854 or equivalent.*

MA 861-862 Principles of Statistical Inference I, II
each 2½:0:3

Two semester sequence in statistical inference. Point and interval estimation of statistical parameters. Theory of statistical estimators. Fundamentals of statistical tests of hypotheses. Second semester extends theory of tests of hypotheses, including sequential tests. Non-parametric methods in statistics. *MA 861 prerequisite: MA 224 or equivalent. MA 862 prerequisite: MA 861.*

MA 863-864 Multivariate Analysis I, II

each 2½:0:3

Multivariate normal distribution, simple, partial, multiple correlation. Generalization of student's ratio, tests of significance of sets of means. Tests of general linear hypothesis. Some generalizations of analysis of variance. *MA 863 prerequisite: MA 862 and MA 153. MA 864 prerequisite: MA 863.*

MA 865-866 Regression and Analysis of Variance I, II

each 2½:0:3

Linear regression of one or more independent variables. Least square estimates of regression coefficients. Gauss-Markov theorem. Confidence regions for and tests of hypothesis about regression coefficients. Test of general linear hypothesis. Multiple classification in analysis of variance. Power of F-test. Alternative models: I and II, mixed models, analysis of covariance and components of variance. *MA 865 prerequisites: MA 862 and MA 153. MA 866 prerequisite: MA 865.*

MA 867 Non-Parametric 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.*

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 theorems and related asymptotic expansions. Infinitely divisible distributions. *MA 871 prerequisite: MA 622 or equivalent. MA 872 prerequisite: MA 871.*

MA 873-874 Theory of Stochastic Processes I, II

each 2½:0:3

Foundations of stochastic processes. Kolmogorov's extension theorem. Properties of sample paths. Conditional expectation. Martingales. Classes of stochastic processes, Gaussian processes, Markov processes, others. Second-order properties. Stationary processes. Applications. *MA 873 prerequisite: MA 872 or equivalent. MA 874 prerequisite: MA 873.*

MA 881-882 Statistical Analysis of Time Series I, II

each 2½:0:3

Careful study of tractable models for statistical analysis of scalar time series. Models treated: (1) "error plus trend" models and (2) stationary stochastic process models with special emphasis on autoregressive models. Estimation, tests of hypotheses and multiple-decision procedures for these models, spectral representation and filtering, estimation of spectral density. *MA 881 prerequisites: MA 153, MA 854 and MA 862. MA 882 prerequisite: MA 881.*

READING, PROJECT, THESIS, DISSERTATION

MA 941-944 Reading in Mathematics I-IV

each 2½:0:3

Courses intended primarily for students who have completed two years of full-time graduate study and who wish to do research in a specialized area. Reading done under guidance of faculty members and devoted mainly to scholarly papers. *Prerequisite: permission of department.*

MA 955-956 Selected Topics in Advanced Mathematics I, II

each 3¼:0:4¼

Review of current mathematical research, designed for mature students. May be given by visiting professor. Specific topics vary, depending on instructor. *Prerequisite: permission of department.*

MA 958-959 Selected Topics in Advanced Mathematics I, II

each 2½:0:3

Same course description as MA 955-956 except for credit structure. *Prerequisite: permission of department.*

MA 997 Thesis for Degrees of Master of Science

each 3 units

Thesis to present results of independent investigation of suitable problem in abstract or applied mathematics. Study must include adequate investigation of existing literature relating to subject. Regular reports on progress of work and regular conferences with assigned faculty advisor required. Reregistration fee, any part: 3-unit charge. *Prerequisite: degree status.*

MA 999 Dissertation for Degrees of Doctor of Philosophy

each 3 units

Results of independent investigation of some problem in mathematics. Must demonstrate ability to do creative work and include original research of caliber deemed worthy of publication in recognized scientific journals. Oral examination on subject of dissertation and related

topics required. Minimum of 24 dissertation units required for degree. Reregistration fee, any part: 3-unit charge. *Prerequisite: degree status and qualifying examination.*

ST 941-942 Readings in Statistics I, II *each 2½:0:3*

Courses intended primarily for students who have completed two years of full-time graduate study and who wish to do research in a specialized area. Reading done under guidance of faculty members and devoted mainly to scholarly papers. *Prerequisite: permission of department.*

ST 958-959 Selected Topics in Statistics I, II *each 2½:0:3*

Review of current statistical research, designed for mature students. May be given by visiting professor. Specific topics vary, depending on instructor. *Prerequisite: permission of department.*

ST 995 Project for Degrees of Master of Science (Statistics) *each 3 units*

Results of detailed study from the field of statistics carried out under the supervision of faculty advisor. *Prerequisite: degree status. Reregistration fee, any part: 3-unit charge.*

ST 997 Thesis for The Degree of Master of Science (Statistics) *each 3 units*

Thesis presents results of independent investigation of suitable aspects of statistics. Investigation of existing literature and related work must be included. Topic is selected with the help of a faculty advisor who also supervises the thesis work. *Prerequisite: degree status. Reregistration fee, any part: 3-unit charge.*

ST 999 Dissertation for The Degree of Doctor of Philosophy (Statistics) *each 3 units*

Results of independent investigation of some area of statistics. Must demonstrate ability to do creative work and include original research of caliber deemed worthy of publication in recognized scientific journals. Oral examination on subject of dissertation and related topics

is required. *Prerequisite: degree status and qualifying examination. Reregistration fee, any part: 3-unit charge.*

Students in other departments should note that there are certain undergraduate courses in mathematics that may be accepted for graduate credit in their departments. Such courses are identified by a † following the course number (e.g., MA 223).

The following courses are offered irregularly in response to student demand:

- MA 001 Pre-collegiate Algebra
- MA 005 Pre-collegiate Trigonometry
- MA 011 Review of Calculus
- MA 111 Calculus Ia
- MA 112 Calculus IIa
- MA 113 Calculus IIIa
- MA 114 Differential Equations
- MA 194 History of Mathematics
- MA 239 Mathematical Modeling
- MA 333 Partial Differential Equations
- MA 503 Mathematical Logic
- MA 535 Vector and Tensor Analysis
- MA 565 Intermediate Differential Equations
- MA 603 Symbolic Logic
- MA 625-626 Measure and Integration Theory I,II
- MA 804 Calculus of Finite Differences
- MA 819-820 Theory of Approximation
- MA 825 Numerical Linear Algebra
- MA 835 Potential Theory
- MA 839 Introduction to Functional Analysis
- MA 841-842 Integral Equations I,II

FACULTY

Lesley Sibner, Professor and Head of Mathematics
B.S., CCNY; M.S., Ph.D., New York University
Partial differential equations; global analysis

Burton Lieberman, Associate Professor of Mathematics and Administrative Officer
B.A., Harvard University; M.S., Ph.D., New York University
Differential equations; stochastic processes; statistics, sport science

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

Leon Herbach, Professor of Mathematics and Statistics
A.B., Brooklyn College; M.A., Ph.D., Columbia University
Reliability, stochastic models of physical systems; Monte Carlo methods

Ronald Hirshon, Professor of Mathematics; B.S., M.S., Brooklyn College; Ph.D., Adelphi University
Group Theory

Erwin Lutwak, Professor of Mathematics
B.S., M.S., Ph.D., Polytechnic Institute of Brooklyn
Convexity

Clifford W. Marshall, Professor of Mathematics
B.A., Hofstra University; M.A., Syracuse University; M.S., Polytechnic Institute of Brooklyn; Ph.D., Columbia University
Graph theory; conflict analysis; applied probability

Edward Y. Miller, Professor of Mathematics
B.A., University of Pennsylvania; M.A., Ph.D., Harvard University
Topology

Paul F. Pickel, Professor of Mathematics
B.S., Ph.D., Rice University
Mathematical programming, computer graphics, artificial intelligence

Stanley Preiser, Professor of Mathematics and Computer Science
B.S., CCNY; M.S., Ph.D., New York University
Numerical analysis; applied mathematics; algorithms; system performance evaluation

Georges Weill, Professor of Mathematics; Lic. Math., Dr.Sc., University of Paris (France);
Ph.D., University of Southern California
Complex analysis; global analysis; partial differential equations

Kathryn Kuiken, Associate Professor of Mathematics
B.A., M.A., Montclair State College; M.S., New York University; Ph.D., Polytechnic Institute of New York
Group Theory

Joel Rogers, Associate Professor of Mathematics
B.S., Ph.D., Massachusetts Institute of Technology
Partial differential equations; fluid mechanics; numerical methods

Deane Yang, Associate Professor of Mathematics
B.A., University of Pennsylvania; Ph.D., Harvard University
Differential geometry; nonlinear partial differential equations; overdetermined systems of partial differential equations

Erich Zauderer, Associate Professor of Mathematics
B.S., Yeshiva College; M.S., Ph.D., New York University
Nonlinear wave propagation; partial differential equations; diffraction problems

El-Bachir Yallaoui, Instructor of Mathematics
"Diplome d'Etudes Superieures", M.S. University de Setif, Algeria; Ph.D., Polytechnic University
Real and Functional Analysis

ADJUNCT FACULTY

Barnet Berin, Lecturer
B.S., CCNY, M.S., Columbia University
Fellow Society of Actuaries

Barbara Cain, Lecturer
B.S., Syracuse University; M.S., New York University

Daniel Drance, Lecturer
M.S., State University of New York, Stony Brook

Issam El-Achkar, Lecturer
B.S.E.E., N.Y. Institute of Technology, M.S., Ph.D., Polytechnic University

Kamal Hajjellie, Lecturer
B.S., N.Y. Institute of Technology; M.S., Fordham University; Ph.D., Polytechnic University

Carl Gogolak, Lecturer
M.A., Fordham University; Ph.D., Polytechnic University

Dale Siegel, Lecturer
B.S., M.S., Ph.D., Polytechnic University

Walter Vohs, Lecturer
B.S., SUNY Maritime College, M.S., New York University

Martin Weinless, Lecturer
B.S., City University of New York

EMERITUS FACULTY

Aaron Fialkow, Professor Emeritus; B.S., M.S., CCNY; Ph.D., Columbia University
Differential geometry; network theory

Ronald M. Foster, Professor Emeritus
B.S., Brooklyn College; M.S., New York University
Network theory; graph theory

Heinrich Guggenheimer, Professor Emeritus; Dipl., Dr.Sc., Swiss Federal Institute of Technology-Zurich (Switzerland)
Differential equations; geometry-convexity

Andrew J. Terzuoli, Professor Emeritus
B.S., Brooklyn College; M.S., New York University
Probability; statistics

INFORMATION MANAGEMENT

Information Management is an interdisciplinary program dealing with the design, operation and maintenance of systems which serve the information needs of business and manufacturing organizations.

Currently, there is a great demand for graduates in this field. Industries in the metropolitan New York area such as banking, finance, retailing, utilities and hospitals, as well as manufacturing have been unable to meet employment requirements in information management for several years. A typical position calls for technical competence and the ability to work closely with computer operations personnel, auditors, consultants, and user department representatives, and other project team members.

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

COOPERATIVE PROGRAM AND INTERNSHIPS

A four to five year cooperative education program is available which permits students to integrate academic courses and career preparation. While earning the B.S. degree, students are able to earn up to 75% of their college expenses. Students who wish a less intensive work experience as part of their education may wish to enroll in a summer or part time internship program.

UNDERGRADUATE PROGRAM

Polytechnic offers a program of study, administered by the Management Department, leading to the Bachelor of Science degree in Information Management. Students are offered both day and evening courses on a full or part-time basis.

The program's objectives are to provide students with the educational background and skills to qualify for entry level positions as application programmers or analysts in the business world. Unlike computer science, where mathematics, science and software development are emphasized, information management is business oriented. Students must be aware of problems encountered by management which require timely information.

This in-depth program enables interested students to move into project leadership positions within one to five years after entering industry without additional courses. Finally the program provides a solid foundation for the student who wishes to pursue graduate study.

REQUIREMENTS FOR THE BACHELOR OF SCIENCE IN INFORMATION MANAGEMENT

The curriculum, requiring 127 credits for graduation, consists of four major components: computing; management/system analysis; humanities; and social sciences.

Credits

<i>Computer Science</i>	21
<i>Humanities</i>	20
<i>Science</i>	6
<i>Industrial Engineering</i>	6
<i>Management</i>	30
<i>Mathematics</i>	14
<i>Social Sciences</i>	24
<i>Free electives</i>	6
Total	127

Computer Science

CS 200	<i>Programming Methodology (Pascal)</i>	3:c:3
CS 201	<i>Data Structures & Algorithms</i>	3:c:3
CS 211	<i>Cobol Programming</i>	3:c:3
CS 308	<i>Intro to Database Systems</i>	3:d:3
<i>Three CS electives (CS 212 strongly suggested, CS 202 & 306 recommended)</i>		<u>9</u>
		21

"c" denotes numerous computer science assignments required

"d" denotes design project required

Humanities

HU 101	<i>Writing & Humanities I</i>	3:0:3
HU 200	<i>Writing & Humanities II</i>	3:0:3
HU 110	<i>Basic Report Writing</i>	3:0:3
HU 119	<i>Public Speaking</i>	3:0:3
HU 251	<i>American Lit. to 1880</i>	
HU 252	<i>American Lit. from 1880 to present</i>	
or		
HU 341	<i>Introduction to Philosophy</i>	3:0:3
HU 344	<i>Introduction to Logic</i>	3:0:3
LA 139	<i>Engineering Ethics</i>	<u>2:0:2</u>
		20

Industrial Engineering

IE 300	<i>Engineering Economy</i>	3:0:3
IE 320	<i>Project Planning & Control</i>	<u>3:0:3</u>
		6

Management Courses

MG 202	Computers in Management	2:3:3
MG 300	Management Process	3:0:3
MG 301	Organizational Behavior	3:0:3
MG 304	Accounting Fundamentals	3:0:3
MG 305	Foundations of Business Systems	3:0:3
MG 306	Financial Management	3:0:3
MG 326	Human Resource Info. Systems	3:0:3
MG 336	M.I.S. Case Studies	3:0:3
MG 400	Senior Internship I	3:0:3
MG 402	Senior Internship II	3:0:3
MG 401	Senior Project Management elective	
		30

Mathematics

MA 101	Calculus I	4:0:4
MA 102	Calculus II	4:0:4
MA 231	Statistical Methods I	3:0:3
MA 232	Statistical Methods II	3:0:3
		14

Sciences

Six credits of Physical Science Courses.	6
LA 130 and/or LA 131 are recommended in order to satisfy all or one of the requirements.	

Social Sciences

SS 104	Main Themes in Contemporary World History	3:0:3
SS 123	History of U.S. From Settlements to Reconstruction and	3:0:3
SS 124	History of the U.S. From Reconstruction through the Cold Wars or	3:0:3
SS 109	Europe, the Early Phase 800-1500 and	
SS 110	the Renaissance and Reformation	
SS 229	Growth of the U.S. Constitution	3:0:3
SS 189	Introduction to Psychology or	3:0:3
LA 132	Intro. to Behavioral Science	
SS 203	Psychology of Learning or	3:0:3
SS 206	Human Cognition and Information Processing	
SS 250	Basic Economics and	3:0:3
SS 265	Money & Banking or	3:0:3
SS 251	Microeconomics and	
SS 252	Macroeconomics	
		24

Graduate courses may be taken as electives by qualified juniors and seniors with advisors' approval. If the total number of credits exceeds those required for the bachelor's degree, these graduate courses may be credited toward a graduate degree in accordance with Polytechnic policy.

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.

Transfer students from other accredited schools are accepted in the B.S. program after evaluations of their transcripts by faculty advisors. Graduates of technology programs may fulfill bachelor's degree requirements in two to two-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

		Hours/Week		
No.	Subject	Cl.	Lab.	Cr.
<i>First Semester</i>				
SS 104	Main Themes in Contemp. World History	3	0	3
HU 101	Writing and the Humanities	3	0	3
MA 101	Calculus I (or MA 100)	4	0	4
CS 211	Cobol Programming	3	0	3
MG 202	Computers in Management	2	3	3
CP 101	Co-op Ed. Seminar I*	0	0	0
SL 101	Freshman Seminar	1	1	0
				16

Second Semester

SS 123	History of the U.S. from Settlement through Reconstruction or	3	0	3
SS 109	The Birth of Modern Europe, the Early Phase, 800-1500			

HU 200	Writing and the Humanities II	3	0	3
MA 102	Calculus II (or MA 110)	4	0	4
CS 200	Pascal	3	c	3
MG 300	Management Process	3	0	3
				16

SOPHOMORE YEAR

First Semester

SS 124	History of the U.S. from Reconstruction through the Cold Wars or	3	0	3
SS 110	The Renaissance and Reformation			
HU 110	Basic Report Writing	3	0	3
SS 189	Intro. to Psychology (or LA 132)	3	0	3
HU 119	Public Speaking	1½	1½	3
SS 251	Microeconomics or	3	0	3
SS 250	Basic Economics			
CS 201	Data Structures and Algorithms	3	0	3
				18

Second Semester

MG 304	Acct. Fundamentals	3	0	3
LA 139	Engineering Ethics (or LA 140)	2	0	2
SS 252	Macroeconomics or	3	0	3
SS 265	Money and Banking			
MG 301	Organiz'l. Behavior	3	0	3
CS 308	Intro. to Data Sys. Science Elective with Lab Component (LA 131 strongly suggested)	3	3	3
				17

JUNIOR YEAR

First Semester

SS 205	Appl. Psychology or	3	0	3
SS 206	Human Cognition and Info. Processing			
HU 251	American Lit. to 1880 or	3	0	3
HU 341	Intro. to Philosophy			
IE 300	Engineering Economy	3	0	3
MG 305	Foundation of Bus. Systems	3	0	3
MG 306	Financial Management	3	0	3
				15

MANAGEMENT

Second Semester

SS 229	Growth of the U.S. Constitution	3	0	3
HU 252	American Lit. from 1880 to Present or	3	0	3
HU 344	Intro. to Logic			
IE 320	Project Planning and Control	3	0	3
	CS Electives			<u>6</u>
				15

SENIOR YEAR

First Semester

MA 231	Stat'l. Methods I	3	0	3
MG 326	Human Resources Info. Systems or	3	0	3
MG 346	Intro. to Telecommunications			
MG 400	Senior Internships I* or			
MG	Elective	3	0	3
CS	Elective	3	0	3
	Science Elective (LA 130 strongly suggested)	3	0	<u>3</u>
				15

Second Semester

MA 232	Stat'l. Methods II	3	0	3
MG 336	M.I.S. Case Studies	3	0	3
MG 402	Senior Internship II or			3
MG 401	Senior Project			
	Free Electives			<u>6</u>
				15

* IF MG 400 is elected by the student, CP 101 will be required. These non-credit courses may be taken in any semester prior to the first work period.

FACULTY

This interdisciplinary program is administered by the Management Department. The faculties of industrial engineering, computer science, humanities, social sciences, and mathematics participate in delivering the program.

MANAGEMENT

The Department of Management offers one undergraduate degree:

Bachelor of Science in Information Management* and five graduate degrees:

- Master of Science in Management
- Master of Science in Organizational Behavior
- Master of Science in Operations Management*
- Master of Science in Telecommunications and Computing Management*
- Master of Science in Management of Technology*

* see separate program listing

THE MASTER OF SCIENCE PROGRAM IN MANAGEMENT

The master of science in management degree (MSM) is recognized, along with the master of business administration (MBA), by the Graduate Management Admission Council as graduate professional management degrees. Most MSM programs are offered by leading engineering schools. Polytechnic's MSM is designed to prepare working professionals for increasing responsibility in management positions. The program is aimed at developing competence in planning and decision-making and in the selection, allocation and direction of human, financial, physical, technological and organizational resources.

These management skills can be applied in a broad range of professional settings both in the private and the public sector; in labor-intensive and in capital-intensive industries; in production-oriented and in service-oriented activities and in traditional as well as in high-technology environments.

Polytechnic's graduate program in management takes a pragmatic, results-oriented approach that emphasizes man-

agement of technology, production management, and strategic planning to achieve long term productivity and profitability. Traditional subjects such as accounting, economics, finance, and marketing are taught, not as special areas of expertise but as basic tools for managerial decision-making.

After completing the core courses, degree candidates build further managerial skills in their choice of 6 concentrations:

- Construction Management
- Human Resource Management
- Information Management
- Quality and Productivity Management
- Management Science
- Technology Management

The program concludes with a course in Business Policy and Strategy which integrates the functional disciplines studied throughout the program. Through case studies the students acquire an understanding of top management's perspective, how organizations set goals, establish policies, and implement strategies to gain competitive advantage.

Polytechnic's students are working professionals, typically engineers and scientists with managerial responsibility. Small classes (averaging 15 or fewer students) enable the students to receive close individual attention from the faculty.

Admission — Criteria for admission include having a bachelor's degree with at least a B average from an accredited college or university and demonstrated evidence of motivation, maturity, and the ability to benefit from and contribute to professional graduate studies. An applicant who does not meet all the criteria may be admitted as a non-degree student with the opportunity subsequently to become a degree candidate. Satisfactory scores on the Graduate Management Admission Test (GMAT) or an acceptable equivalent test may be used as support for admission to degree studies.

Degree Requirements — The MSM requires completion of a minimum of 12 courses, or 36 units, with a B average or better. Students who lack prerequisites may be required to take up to 4 additional basic courses, or 12 units. Transfer credits of 9 units may be granted for graduate courses taken previously, as evaluated by an advisor.

THE CURRICULUM

1. **Basic and Core Courses.** The basic and core courses provide a management base upon which students can build a variety of specializations within the degree programs. These courses provide intensive introductions to the several disciplines required of professional managers. Students who have taken these courses elsewhere or previously at Polytechnic, or who have had equivalent experiences may be excused from them.

Upon proof of competence, an advisor can waive any basic or core course. However, students are required to complete a minimum of 36 units (12 courses) at the 600 level or above.

The Basic Courses:

- MG 502 *Computers in Management*
- MG 503 *Economic Environment of Management*
- MG 504 *Managerial Accounting*
- MG 505 *Statistical Analysis*

The Core Courses:

- MG 600 *Management Process*
- MG 601 *Organizational Behavior*
- MG 606 *Managerial Finance*
- MG 607 *Marketing*
- MG 608 *Managerial Economics and the Economic Environment*

2. **Areas of Concentration.** Students must choose areas of concentration. These may be one of those listed below or, with the advisor's approval,

MANAGEMENT

al, a set of courses designed to meet students' special needs. A minimum of four courses must be selected in any one area of concentration. Courses in all the available options are shown below.

3. **Free Electives.** Two graduate courses may be chosen from those offered by any programs of Polytechnic with the advisor's consent.
4. **Strategic Management, with Project (MG 970).** This required integrating course is recommended for students' final semester. It includes a project normally in the area of students' specialization. In special cases, MG 997, Thesis for Degree of Master of Science, may be substituted for students who wish to produce a major dissertation in a specialty.

CONCENTRATION COURSE REQUIREMENTS

Each concentration sequence consists of a minimum of four courses. Students who take more than the minimum number of required courses may count additional courses as electives. Substitutions may be made with an advisor's approval in any concentration areas.

Construction Management

Select four:

MG 631	<i>Organizational Theory and Design</i>
MG 664	<i>Management and the Legal System</i>
MG 810	<i>Project Planning and Control</i>
MG 820	<i>Project Assessment & Management</i>
MG 825	<i>Construction Administration</i>
MG 826	<i>Construction Estimates and Costs</i>
MG 827	<i>Specifications and Contracts</i>
MG 830	<i>Formulation and Analysis of Public Works</i>

Human Resource Management

Required:

MG 612	<i>Human Resource Management</i>
MG 633	<i>Research Methods</i>

Electives — Select two:

MG 611	<i>Career Management</i>
MG 613	<i>Industrial Relations</i>

MG 616	<i>Job and Workplace Design</i>
MG 617	<i>Performance Measurement and Reward Systems</i>
MG 622	<i>Personnel Psychology</i>
MG 623	<i>Training in Organizations</i>
MG 624	<i>Organization Development</i>
MG 625	<i>Seminar in Career Management</i>
MG 626	<i>Human Resource Information Systems</i>
MG 627	<i>Human Resources and Technological Change</i>
MG 631	<i>Organizational Theory and Design</i>

Information Management

Select four:

MG 612	<i>Human Resource Management</i>
MG 626	<i>Human Resource Information Systems</i>
MG 650	<i>Management of the Information Function</i>
MG 654	<i>Economics of Information Systems</i>
MG 664	<i>Management and the Legal System</i>
MG 716	<i>Commercial Data Processing Systems and Design</i>
MG 737	<i>Analysis and Design of Management Information Systems</i>
MG 810	<i>Project Planning and Control</i>
MG 820	<i>Project Assessment & Management</i>
CS 603	<i>Design and Analysis of Algorithms I</i>
CS 681	<i>Information Privacy and Security</i>

Quality and Productivity Management

Required:

MG 630	<i>Operations Management</i>
MG 635	<i>Introduction to Total Quality Management</i>

Select two:

MG 612	<i>Human Resource Management</i>
MG 618	<i>Introducing New Methods of Work — Leading Change</i>
MG 624	<i>Organization Development</i>
MG 645	<i>Productivity Management</i>
MG 705	<i>Managerial Planning Process</i>
MG 850	<i>Cost Systems</i>
MG 868	<i>Strategic Management of Productivity</i>

Management Science

Students electing this option should substitute MA 551 for MG 505 in the basic courses.

NOTE: IE 624 HAS SEVERAL PREREQUISITES

Select four:

MG 714	<i>Modeling of Social and Managerial Systems</i>
MG 810	<i>Project Planning and Control</i>
IE 624	<i>Computer-Augmented Case Studies in Management Science</i>
IE 627	<i>Operations Research: Deterministic Models</i>
IE 628	<i>Operations Research: Stochastic Models</i>
IE 680	<i>System Simulation</i>

Technology Management

Required:

MG 866	<i>Technology, Management and Policy</i>
MG 865	<i>Managing the Innovative Process</i>

Select two:

MG 624	<i>Organization Development</i>
MG 627	<i>Human Resources and Technological Change</i>
MG 630	<i>Operations Management</i>
MG 645	<i>Productivity Management</i>
MG 664	<i>Management and the Legal System</i>
MG 672	<i>Technological Forecasting</i>
MG 820	<i>Project Assessment & Management</i>
MG 865	<i>Managing the Innovative Process</i>
MG 867	<i>Technology Strategy</i>
MG 868	<i>Strategic Management of Productivity</i>

MASTER OF SCIENCE IN ORGANIZATIONAL BEHAVIOR

Program — A graduate evening program requiring 36 units of course-work is offered to students who wish to specialize in organizational behavior, a field concerned with solving human problems in modern organizations. The program includes both theoretical and practical courses relevant to organizational behavior and human resource management.

Admission — Applicants must meet the basic admission requirements of the graduate programs in Management. Those without undergraduate courses in psychology will be required to remove

this deficiency. Students who have not completed an undergraduate course in statistics will be required to enroll in MG 505, Statistical Analysis. Those with little or no background in computers must make up the deficiency by enrolling in MG 502, Computers in Management. These courses are in addition to degree requirements.

THE CURRICULUM

1. **Required Core Courses** - An organizational behavior base consists of three core courses upon which the student can build a variety of specializations within the degree program. Core courses provide an introduction to several areas basic to organizational behavior. Students who have previously completed courses in any of these areas, may be excused from taking them by presenting proof of competence and receiving waivers from the Program Director. Other courses must then be substituted with permission of the Program Director.

The core courses are:

MG 601 *Organizational Behavior*
MG 631 *Organizational Theory and Design*
MG 633 *Research Methods*

2. **Areas of Concentration** - Students must choose three areas of concentration, each consisting of two courses. These may be three of the concentrations listed below or, with advisor's approval, may consist of a series of six courses designed to meet students' special needs.

Courses in each of the following available areas of concentration are shown below:

Career Management

MG 611 *Career Management*
MG 625 *Seminar in Career Management*

Labor Relations

MG 613 *Labor Relations*
MG 614 *Collective Bargaining*

Information and Technological Change

MG 626 *Human Resource Information Systems*
MG 627 *Human Resources and Technological Change*

Performance and Motivation Management

MG 616 *Job and Workplace Design*
MG 617 *Performance Measurement and Reward Systems*

Personnel and Human Resources

MG 612 *Human Resource Management*
MG 622 *Personnel Psychology*

Training and Development

MG 623 *Training in Organizations*
MG 624 *Organization Development*

3. **Free Electives** - Two appropriate graduate courses may be chosen from any program at Polytechnic with advisor's consent. These could include courses from any concentration not required in students' programs, other courses in management, or courses in computers, psychology and social sciences.

4. **Research Projects** - MG 634 Applied Research Methods

All students are required to submit an independent research project. In special cases, MG 997, a thesis for degree of master of science, may be substituted for students who wish to produce a major research project.

CERTIFICATE PROGRAMS

The Department of Management offers several certificate programs designed for professionals with work experience. A certificate program required five courses, which are selected according to individual needs. Applicants for certificate programs must hold bachelor's degrees. On completion of a sequence with an average grade of B or better,

students are issued certificates. Those who choose to work towards the master's degree are able to apply all courses taken toward a certificate, upon admission, toward fulfillment of a degree program. Additional information may be obtained from the department.

Management Certificate — This program is designed to foster professional and personal growth through intensive studies of the latest advances in management processes and the newest quantitative techniques, ranging from management information systems to decision models. Management certificates are offered in the following fields:

- Construction Management
- Human Resource Management
- Information Management
- Quality and Productivity Management
- Operations Management
- Technology Management

Organizational Behavior Certificate — This program involves intensive studies of the latest knowledge and techniques for dealing with human problems in organizations. Individualized programs make it highly appropriate for specialists as well as generalists to improve and update their knowledge and skills in areas ranging from individual motivation to organizational development.

UNDERGRADUATE COURSES

MG 202 Computers In Management 2:3:3

Introduction of basic computer hardware and software concepts. Survey of operating systems and programming languages. Heavy emphasis on personal computer applications and management-oriented application packages in word processing, database management, spreadsheets, communications, and business graphics. Also listed under LA 125.

MG 300 Management Process 3:0:3

Introductory management course for undergraduates. Primary focus is the management process: planning, organiz-

ing, staffing, controlling, directing and decision making. Attention is given to the roles of various disciplines within management as well as to the traditional business functions of marketing, accounting, finance, production, engineering, research and development.

MG 301 Organizational Behavior 3:0:3

Study of human behavior in organizational settings. Emphasis on motivation, informal and formal group dynamics; interpersonal relationships; supervision; leadership; communication theory; attitude and job satisfaction; work-stress; career development; creativity. Analyses of administration problems by case studies and simulated situations. Also listed under SS 299

MG 304 Accounting Fundamentals 3:0:3

Managerial approaches to problems of cost determination and analysis. Job order, process and standard cost systems. Analysis of indirect manufacturing expenses, preparation and analysis of balance sheets, income and manufacturing statements. Relations between accounting and engineering functions.

MG 305 Foundations of Business Systems 3:0:3

This course provides the student with a systems perspective on the specification, development, implementation, and maintenance of organizational information technology.

MG 306 Financial Management 3:0:3

This survey course in financial management is designed to provide the student with an understanding of various financial reports and instruments. Specifically, the student will become acquainted with the origins of the information appearing on balance sheets, income, and other statements. An appreciation will also be gained for the use of techniques — such as financial ratio analysis — for assessing the firm's overall productivity and health. Financial planning and analysis, and capital budgeting, will also be treated.

MG 326 Human Resource Information Systems 3:0:3

To provide each class participant with an understanding of: what an HRIS is; how and why HRIS's have evolved; how organizations acquire and implement HRIS's; how HRIS's are operated and enhanced; software used in the HR function; data issues, analysis and presentation; supporting HR end users; and HRIS issues and trends. *Prerequisite: Senior standing or permission of instructor.*

MG 336 M.I.S. Case Studies 3:0:3

Information systems (IS's) not only impact the end-user, but often warrant, to varying degrees, the restructuring of organizations. The readings, lectures, and case studies that make up this course are designed to provide the student with a variety of perspectives on the impact of information technology on organizations — including appraisals of IS technology's contributions to firm efficiency and effectiveness.

MG 400 and MG 402 Senior Internship I and II 3 credits each

To give students an opportunity to work in an industrial, business or governmental environment; one which will encourage them to apply the knowledge that they have acquired through the information management curriculum to the solution of related problems in the firm or agency. It also seeks to orient the student to the world of work, and provide a perspective on the duties, responsibilities and potential benefit of his or her intended profession. *Prerequisite: Senior status and completion of CP 101.*

MG 401 Senior Project 3 credits

Independent work integrating students' knowledge under faculty guidance. Students design systems required to manage information regarding specific management functions. *Prerequisite: senior standing in information management.*

GRADUATE COURSES

MG 502† Computers in Management 2½:0:3

Computer literacy for management problem-solving, information systems, computer technology, software and vocabulary. Advantages and disadvantages of alternatives ranging from large mainframes to time-sharing networking, batch processing, personal computers and programmable calculators. Survey of software, compilers, interpreters, assemblers and language important to managers. Examples and cases of decision-support systems and their operation in office automation, financial analysis and other business applications.

MG 503† Economic Environment of Management 2½:0:3

Central problems of economic society, supply and demand analyses, structures of industrial markets, factors of production, profits and incentives, national income accounting, income determination, business cycles, monetary and banking systems, governmental influences on the economy, international trade and finance.

MG 504† Managerial Accounting 2½:0:3

Aspects of accounting of practical use to the manager. Stress on understanding of financial statements rather than on book-keeping procedures. Internal management usage of accounting data: job orders, process and standard costing; relations among accounting, economic and financial perspectives.

MG 505† Statistical Analysis 2½:0:3

Fundamental statistical models and their uses in decision-making. Emphasis on alternative techniques, their assumptions and limitations. Topics include descriptive statistics; probability-concepts of probability, probability distributions both discrete and continuous; sampling methods, estimation, hypothesis testing, regression and correlation analysis; time series, chi-square testing.

MG 600 Management Process

2½:0:3

Establishment of conceptual perspectives of major schools of management thought, including scientific management, classical administrative theory, human relations, behavioral system theories.

MG 601 Organizational Behavior

2½:0:3

Integration of behavioral science theories, concepts, research and techniques for understanding of human behavior in organizations. Motivation and job satisfaction, personality and conflict, group dynamics, interpersonal relationships, supervision and leadership, communication, organization structure and design, impact of technology, career development.

MG 603 Organizational Behavior and Management Process in Innovative Corporations

2½:0:3

Introduction to issues and concepts in organizational and administrative behavior, with emphasis on continually changing organizations. Management processes for flexible and innovative organizations. The evolution of technology-intensive industries and business organizations. The role of technology in the growth of the modern firm. Human resource management and organization development in technology-intensive firms.

MG 606 Managerial Finance

2½:0:3

Analyses of principles and practices of finance function and its application in organizations. Survey of uses of financial instruments, sources and uses of short- and long-term funds available to business; capital budgeting under certainty and uncertainty; cost of capital and dividend policy; working capital management. *Prerequisite: MG 504 or equivalent.*

MG 607 Marketing

2½:0:3

Marketing concepts, processes and institutions: positioning, segmentation, product life cycles. Integration of marketing with new product planning, design and development. Strategies for technology based products, services, and processes.

Market research, consumer behavior, advertising, promotion and sales. The special character of industrial and governmental markets. International markets. *Co/Prerequisite: MG 503.*

MG 608 Managerial Economics and the Economic Environment

2½:0:3

Microeconomic analysis and the macroeconomic environment for managers. Economic basis for managerial decisions in production, investment and technology strategy. Economics of the firm, business cycles, economic growth, international trade, financial institutions, currency systems. The economics of innovation and entrepreneurial activity. The role of technology in economic growth and in international competition. *Prerequisite: MG 503.*

MG 609 Managerial Accounting and Finance

2½:0:3

Elements of accounting and finance of importance to managers of technology. Analysis of principles and practices of the finance function and its application in organization. Financing methods for internal and external ventures and innovations; capital budgeting; R&D portfolio analysis. Contrast of strategic managerial perspectives emphasizing innovation and development with those of accounting, economics, and finance emphasizing short-term return and investment. Cases using accounting and financial software packages.

MG 610 Quantitative Analysis for Managerial Decisions

2½:0:3

Application to the management of technology of quantitative and analytical techniques such as probability, statistical inference, correlation and regression, decision theory, forecasting, linear programming, and queuing models. Production/operations management techniques. Cases and problems selected from real world technology management experience including computer supported decision-making and simulation.

MG 611 Career Management

2½:0:3

An examination of careers from the perspectives of both management and

individuals. Specific issues include career stage models, organizational entry, career pathing, mid-career crisis, career change, continuing education and retraining, professional obsolescence, career re-entry, tokenism, job loss and underemployment. Career planning/development programs used by individuals and organizations will be evaluated. *Prerequisite: MG 601 or permission of instructor.*

MG 612 Human Resource Management

2½:0:3

Personnel functions are investigated from the perspectives of individual managers and the total organization. Topics include work force characteristics, recruitment and development, motivation, performance evaluation and rewards, effects of government policy on legislation and the changing labor force. *Prerequisite: MG 601 or permission of instructor.*

MG 613 Labor Relations

2½:0:3

Policies and philosophies of management, organized labor and government with regard to solution of labor problems. Evaluation of industrial relations problems, particularly those of collective bargaining, emphasizing interrelationships with social, economic and legal trends. *Co/Prerequisite: MG 600 or permission of instructor.*

MG 614 Collective Bargaining

2½:0:3

Analysis of nature of the collective bargaining process, its major issues and points of contention. Major trends examined with consideration given to broad economic and social implications. *Prerequisite: MG 613 or permission of instructor.*

MG 616 Job and Workplace Design

2½:0:3

An examination of the interaction among individual, job design and work environment characteristics. Topics include work analysis; task and workspace design; impact on communication; job satisfaction; motivation and productivity; implications of and responses to new technologies; skills obsolescence and retraining; job and work environment

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redesign; socio-technical design approaches; emerging role of artificial intelligence.

MG 617 Performance Measurement and Reward Systems 2½:0:3

An introduction to practical approaches in the establishment of a performance appraisal system that includes theoretical and applied issues. Reasons for implementing a performance appraisal system in organizations are addressed. Other topics include coaching, feedback, and performance evaluation. The role of compensation benefits and other rewards in attracting, retaining and motivating employees.

MG 618 Introducing New Methods of Work — Leading Change 2½:0:3

Successful introduction of new methods of work embodied in new production paradigms such as JIT/TQC etc., require management and workers to change long-established ways of working. This course provides students with insight into the impact of culture on new product development, and product realization. Leadership, education and training techniques appropriate to the new environment are studied. Also listed under MN 618.

MG 619 Employee Scheduling 2½:0:3

Study of employee scheduling, issues, problems and methods. Students develop, analyze and solve a variety of problems on days-off scheduling, work tours, integration of work week, scheduling part-time employees, rest periods and vacations using available software. Project work includes determining staffing requirements. Case examples from service and manufacturing industries. Also listed under IE 770.

MG 622 Personnel Psychology 2½:0:3

Examination of theory, research and practice concerning individual differences relating to organizational behavior with emphasis on the personnel selection process, measurement of predictors, criteria for validation and decision-making strategies. *Prerequisites:* MG 601 and MG 505 or permission of instructor.

MG 623 Training in Organizations 2½:0:3

The roles of training in organizations, focusing on department and line managers. Subjects addressed include needs analysis, preparation of employees for jobs, management development, training program design, evaluation and employee obsolescence. *Prerequisite:* MG 601 or permission of instructor.

MG 624 Organization Development 2½:0:3

Applied theory and research related to process of managing change in organizations. Practical application of group, intergroup and individual changes. Planned structural revisions in formal organizations. Dynamics of organizational change processes. Experimental techniques and seminar approaches emphasized. *Prerequisite:* MG 601.

MG 625 Seminar in Career Management 2½:0:3

Examination of the latest concepts, research and practices pertaining to professional and managerial careers in organizations. Emphasis is on current issues and problems in career management. Experts and resource materials are utilized in examining research findings as well as in studying career development and planning practices and programs which have been established in organizations. *Prerequisite:* MG 601 or permission of instructor.

MG 626 Human Resource Information Systems 2½:0:3

Design, selection, implementation, enhancement and operation of Human Resources Information systems (HRIS) in organizations. Organizational, legal and political issues as well as hardware, software, applications and communications in HRIS. The uses of time-sharing, personal and minicomputers and mainframes. Focus on design and use of HRIS to facilitate objectives of human resource functions, as well as to support entire organizations. Also listed under SS 678.

MG 627 Human Resources and Technological Change 2½:0:3

Examination of the impact of technological changes on human resources and their management. An overview of technological changes and their effects on the work force, focusing on changes in supply and demand as well as the obsolescence of knowledge and skills. Topics include utilization, human resources planning, job redesign, resistance to change, organizational change, continuing education and retraining, productivity and innovation, inter-organizational cooperation, roles of government, and international issues. *Co-requisite:* MG 601 or permission of the instructor. Also listed under SS 679.

MG 630 Operations Management 2½:0:3

Analytic techniques for designing and operating production and service systems, including facility layouts and locations, capacity planning, job sequencing, inventory control, and quality control. Introductory linear programming and other formal methods. Cases and managerial perspective.

MG 631 Organization Theory and Design 2½:0:3

Analysis of theories of large-scale organizations focusing on their structure and design. Includes characteristics of bureaucracy, adhocery, suboptimization, human dynamics and informal systems, influence and control systems, planned change. Examination of both formal and informal organizations through varieties of research and case studies. *Prerequisite:* MG 601 or permission of instructor.

MG 633 Research Methods 2½:0:3

An introduction to theories and techniques of research methods. Primary objectives are to provide understanding and appreciation of why and how organizational research is carried out. Survey of research methods. Research projects are designed and analyzed. *Prerequisite:* MG 505 or permission of instructor.

MG 634 Applied Research Methods 2½:0:3

Integration and application of advanced research techniques utilized in studies of organizations. Students develop and carry out individual applied research projects. *Prerequisite:* MG 633 or permission of instructor.

MG 635 Introduction to Total Quality Management 2½:0:3

Total Quality Management (TQM) proposes that organizations take a holistic approach to quality. The quality of a firm's products is a function of their adherence to advertised specifications, how the products are delivered and serviced by the firm, and the products' long-term performance vis-a-vis competitors' products, among other factors. TQM proponents claim that designing quality into products — rather than simply trying to "inspect" quality into them — and effectively organizing and motivating the workforce are the main factors contributing to low production costs, and ensuring a perception of high quality on the part of the consumer. The effectiveness of TQM is examined using articles and case studies.

MG 645 Productivity Management 2½:0:3

Modern approaches to productivity measurement, evaluation, planning and improvement in manufacturing and service industries. Participants develop productivity models for various types of organizations. *Prerequisite:* Graduate standing or permission of instructor. Also listed under IE 645.

MG 650 Management of the Information Function 2½:0:3

Structures of information processing, storage, transport and user services within organizations. Relations of distributed processing, distributed databases, and telecommunication network topology to organizational structures. Management of voice and data integration. Hardware and software evaluation and acquisition; benchmarking; information systems contracting; pricing of information services. Operation of information systems.

MG 654 Economics of Information systems 2½:0:3

Concepts of market supply and demand as they apply to markets for information services and products; rationales for, and nature of, emerging applications of information systems; availabilities and pricing of services; methods of economic decision making and justification of business information systems.

MG 664 Management and the Legal System 2½:0:3

Impacts of the legal system on corporate strategy, managerial decisions and planning processes. Issues covered include: protection of intellectual and technological properties; consumer, contract, commercial and secured financing laws; employer liability to, and for, employees; negligence and risk-management from legal and corporate viewpoints, and constitutional and regulatory aspects of conducting business on a multi-state basis. The legal system from the perspective of individual managers as agents, contract-makers, etc.

MG 671 Business and Economic Forecasting 2½:0:3

Forecasting for managerial decision and control. Statistical vs. judgmental methods. Smoothing and analyses of trends, seasonal factors, cycles and random variations. Econometric forecasting. Economic indicators and sources of information. Applications to the national economy, industry sales, corporate profits, financial institutions, government expenditures, etc. *Prerequisite:* IE 608 or equivalent.

MG 672 Technological Forecasting 2½:0:3

Introduction to problems of technological forecasting. Morphological analyses, extrapolation of trends, heuristic and intuitive forecast. Consideration of rational directing of technological changes. Students prepare forecasts on topics of choice. Also listed under SS 672.

MG 700 New Enterprise and Small Business Management 2½:0:3

Characteristics, opportunities, and hazards of new and small business firms

with special attention given to technology, engineering and manufacturing concerns. A variety of operating problems in different stages of a small company's life cycle are considered. Actual business cases involving opportunity-finding and decision-making are utilized for students to gain insights into their attitudes towards risk-taking and in developing their own action-taking skills. *Prerequisite:* Advanced Standing.

MG 705 Managerial Planning Processes 2½:0:3

Introduction to strategic management and to formal planning as methods for translating business goals into procedures or actions. Tactical planning at operating levels. Development of foresight and classical methods for gathering information essential to decision-making in large-scale organizations. *Prerequisites:* MG 600 and MG 601.

MG 716 Commercial Data-Processing Systems Design 2½:0:3

Functional relationships of information across the commercial environment and their relevance in the design of management information systems. Present and future roles of personal computers and terminals in information interchange. Necessary communication techniques and protocols to accomplish mainframes to personal computer connections. (Not open to students who have taken MG 316.) *Prerequisite:* MG 502.

MG 727 Case Studies in Management Science 2½:0:3

Application of scientific and analytic methods to solving management decision-making problems, drawn from current practice and literature. *Prerequisite:* permission of the instructor.

MG 736 Information Systems and Technology in Management 2½:0:3

Defining information needs for the management of the continually-innovating firm. Understanding information based service industries such as telecommunications and financial services. Technical aspects of data processing and telecommunications systems of importance to the manager. Management Information Systems for operations, control and

planning. Decision support systems, expert systems and AI. MIS requirements for production and office automation. Issues of hardware and software systems development, evaluation and acquisition. Problems of learning, training, privacy and security.

MG 737 Analysis and Design of Management-Information Systems 2½:0:3

Roles of information systems in management decision-making processes. Detailed development of management-information systems through planning, design and implementation, introduction to information theory, the value of information. The information system and changes in the organization, examples and applications. *Prerequisite:* MG 502.

MG 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 760 International Development: Management and Technology 2½:0:3

The course provides a framework for development issues of particular significance to students in engineering and management. Economics of science and technology, appraisal and management of development projects and programs, appropriate technology and mechanisms of technology transfer. Political criteria and the impact of technological decision on social and economic change in developing countries.

MG 800 Policy Analysis and Planning 2½:0:3

Systems analyses of policy choices in areas facing federal and regional governments. Cost-benefit methods and related analytical techniques. Analyses and planning in urban contexts. Future-oriented studies. Economic and technological projects. New technologies and their cultural and ecological implications.

MG 810 Project Planning and Control 2½:0:3

Network planning techniques for project management and resource allocation. Emphasis on PERT, LOB, CPM and probabilistic generalized networks. Heuristic models for multi-project scheduling and resource leveling. Network development, computer adaptation, progress reports and project monitoring. *Prerequisite:* knowledge of computer programming. Also listed under IE 620 and CE 828.

MG 820 Project Assessment & Management 2½:0:3

Managing technology-based projects ranging from individual research and development to large scale and complex technological systems. Feasibility and risk analyses. Project selection and portfolio optimization. Alternative financing methods. Functional and administrative structures, coordination and scheduling of activities, personnel planning, negotiations and contracts, computer-based techniques. cost estimation, capital budgeting, cost controls, effective matrix management. Also listed under CE 820.

MG 825 Construction Administration 2½:0:3

Management techniques of construction are discussed in relation to alternate means of project execution. Organizational structures, management systems, and controls are examined from the points of view of owners, the constructors, and the professional construction managers. Also listed under CE 825.

MG 826 Construction Estimates and Costs 2½:0:3

Techniques for estimating costs of capital projects and methods for effective cost control during project execution are taught with emphasis on principles of good management. Class project. Also listed under CE 826.

MG 827 Specifications and Contracts 2½:0:3

Principles of contract law applied to construction; legal problems in preparing and administering construction contracts.

Prerequisite: MG 825. Also listed under CE 827.

MG 830 Formulation and Analysis of Public Works Projects 2½:0:3

Methods for the identification, formulation, preliminary appraisal, and detailed analysis of individual projects and systems of civil engineering projects. Different approaches appropriate for government agencies, public utilities, industrial firms, and private entrepreneurs. Planning considers projects that satisfy single and multiple purposes and objectives, meet local and regional needs, and take advantage of opportunities for development. Financial and economic analyses, including sensitivity and risk analysis. Mathematical models for evaluation of alternatives and optimization. Impacts of projects: environmental, social, regional economic growth, legal and institutional, and public involvement. Also listed under CE 781.

MG 850 Cost Systems 2½:0:3

Methods used in industry for predicting and recording costs. Design and operation of standard and direct cost-accounting systems. *Prerequisite:* MG 504.

MG 860 Financial Planning, Internal Reporting and Operational Control 2½:0:3

The techniques of planning and control at various levels within the enterprise with emphasis on system analysis and quantifiable aspects of individual or corporate productivity. Applications in the public and private sectors. Budgeting, monitoring and evaluation of performance, "expense and investment centers," transfer pricing, relationship between control systems and organizational goals. *Prerequisites:* MG 504 and MG 606.

MG 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, manufactur

ing or marketing. Techniques appropriate to collecting, analyzing and reporting marketplace information to management are explored. *Prerequisites:* MG 605 and MG 607.

MG 864 Product Planning 2½:0:3

Systematic studies of processes followed by successful companies in creating commercially viable products from technology developed by or available to them. Steps involved up to market entry are reviewed sequentially: initial search; preliminary evaluation; organizing, etc. Financial aspects of product development. *Prerequisites:* MG 600 and MG 607.

MG 865 Managing the Innovative Process 2½:0:3

Managing research, development, and engineering; technical and support professionals; and technology transitions. Staffing, organizing, budgeting, planning, controlling, and evaluating R&D projects. Integrating R&D management with other functions, such as corporate strategy, new product development, marketing, production, and finance. Project selection and balancing the portfolio. Technology forecasting and applications assessment. Communication of technical information within the corporation; corporate acquisition of technical knowledge. *Prerequisite:* MG 600.

MG 866 Technology Management and Policy 2½:0:3

Topics and issues in private and public management; considerations of technology in strategic planning for high-technology corporations; government's roles in directing technology, defense, space, and energy. Managing large-scale technological enterprises. Science and technology in international relations.

MG 867 Technology Strategy 2½:0:3

Technology as a strategic variable. Entrepreneurial high-tech strategies: from start-up companies to large corporations. Introducing new technologies: timing and choice. Strategic alliances. The changing role of industrial R&D in technology strategy. Technology strategy for global markets. Japanese and

European comparisons; prospective effects of 1992 European Economic Community integration and changing Japanese policies towards R&D. Legislative, judicial and regulatory processes as they affect technology strategy. Legal aspects of multinational transactions, intellectual property and technology transfer.

MG 868 Strategic Management of Productivity 2½:0:3

Issues relating to U.S. productivity relative to that of its trading partners and competitors in international trade. Analyses of American management strategies. Current controversies and their theoretical and empirical foundations. Time horizons for research and development, for market forecasting and new product development, for financial controls and portfolio analyses, and for valuation of managerial performance. Efforts to define long-term, strategic roles for productivity in manufacturing and in providing services within the firm or to the market. Reassessment of the strategic function of the management of production. Cases and Readings. *Prerequisite:* Advanced standing.

MG 869 Manufacturing: Productivity, Technology and Management 2½:0:3

Manufacturing technology and organizational structure. Product development and process change. Managing the learning curve; conflicts between innovation and productivity. Manufacturing as an element of corporate strategy. Flexible manufacturing systems. Automation and information systems. CAD/CAM and computer integrated manufacturing systems. Quality control.

MG 870 Managerial Implications of Current Developments in Science and Technology 2½:0:3

Review and update of important fields of scientific research. A survey of specific technologies of current and emerging importance to managers. Assessments of the state of the art by experts from selected fields. Emphasis on analysis of opportunities for commercial applications and threats to existing products and processes. Development of ways of thinking systematically about applications

of new technologies of various kinds, including implications for new products and industries.

MG 871 Manufacturing Strategies 2½:0:3

Strategies, tools, processes and techniques for improving the profitability and competitiveness of modern manufacturing businesses. Emphasis is on developing the proper interrelationship between manufacturing processes systems and organization structure for a business to prosper through a process of ongoing improvement. Students will develop unique business strategies, including actions, changes in systems and structure to accomplish the chosen strategy. Also listed under MN 622.

MG 969 Operations Strategy 2½:0:3

Operations Strategy is an advanced topics case oriented course which relates the firm's business strategy to its long-term commitments in terms of the productive capacity of operations, inventory control, quality control, product and process design, and human resources development. This is unlike operations management courses, which usually focus on short-term decisions within these areas.

MG 970 Strategic Management 2½:0:3

Strategic thinking and practice from the general management perspective to strategic analytical methods, and to current concepts of strategy in technology-intensive corporations. The formulation and implementation of strategy and strategic planning in the organization. Strategic portfolios and other planning systems. The analysis of competition within and industry and of the elements of value that contribute to competitive advantage. Strategic issues for international business and multinational corporations. *Prerequisite:* advanced standing.

MG 975 Selected Topics in Management 2½:0:3

Current topics in various fields analyzed and discussed. *Prerequisites:* advanced standing and permission of instructor.

MG 976-977 Readings in Management *each 3 units*

Directed individual study of supervised readings in advanced areas of management. *Prerequisite: permission of dean.*

MG 985 Selected Topics in Organizational Behavior *2½:0:3*

Discussion and analysis of current topics in organizational behavior. *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, advisor and department director.*

FACULTY

Ernest Racz, Director of Management and Provost of the Long Island Center
B.A., Franklin & Marshall College;
M.Div. Lancaster Theological Seminary;
M.A. Ed.D., Teachers College,
Columbia University
Quality Management

A. George Schillinger, Professor of Management and Program Director, Management of Technology
B.E.E., City College of New York;
M.S., Eng. Sc.D., Columbia University
General management, technology management, corporate strategy

Anthony J. Wiener, Professor of Management
A.B., J.D., Harvard University
Corporate strategy, forecasting and planning, technology management, public policy

Nancy Needham, Industry Professor of Management, Associate Director of CATT
B.A., Wellesley College; M.B.A., D.B.A., Harvard University
International telecommunications and financial services

Seymour Kaplan, Associate Professor of Operations Research and Management Science
B.S., Newark College of Engineering;
M.S., Ph.D., New York University
Economic modeling, linear programming

Harold G. Kaufman, Associate Professor of Management and Program Director, Organizational Behavior
B.M.E., Cooper Union; M.I.E., Ph.D., New York University
Career management, science and engineering manpower obsolescence and continuing education

Byron David, Assistant Professor and Program Director, Operations Management
B.A., Queens College of City University of New York; M.S., Polytechnic Institute of New York; M.B.A. and Ph.D., Baruch College, City University of New York
Operations strategy, productivity management

Thomas Conoscenti, Academic Associate, Program Director, Farmingdale Campus
B.S., M.A., New York University
Economics, statistics, public policy

E. Hart Rasmussen, Program Director, Westchester Graduate Center; Adjunct Professor; Licensed Professional Engineer in New York and New Jersey;
M.S.(Chem.Eng.) Polytechnic University of Denmark
Project management, control systems

ADJUNCT FACULTY

Kathleen, MacDonald, Adjunct Professor
B.S., Columbia University; M.A., Columbia University Teachers College; MBA Golden Gate University; Ed.D. Columbia University Teachers College

Sylvester Marino, Adjunct Professor
B.S., Fordham University; MBA, St. John's University; Ed.M., Ed.D., Columbia University Teachers College

Stanley S. Willing, Adjunct Professor
B.A., M.A., Ed.D., New York University

Siegfried Altscher, Adjunct Associate Professor
B.A., Brooklyn College; M.S., Ph.D., Polytechnic Institute of New York

Steven Azzaro, Adjunct Associate Professor
B.S., Rutgers University; M.B.A., New York Institute of Technology

Richard Buda, Adjunct Associate Professor
B.A., Iona College; B.A., M.A., John Jay College of Criminal Justice; Ph.D., Stevens Institute of Technology

Michael Cortegiano, Adjunct Associate Professor
B.S., Fairfield University

Edward Greenbaum, Adjunct Associate Professor
B.S., Arnold College; M.A., New York University; M.S., Cornell University

Donald Harris, Adjunct Associate Professor
B.A., Ohio Wesleyan University; M.B.A., New York University; Ph.D., Columbia University

Stanley J. Jacoby, Adjunct Associate Professor
B.S., Polytechnic Institute of New York; M.S., Columbia University; M.M.S., Stevens Institute of Technology;
Professional Engineer

Joel Joseph, Adjunct Associate Professor
B.A., Yale University; J.D., Hofstra Law School

Mark Kurman, Adjunct Associate Professor
B.A., New York University; M.A., Ph.D., Bowling Green State University

Daniel E. Lupton, Adjunct Associate Professor
B.A., M.Ed., S.T.L., Loyola University; M.A., Indiana State University; M.B.A., Ph.D., University of Chicago

Patrick McNelis, Adjunct Associate Professor
B.E.E., Manhattan College; M.S.E.E., Polytechnic Institute of New York

Ary Mossiman, Adjunct Associate Professor
B.S., Pratt Institute; M.S., Long Island University; M.S.M., Polytechnic Institute of New York

William Raichle, Adjunct Associate Professor
B.S., St. Francis College; M.S., Shippensburg State University; Ph.D., New York University

Kevin Rooney, Adjunct Associate Professor

Robert Schiffer, Adjunct Associate Professor
B.S., M.B.A., Adelphi University

Mark B. Sokol, Adjunct Associate Professor
B.A., Queens College; M.A., Ph.D., University of Maryland, College Park

Arthur R. Szeglin, Adjunct Associate Professor
B.S., M.S., Polytechnic Institute of Brooklyn, M.A., Ph.D., Hofstra University

Kenneth Walden, Adjunct Associate Professor
B.S., City College of New York; M.S., New York Institute of Technology

Richard N. Walton, Adjunct Associate Professor
B.S., Columbia University; M.B.A., New York University

Peter M. Kash, Adjunct Assistant Professor
B.S., S.U.N.Y. at Binghamton; M.B.A., Pace University

David Krautheimer, Adjunct Assistant Professor
B.S.E., New York Institute of Technology; M.S., C.W. Post

Susan Meyer, Adjunct Assistant Professor
B.A., S.U.N.Y. Albany; M.A., New York University; Ed.D., Columbia University

Jeremy Graham, Adjunct Instructor
B.S., Hunter College; M.S., Ph.D. Candidate, Baruch College

Richard Peeler, Adjunct Instructor
B.S.; Loyola University

MANAGEMENT OF TECHNOLOGY

The Department of Management offers a Master of Science executive program in the Management of Technology.

Technology-intensive corporations need a capacity for rapid innovation in products, services, processes, and strategies, and this distinguishes them from traditional high volume mass production or service companies of previous decades. Polytechnic's new executive program in technology management is designed for a wide range of managers who need to acquire the knowledge and skills with which to compete in world markets that are increasingly technological, rapidly evolving and constantly changing. The primary goal of the program is to train managers in the new requirements of innovative organizations.

The program is well suited for engineers and scientists with increasing managerial responsibility in areas such as research, development, operations, computer science, and engineering. Most have already achieved some managerial responsibility, and have reached a point in their careers at which formal training in management has become important for future advancement.

The program, however, is not only aimed at practicing scientists and engineers. Professionals working in finance, banking, telecommunications, and other technological environments will also find the program of relevance and value. Business managers in functional areas such as marketing, sales, and finance who want to obtain a deeper understanding of how their technology-intensive companies work, in preparation for general management positions, would also find the Polytechnic program profitable.

The program is given in an *executive format*, that is, classes meet every other week for two full days, Friday and Saturday at Polytechnic's Westchester Center at Hawthorne, New York. Breakfast, lunch, and coffee breaks are provided. All classes are videotaped and the tapes are available for viewing on campus or at home.

An all-inclusive fee for this program covers tuition and fees, textbooks and other educational materials, special tutorials and lectures, meals on class days, and videotapes of all classes and lectures.

ADMISSION REQUIREMENTS AND APPLICATION INFORMATION

Admission to the program requires a baccalaureate degree from an accredited institution with a superior undergraduate record, a minimum of two years work experience in the field of management and company support.

Applications for admission are accepted throughout the year, but admission is for fall semesters only, as the program is completely specified for all students. Because enrollment is limited, early application is strongly recommended.

DEGREE REQUIREMENTS AND CURRICULUM

The general requirements for Master of Science degrees stated elsewhere in this catalog apply to this program. The curriculum consists of 12 course (36 units) which are taken by every student. There are no elective courses or units in this program.

The 12 courses which constitute the program curriculum are:

First Semester

- MG 603 *Organizational Behavior and Management Process in Innovative Corporations*
- MG 609 *Managerial Accounting and Finance*
- MG 865 *Managing the Innovative Process*

Second Semester

- MG 610 *Quantitative Analysis for Managerial Decisions*
- MG 736 *Information Systems and Technology in Management*
- MG 867 *Technology Strategy*

Third Semester

- MG 869 *Manufacturing: Productivity, Technology and Management*
- MG 607 *Marketing*
- MG 608 *Managerial Economics and the Economic Environment*

Fourth Semester

- MG 820 *Project Assessment and Management*
- MG 870 *Managerial Implications of Current Developments in Science and Technology*
- MG 970 *Strategic Management*

COURSE DESCRIPTIONS

The following courses are unique to this program. For other course descriptions, refer to the "Management" section of this catalog.

MG 603 Organizational Behavior and Management Process in Innovative Corporations

Introduction to issues and concepts in organizational and administrative behavior, with emphasis on continually changing organizations. Management processes for flexible and innovative organizations. The evolution of technology-intensive industries and business organizations. The role of technology in the growth of the modern firm. Human resource management and organization development in technology-intensive firms.

MG 609 Managerial Accounting and Finance

Elements of accounting and finance of importance to managers of technology. Analysis of principles and practices of the finance function and its application in organization. Financing methods for internal and external ventures and innovations; capital budgeting; R&D portfolio analysis. Contrast of strategic managerial perspectives emphasizing innovation and development with those of accounting, economics, and finance emphasizing short-term return and investment. Cases using accounting and financial software packages.

MG 865 Managing the Innovative Process

Managing research, development, and engineering; technical and support professionals; and technology transitions. Staffing, organizing, budgeting, planning, controlling and evaluating R&D projects. Integrating R&D management with other functions, such as corporate strategy, new product development, marketing, production, and finance. Project selection and balancing the portfolio. Technology forecasting and applications assessment. Communication of technical information within the corporation; corporate acquisition of technical knowledge.

MG 610 Quantitative Analysis for Managerial Decisions

Application to the management of technology of quantitative and analytical techniques such as probability, statistical inference, correlation and regression,

decision theory, forecasting, linear programming, and queuing models. Production/operations management techniques. Cases and problems selected from real world technology management experience including computer supported decision-making and simulation.

MG 869 Manufacturing: Productivity, Technology and Management

Manufacturing technology and organizational structure. Product development and process change. Managing the learning curve; conflicts between innovation and productivity. Manufacturing as an element of corporate strategy. Flexible manufacturing systems. Automation and information systems. CAD/CAM and computer integrated manufacturing systems. Quality control.

MG 870 Managerial Implications of Current Developments in Science and Technology

Review and update of important fields of scientific research. A survey of specific technologies of current and emerging importance to managers. Assessments of the state of the art by experts from selected fields. Emphasis on analysis of opportunities for commercial applications and threats to existing products and processes. Development of ways of thinking systematically about applications of new technologies of various kinds, including implications for new products and industries.

FACULTY

A. George Schillinger, Professor of Management
Director, Management of Technology Program
B.E.E., City College of New York;
M.S., Eng.Sc.D., Columbia University

Anthony J. Wiener, Professor of Management
Associate Director, Management of Technology Program
A.B., J.D., Harvard University

Seymour Kaplan, Associate Professor of Operations Research and Management Science
B.S., Newark College of Engineering;
M.S., Ph.D., New York University

Byron David, Assistant Professor of Management
Program Director, Operations Management
B.A., Queens College of CUNY;
M.S., Polytechnic Institute of New York; M.B.A., Ph.D., Baruch College

ADJUNCT FACULTY

Bernard Abramson, Adjunct Professor of Management
B.S., Cambridge University;
M.S., London University

E. Hart Rasmussen, Adjunct Professor of Management
Director, Management Programs, Westchester Graduate Center
B.S., M.S., Technical University of Denmark

Lowell W. Steele, Adjunct Professor of Management of Technology
B.A., Dartmouth; M.B.A., Harvard University; Ph.D., Massachusetts Institute of Technology

Joseph Schlosser, Adjunct Professor of Management
B.A., Notre Dame; M.Ed., University of Massachusetts; Ph.D., Wharton School

Duncan D. Sutphen, Adjunct Professor of Management
B.A., Princeton University

OPERATIONS MANAGEMENT

The master's degree program in operations management addresses the productivity needs of manufacturing and service operations. It is a unique 36 unit curriculum that requires the student to view the productivity of the organization from financial, engineering, and production perspectives. The MSOM graduate is equipped with a working knowledge of methods that can enhance his or her decision-making effectiveness in the areas of project planning, resource allocation, inventory management, work-force management, and quality control.

In addition to their prevalence in manufacturing industries, operations managers are found in health care organizations, financial institutions, insurance companies, mass transit systems, hotels, distribution outlets, etc. — often with the title of "vice-president of operations".

This interdisciplinary program is administered by the Department of Management, and is built on Polytechnic's recognized strengths in management, as well as in manufacturing and industrial engineering.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE

The MSOM curriculum is designed to provide the student with an appreciation for the disciplines that are most pertinent to service and manufacturing operations. The "preliminary courses" are intended for those students who need to enhance their preparation for this master's program. The applicant is expected to have adequate preparation in statistics, accounting, computer usage, and English composition. The "core

courses" cover a broad scope of disciplines that are essentially industry neutral, while the "major electives" provide the student with the opportunity to study a selection of subjects in some depth, some of them industry specific. Each grouping of major electives has a distinct orientation, as indicated below. Additionally, there is a required case oriented "advanced topics course" which relates the firm's business strategy to such long-term operations commitments as inventory policy, productive capacity, quality control policy, etc; and, is intended to provide the student with some insights on the top operating officer's contributions to strategic planning.

To be eligible for admission into this program, applicants must hold a baccalaureate degree or its equivalent from an accredited institution. This degree may be in any area except industrial engineering.

A. Preliminary Courses (0 units towards the degree)

May be waived on the basis of the student's professional experience and/or previous college coursework; otherwise, these courses, or their equivalents, must be taken in addition to the 36 units required for the MSOM.

MG 502	<i>Computers in Management</i>
MG 504	<i>Managerial Accounting</i>
MA 551	<i>Applied Statistics (Data Analysis)</i>
HU 522	<i>Seminar in Written English</i>
	<i>or</i>
HU 605	<i>Report Writing</i>

B. Core Courses (21 units)*

MG 608	<i>Managerial Economics and the Economic Environment</i>
MG 600	<i>Management Process</i>
	<i>or</i>
MG 601	<i>Organizational Behavior</i>
IE 611	<i>Statistical Quality Control</i>
MG 616	<i>Job and Workplace Design</i>
MG 630	<i>Operations Management</i>
MG 645	<i>Productivity Management</i>
MG 810	<i>Project Planning and Control</i>

C. Major Electives (12 units)

A total of four courses must be chosen, with not more than two from each group.

- * If any of these courses are waived due to previous coursework, then graduate transfer credits and/or substitute graduate courses taken at the Polytechnic can, with the written approval of the MSOM Program Director, be used to fulfill the unit requirements.

Quality Management

IE 612	<i>Advanced Quality Control</i>
MG 635	<i>Introduction to Total Quality Management</i>

Manufacturing

IE 776	<i>Manufacturing Resource Planning</i>
IE 777	<i>Manufacturing Improvement Curves</i>
IE 785	<i>Computer Integrated Manufacturing Systems</i>

Human Resources

- MG 612 *Human Resource Management*
 MG 623 *Training in Organizations*
 or
 MG 611 *Career Management*
 MG 627 *Human Resources &
 Technological Change*

Work Design

- MG 618 *Introducing New Methods of
 Work*
 IE 775 *Industrial Safety Engineering*
 SS 926 *Environmental Psychology*

Management Information Systems

- MG 626 *Human Resource Information
 Systems*
 MG 650 *Management of the Information
 Function*
 MG 737 *Analysis & Design of
 Management Information
 Systems*

- D. Advanced Topics Course (3 units) —
 this is a required course which must
 be taken during the student's last
 year of studies.

- MG 969 *Operations Strategy*

The total number of units required
 for the MSOM degree is 36. Each
 course in the program is 3 units and
 meets for 2½ hours per week.

FACULTY

This interdisciplinary program is
 administered by the Management Depart-
 ment. The faculties of manufacturing
 engineering, industrial engineering,
 computer science, social sciences and
 mathematics participate in delivering this
 program.

TELECOMMUNICATIONS AND COMPUTING MANAGEMENT

The Department of Management of the Polytechnic University, supported by the school of Electrical Engineering and Computer Science in conjunction with the Center for Advanced Technology in Telecommunications (CATT) offers a master of science program in telecommunications and computing management.

This program was started in 1984 with the express purpose of providing education for executives faced with new challenges and opportunities in the rapidly developing areas of telecommunications and computing. The Master of Science in Telecommunications and Computing Management is a rigorous two-year, four-semester program consisting of 12 courses and an independent research project.

The curriculum was developed by CATT and senior faculty in conjunction with a private sector advisory board.

Current functions are to:

- (i) monitor the effectiveness of the program,
- (ii) help keep the detailed course syllabi current, and
- (iii) propose changes in the program in light of experience.

The philosophy of the program is to provide a solid foundation in telecommunications and computing technology and management in the initial semesters of the program, followed in the final year by coursework integrating technology and management skills. Case studies, practical exercises, and research investigations are used throughout the program.

Students are experienced working professionals in telecommunications and computing. About half the students are employed by providers of telecommunications and computing services, and the other half by users of these services.

The program is given in an *executive format*, that is, classes meet every other week for two full days, Friday and Saturday at Polytechnic's Westchester Center at Hawthorne, New York. Breakfast, lunch, and coffee breaks are provided. All classes are videotaped with tapes made available for viewing on campus or at home.

An all-inclusive fee covers tuition and fees, textbooks and other educational material, special tutorials and lectures, meals on class days, and access to videotapes of all classes and lectures.

ADMISSION REQUIREMENTS AND APPLICATION INFORMATION

Admission to the program requires a baccalaureate degree from an accredited institution with a superior undergraduate academic record, a minimum of two years work experience in the field of telecommunications and/or computing, and employer support.

Applications for admission are accepted throughout the year, but admission is for fall semesters only. Because enrollment is limited, early application is strongly recommended.

DEGREE REQUIREMENTS AND CURRICULUM

The general requirements for Master of Science degrees stated elsewhere in this catalog apply to this program. The curriculum consists of 12 courses (36 units) which are taken by every student, plus an independent research project which must be completed during the second year of the program. There are no elective courses in this program.

The 12 courses which constitute the program curriculum are:

FALL FIRST SEMESTER

ML 535	<i>Elements of Communication Networks</i>
MG 600	<i>Management Process</i>
MG 609	<i>Managerial Accounting and Finance</i>

SPRING SECOND SEMESTER

EL 635	<i>Principles of Communications Networks</i>
MG 652	<i>Telecommunications Regulation, Policy, and Law</i>
MG 820	<i>Project Management</i>

FALL THIRD SEMESTER

EL 735	<i>Communications Networks</i>
MG 607	<i>Marketing Management</i>
MG 654	<i>Economics of Information Systems</i>

SPRING FOURTH SEMESTER

CS 682	<i>Network Management and Security</i>
MG 650	<i>Management of Information Systems</i>
MG 970	<i>Business Policy and Strategy</i>

COURSE DESCRIPTIONS

The courses described below are unique to this program and cannot be applied to any other degree program. For other course descriptions, refer to the appropriate other sections of this catalog (Management, Electrical Engineering, Computer Science).

MG 609 Managerial Accounting and Finance *3 units*

Aspects of accounting and finance of practical use to the manager. Relations among accounting, economic, and financial perspectives. Analysis of principles and practices of the finance function, and its application in organizations.

MG 652 Telecommunications Regulation, Policy, and Law *3 units*

The relationships between the development of the telecommunications industry, national growth, and the development of telecommunications policy issues and policy making organizations. Analysis of the major issues which have impacted the telecommunications industry and commerce and society generally. The options and opportunities afforded by recent regulatory and policy issues.

MG 965 Independent Research Project *3 units*

During the second year each student completes an independent, applied research project on a topic of practical importance to his/her employer. The purpose of the project is to give students an opportunity to apply and integrate the subjects taught in the program by working directly with a faculty member.

FACULTY

Ivan T. Frisch, Professor of Electrical Engineering and Computer Science
Director, Center for Advanced Technology in Telecommunications
B.S. (Physics), Queens College; B.S., M.S., Ph.D. (Electrical Engineering), Columbia University
Computer communications, network control, information systems.

A. George Schillinger, Professor of Management
B.E.E., City College of New York; M.S., Eng., Ph.D., Columbia University
General management, technology management, corporate strategy.

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B.S., Stanford University; Ph.D., University of California at Berkeley
Computer communications, telecommunications.

Byron David, Assistant Professor of Management;
B.A., Queens College of CUNY; M.S., Polytechnic Institute of New York; M.B.A., Ph.D., Baruch College, CUNY
Operations management.

Nancy J. Needham, Industry Professor of Management
Academic Director, Telecommunications and Computing Management program
B.A., Wellesley College;
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International telecommunications and financial services.

ADJUNCT FACULTY

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Kenneth Gross, Adjunct Professor of Management;
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Aaron Kershenbaum, Adjunct Professor of Computer Science
B.S., M.S., Polytechnic Institute of Brooklyn; Ph.D., Polytechnic Institute of New York

E.Hart Rasmussen, Adjunct Professor of Management
Director, Management Programs, Westchester Graduate Center
B.S., M.S., Technical University of Denmark

M. Kimberly Rupert, Adjunct Professor of Management
B.S., Massachusetts Institute of Technology; M.A., Georgetown University; Ph.D., Yale University

R.Joseph Schlosser, Adjunct Professor of Management
B.A., Notre Dame; M.Ed., University of Massachusetts; Ph.D., Wharton School

Andrew Snow, Adjunct Professor of Electrical Engineering
B.S., M.S., Old Dominion University

CONTEMPORARY LIBERAL ARTS CORE CURRICULUM

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

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

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

The liberal arts have traditionally been associated with education for liberty or freedom.

In a world permeated by modern science and technology, individuals who fail to understand the basic character of scientific and technological thought and action are unable to exercise full human freedom.

Recognizing the need for education integrating science, technology and society (STS) studies, Polytechnic University has developed a unique program. This program constitutes a new vision of the liberal arts.

At the heart of this program is the Contemporary Liberal Arts Core Curriculum. Developed through a grant from the Andrew W. Mellon Foundation, the curriculum consists of a sequence of 48 semester credit hours. The sequence opens with a general presentation of the science-technology-society interaction and then moves on to three different sets of courses:

1. Basic introductions to mathematics, computers, and the physical, biological, and behavioral sciences.
2. Interdisciplinary courses in ethics and technology and STS interactions in the areas of materials, machines, energy, and information.
3. A senior seminar and thesis.

Besides this sequence, the Core Curriculum assumes the general University requirements of six credit of writing and the humanities, and three credits of contemporary world history.

This core curriculum is based on the idea that a well-educated liberal arts graduate should be able to understand creativity from the fine arts to technology and be able to appreciate the poetics of artificial as well as natural languages.

Students majoring in other disciplines are able to take the following courses from this curriculum to satisfy humanities and social science elective requirements:

LA 110	<i>Technology and Society in Historical Perspective</i>
LA 132	<i>Introduction to Behavioral Science</i>
LA 139	<i>Engineering Ethics</i>
LA 140	<i>Ethics and Technology</i>
LA 141	<i>Materials and Social Issues</i>
LA 142	<i>The Cultures of Machines</i>
LA 143	<i>Computers, Cultures, and Society</i>
LA 144	<i>Energy Technology and Social Issues</i>
LA 150	<i>The Making of Connections</i>

Typical Course of Study for The Bachelor of Science Degree in Humanities, Specialized Journalism, or Social Sciences

FRESHMAN YEAR

No.	Subject	Credits
HU 101	<i>Writing & Humanities I</i>	3
HU 200*	<i>Writing & Humanities II</i>	3
SS 104*	<i>Main Themes in Contemporary World History</i>	3
LA 121	<i>Principles of Mathematics II</i>	4
LA 130	<i>Introduction to Physical</i>	4
LA 110	<i>Technology and Society in Science historical Perspective</i>	3
CS or EL**		6
LA 120	<i>Principles of Mathematics I</i>	4
LA 125	<i>Introduction to Computers</i>	3
SL 101	<i>Freshman Seminar</i>	0
	<i>Total Credits</i>	16
	<i>Total Credits</i>	17

SOPHOMORE YEAR

No.	Subject	Credits
LA 132	<i>Introduction to Behavioral</i>	4
LA 131	<i>Introduction to Biological Science</i>	4
CS or EL**		12
LA 140	<i>Ethics and Technology</i>	3
CS or EL**		9
	<i>Total Credits</i>	16
	<i>Total Credits</i>	16

JUNIOR YEAR

LA 141	<i>Materials and Social Issues</i>	3
LA 143	<i>Computers, Cultures, and</i>	3
LA 142	<i>The Cultures of Machines Society</i>	3
CS or EL**		9
LA 144	<i>Energy Technology and Issues</i>	3
CS or EL**		9
	<i>Total Credits</i>	15
	<i>Total Credits</i>	15

SENIOR YEAR

LA 150	<i>The Making of Connections</i>	3
LA 160	<i>Senior Thesis</i>	4
CS or EL**		12
CS or EL**		12
	<i>Total Credits</i>	15
	<i>Total Credits</i>	16

SUMMARY OF REQUIREMENTS

Institute Requirements:

(HU 101, HU 200**, SS 04**)	9
Liberal Arts core	48
Concentrated studies	33-42

Electives:

Humanities	6
Social Sciences	6
Free electives***	15-24
<i>Total credits for graduation</i>	126

* Students may elect to take IS 140 (Language and Communication) and IS 141 (The Self and Society) in place of HU 200 and SS 104.

** CS = concentrated studies in the major; EL = electives.

*** Students may elect a minor in a discipline other than their major. A minor may be in such fields as Information Management (12 credits), Computer Science (12 credits) or Life Sciences (14 credits).

UNDERGRADUATE COURSES

LA 110 Technology and Society in Historical Perspective 3:0:3

An examination of the role of secular and religious ideas in shaping technology, and the subsequent impact of technology on events and values. Psychological profiles of inventors and innovators. Invention, innovation, and diffusion of technology. The impact of the assembly line, telecommunications, computers, plastics, television and rockets. Emerging trends: miniaturization, robotics, biotechnology and space industrialization.

LA 120-121 Principles of Mathematics I & II each 4:0:4

An introduction to the principles of finite mathematics and calculus. Focus is on the mathematical concepts of the number system, units, integration, probability, statistics, derivatives, and matrices.

LA 125 Introduction to Computers 2:3:3

Introduction to the basic principles of computer and information processing for non-technical students. Survey of operating systems and programming languages. Heavy emphasis on personal computer applications for the liberal arts: application packages in word processing, database management, spreadsheets, communications, and graphics.

LA 130 Introduction to Physical Science 4:0:4

This course is designed to convey the excitement of the human experience called "physical science," and its connections with the issues that concern all men and women--the impact of science on technology and civilization, culture, and world views. Topics include: space-time, motion and force, work and energy,

states of matter, the microscopic and macroscopic approach in the science of chemistry. Experiments are conducted at the discretion of the instructor.

LA 131 Introduction to Biological Science 3:3:4

An investigation of the origin of life and the characteristics of living things. Studies include an examination of evolution and its mechanisms which have resulted in the ecological diversity of the biosphere; Considers the effects of technology on ecology. Laboratory experiments and field trips are used to further elucidate these concepts.

LA 132 Introduction to Behavioral Science 3:3:4

An examination of psychological concepts and methodologies central to understanding behavior. Topics: sensation and perception, acquisition and maintenance of behavior, social behavior, abnormal behavior. Students conduct experiments in signal detection, verbal learning, and social conditioning of judgments.

LA 139 Engineering Ethics 2:0:2

An introduction to professional engineering ethics presented through the history of engineering, codes of conduct of the professional societies, contemporary case studies, and discussion of hypothetical situations. No essential duplication of HU 347 or IE 302, *Prerequisites:* HU 200 or IS 140; completion of at least 40 credits.

LA 140 Ethics and Technology 3:0:3

An examination of some basic ethical theories of human action and how these relate to technological making and using. Use is made of case studies representing various ethical problems as well as some classic ethical texts. Includes issues of professional engineering ethics. *Prerequisite for engineering majors:* HU 341, HU 348, HU 349, LA 110, LA 139, or LA 143.

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LA 141 Materials and Social Issues 3:0:3

An examination of the origins, properties, and uses of metals, polymers, and other materials. New frontiers in the development of materials. The impact of materials on contemporary society. Laboratory demonstrations throughout the course. *Prerequisite for engineering majors: HU 341, HU 348, HU 349, LA 110, LA 139, or LA 143.*

LA 142 The Cultures of Machines 3:0:3

An examination of machines in both their technical and human aspects. An analysis of work and power and the use of machinery to duplicate and extend human dexterity and skill. Discussion of the human aspects includes the relation between machines and different social orders and humanization vs. dehumanization by machines. *Prerequisite for engineering majors: HU 341, HU 348, HU 349, LA 110, LA 139, or LA 143.*

LA 143 Computers, Cultures, and Society 3:0:3

Explores the nature of information, communications, and their associated systems and technologies; introduction to information theory and information processing; cultural, economic, and political implications of the communications-computer revolutions.

LA 144 Energy Technology and Social Issues 3:0:3

An integrated study of energy technologies and resources, their contemporary problems and future prospects. Review of basic physical principles; history of energy resources and technologies; contemporary energy technologies, with the social and ethical problems they pose; alternative technologies and social prospects for the future. *Prerequisite for engineering majors: HU 341, HU 348, HU 349, LA 110, LA 139, or LA 143.*

LA 150 The Making of Connections 3:0:3

An interdisciplinary seminar devoted to examining basic issues introduced by previous courses: questions concerning the relationships between machines and human nature, freedom and the individual in a technological society, science-technology and the imagination, social justice and technological limits. Explores probable futures and alternative social policies in light of rapid scientific and technological change. For each offering, the specific focus of this seminar is determined by the instructor. *Prerequisite for engineering majors: HU 341, HU 348, HU 349, LA 110, LA 139, or LA 143.*

LA 160 Senior Thesis 4:0:4

An individual research project culminating in a substantial paper. Subject to be chosen by student in consultation with a thesis advisor.

FACULTY

Michael Alfano, Visiting Assistant Professor of Philosophy

William Blesser, Professor and Director of Bioengineering

Edward Cassidy, Professor of Electrical Engineering

Carmine D'Antonio, Professor of Metallurgy

Duane DeVries, Head of Humanities & Communications and Associate Professor of English

Frederick Eirich, Distinguished Professor of Polymer Chemistry

Ernest M. Loebl, Professor of Physical Chemistry

Shirley Motzkin, Professor of Biology

Jane Robinett, Assistant Professor of Humanities and Communications

Kurt Salzinger, Professor of Psychology

Romualdas Sviedrys, Associate Professor of History of Technology

Nancy Tooney, Associate Professor of Biochemistry and Associate Dean of Arts and Sciences

HUMANITIES AND COMMUNICATIONS

The Department of Humanities and Communications offers undergraduate degree programs in journalism and technical writing and in the humanities. The department also offers a unique program in specialized journalism leading to an M.S. degree. The graduate and undergraduate programs exploit the advantages and strengths of a technological university and thus are particularly beneficial to students who combine strong interests in the humanities or journalism and technical writing with interests in science and technology.

In a world of narrowly focused specialists, human progress depends upon those who can synthesize knowledge and communicate it with real understanding. Such persons are not locked into rigid academic disciplines and patterns of thinking; they are as intellectually comfortable in the sciences as in the arts and humanities. While such persons are rare, they are in demand in virtually every profession and can expect to fill vital roles in fields which are only now being explored. These programs give men and women in the humanities and in communications integrated educations.

The department also plays an essential role in the education of students who are majors in other departments. Today's engineers and scientists must know the humanities in order to make well-reasoned decisions involving human values implicit in technological options, to understand the ways human beings see themselves and the natural and social worlds, and to communicate effectively.

As freshmen, all students admitted to Polytechnic University are placed at appropriate levels in the freshman English sequence. On the basis of an English composition placement test evaluated by the department, most students are placed in one of the standard freshman courses (HU 101 or HU 103); some may be exempted and placed in HU 200, the second required course of the sequence; others may first be required to take one

or more semesters of an introductory course in English (HU 008 or HU 009) with a reduced course load (a maximum of 14 credits).

After completing HU 101 (or HU 103) and HU 200¹, non-majors are encouraged to complete a sequence of courses in one or more of the disciplines within the department—literature, art and music, philosophy and religion, or modern languages. Courses in public speaking and technical writing are especially practical for students preparing for careers in engineering or science. All students should check the special requirements of their departments. Engineering and computer science majors should read carefully the requirements governing their selection of humanities and social sciences courses. These requirements will be found in the Degree Requirements section at the front of this catalog and under the individual department's course listings. Up-to-date information about such requirements is also available from departmental advisors.

UNDERGRADUATE PROGRAMS

The Department of Humanities and Communications offers Bachelor of Science degrees in Journalism and Technical Writing and Bachelor of Science degrees in Humanities.

REQUIREMENTS FOR THE B.S. DEGREE IN JOURNALISM AND TECHNICAL WRITING

Our graduates have successful careers in journalism, science writing and technical writing. Science and technical writers in particular—those with the skills of journalists combined with strong interests in science and technology—continue to be in great demand. In these

occupations, professional status and salaries are virtually on a par with those of engineers. Majors in journalism and technical writing arrange programs of studies in consultation with departmental advisors. Generally they also fulfill the requirements of the contemporary liberal arts core curriculum outlined in the preceding section of this catalog. A maximum of nine credits in graduate courses in Specialized Journalism may be taken to satisfy the undergraduate degree requirements. These courses are usually taken no earlier than the second half of the junior year.

Core Curriculum:

	Credits
<i>Humanities (HU 101 and HU 200)²</i>	6
<i>Social Sciences (SS 104)¹</i>	3
<i>Mathematics & Computers (LA 120, 121, 125)</i>	11
<i>Science (LA 130, 131, 132)</i>	12

Interdisciplinary courses:

<i>(LA 110, 140, 141, 142, 143, 144, 150, 160)</i>	25
<i>Journalism and Technical Writing Courses</i>	33

Electives:

<i>Humanities electives</i>	6
<i>Social Sciences electives</i>	6
<i>Free electives</i>	24
<i>Total credits required for graduation</i>	126

REQUIREMENTS FOR THE B.S. DEGREE IN THE HUMANITIES

For students wishing to pursue a degree in the humanities, the department offers specializations in literature, philosophy, and general humanistic studies (a multidisciplinary major in the humanities). Here, too, students work out a

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program of studies in consultation with a departmental advisor. Generally they also fulfill the requirements of the contemporary liberal arts core curriculum outlined in the preceding section of this catalog. Students who wish to obtain certification for teaching in public schools in the New York City area should plan to take the necessary education courses at another institution. Credit will be given for these education courses as free electives in meeting degree requirements.

Core Curriculum:

	Credits
<i>Humanities (HU 101 and HU 200)¹</i>	6
<i>Social Sciences (SS 104)¹</i>	3
<i>Mathematics & Computers</i>	
<i>(LA 120, 121, 125)</i>	11
<i>Science (LA 130, 131, 132)</i>	12

Interdisciplinary courses:

<i>(LA 110, 40, 141, 142, 143, 144, 150, 160)</i>	25

<i>Humanities Courses</i>	39
<i>Electives</i>	
<i>Social Sciences electives</i>	6

<i>Free Electives</i>	24
<i>Total credits required for graduation</i>	126

OTHER UNDERGRADUATE DEPARTMENTAL PROGRAMS

Dual undergraduate degrees -- A few students elect to pursue dual undergraduate degrees--one in journalism and technical writing and another in engineering, science or mathematics. Besides completing all requirements for degrees in engineering (136 credits), science (128 credits), or mathematics (128 credits), students must complete an additional 33 credits of communications courses in the Department of Humanities and Communications, for a total of 161 or 169 credits. These courses must be approved by a departmental advisor. Other combinations are possible, such as dual degrees in the humanities and either social sciences or management.

Interdisciplinary Studies--The purpose of the interdisciplinary studies program, sponsored by the Department of Humanities and Communications and the Department of Social Sciences, is to enhance the humanistic elements of

education. The program promotes courses, seminars and special lectures demonstrating the fruitfulness of interdisciplinary approaches to human knowledge. IS 140-141 is a year-long, unified humanities/social sciences sequence intended for freshman students. This sequence may be taken in place of the HU 200/SS 104 requirement for undergraduates. IS 145 and IS 146 may be taken as advanced humanities/social science electives.

Core Curriculum--A contemporary liberal arts core curriculum, representing a new vision of liberal education, is required for students in Bachelor of Science degree programs in the departments of Social Sciences and the Humanities and Communications. For a full description, see the previous section of this catalog. If students transfer from another major, science and engineering courses already taken may be substituted for some of the courses in the core curriculum.

MASTER OF SCIENCE DEGREE IN SPECIALIZED JOURNALISM

The Department of Humanities and Communications offers a master of science degree in specialized journalism. To be eligible for admission to this program, applicants must hold a baccalaureate degree or its equivalent from an acceptable institution of higher learning. The department admits students holding undergraduate degrees in the humanities, journalism, engineering, the sciences and the social sciences.

Applicants are expected to have an excellent command of English and should have taken as undergraduates at least one semester of college-level mathematics and one year of college-level science (to be met by any combination of courses in biology, chemistry, physics, geology, geography, engineering and history of science). Applicants lacking any of these courses may be matriculated on a provisional basis--as long as they meet all other requirements for admission--but are required to take undergraduate courses to fulfill the basic requirements for admission. No graduate cred-

its are given for such undergraduate courses taken to meet deficiencies.

In general, applicants should have a minimum undergraduate grade point average of 3.0 from an accredited college or university. However, candidates with lower grade-point averages may be considered if they have demonstrated success in some area of professional writing. Others with lower grade-point averages may be admitted provisionally or as non-degree students. Applicants are not required to take the Graduate Record Examination.

FIELDS OF SPECIALIZATION

Business-Magazine Journalism

Trade-magazine journalism entails writing and editing news and feature articles for technical and marketing-oriented publications serving particular industries. Such publications may be owned by independent publishing companies, professional societies or large corporations.

Financial Reporting

Financial and business reporting calls for professional journalists who can write about business and finance for knowledgeable business professionals and market analysts as well as the general public. Writers should have a solid background in economics and a clear understanding of business and financial concepts and terminology (including the workings of the various exchanges) in order to report and interpret developments accurately and comprehensibly. Clear, crisp, concise writing is a necessity.

Industrial Advertising and Public Relations

Industrial advertising and public relations work is concerned with the promotion of corporate products to industrial clients rather than to the general public. Industrial advertising involves copywriting, choosing graphics, selecting media, organizing ad campaigns and performing market research. Those in this profession work as copywriters, account executives, advertising managers and media directors.

Industrial public relations work has the same overall goals as industrial advertising—to promote a positive corporate image to industrial clients. Public relations workers issue news releases of new products and technological advances to the trade and business press serving their clients' industries, hold press conferences to announce new products and technology developed by client companies, prepare feature articles on company products for publication in business magazines and technical journals, write speeches for engineering and management personnel and prepare literature (product brochures, annual reports, house organs and other technical and semi-technical material) for distribution to corporate customers.

Medical and Science Reporting

Medical and science writers or editors work on magazines serving physicians, nurses and other technical and scientific personnel; on the news staffs of print and broadcast media; on public relations staffs of pharmaceutical houses and hospitals, medical schools and research centers; in the writing departments of corporations; and in editing departments of textbook publishers. In addition to writing clearly and succinctly, writers and editors must have sound backgrounds in the sciences.

Technical Writing

Technical writers—also called publications engineers and engineering writers—gather, organize, write and edit technical and scientific materials for management and technical personnel within their own companies as well as for customers and prospective customers. Such information takes a variety of forms: proposals to the federal government and to other corporations for primary and sub-contract work, progress reports on government-sponsored programs, manuals for use by customer-service and maintenance personnel, corporate-capability brochures and technical and scientific news releases. Technical writers may also be called upon to write speeches and business-magazine articles for scientists and engineers.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE

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

	Units
JW 600 <i>Introduction to Specialized Journalism</i>	3
JW 601 <i>Style for the Professional Writer</i>	3
JW 602 <i>Proposal Writing</i>	3
JW 603 <i>Reporting on Science, Technology and Medicine</i>	3
JW 604 <i>Graphics and Production Techniques</i>	3
JW 607 <i>Writing News for Radio and Television</i>	3

The remaining 18 units are taken in elective courses. Generally, students select electives from among the remaining graduate courses offered in the department. Students who wish to enhance their scientific and technical knowledge or who are interested in management or social sciences courses may take a maximum of nine credits of graduate courses in other departments of Polytechnic University. Approval for this option must be given by the head of the department.

Elective courses are usually conducted as workshops, providing students with the kinds of writing and editing assignments they receive when actually working in the field.

While students select their individual programs in consultation with an advisor, the department strongly recommends that they select most of their electives in one of the five specializations below.

Business-Magazine Journalism

	Units
JW 511 <i>Technical Writing about Digital Electronics</i>	4
JW 608 <i>Introduction to Documentation</i>	3
JW 609 <i>Computer Documentation</i>	3
JW 620 <i>Financial and Business Reporting</i>	3
JW 621 <i>Reporting and Editing for the Business Press</i>	3
JW 622 <i>Writing Copy for Industrial Public Relations</i>	3
JW 624 <i>Writing Product-Information Copy</i>	3
JW 641 <i>Graphics Workshop</i>	3
JW 701 <i>Special Project in Professional Writing</i>	3

Financial Reporting

JW 608 <i>Introduction to Documentation</i>	3
JW 609 <i>Computer Documentation</i>	3
JW 620 <i>Financial and Business Reporting</i>	3
JW 621 <i>Reporting and Editing for the Business Press</i>	3
JW 622 <i>Writing Copy for Industrial Public Relations</i>	3
JW 623 <i>Publications Management and Budgeting</i>	3
JW 641 <i>Graphics Workshop</i>	3
JW 701 <i>Special Project in Professional Writing</i>	3

Industrial Advertising and Public Relations

JW 608 <i>Introduction to Documentation</i>	3
JW 609 <i>Computer Documentation</i>	3
JW 621 <i>Reporting and Editing for the Business Press</i>	3
JW 622 <i>Writing Copy for Industrial Public Relations</i>	3
JW 624 <i>Writing Product-Information Copy</i>	3
JW 628 <i>Writing Industrial Advertising Copy</i>	3
JW 629 <i>Writing the Marketing Report</i>	3
JW 641 <i>Graphics Workshop</i>	3
JW 710 <i>Special Project in Professional Writing</i>	3

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Medical and Science Reporting

JW 603	<i>Reporting on Science, Technology and Medicine</i>	3
JW 608	<i>Introduction to Documentation</i>	3
JW 609	<i>Computer Documentation</i>	3
JW 621	<i>Reporting and Editing for the Business Press</i>	3
JW 625	<i>Advanced Medical Reporting</i>	3
JW 626	<i>Medical Public Relations</i>	3
JW 627	<i>Writing Copy on Pharmaceuticals and Drugs</i>	3
JW 641	<i>Graphics Workshop</i>	3
JW 701	<i>Special Project in Professional Writing</i>	3

Technical Writing

JW 511	<i>Technical Writing about Digital Electronics</i>	4
JW 603	<i>Reporting on Science, Technology and Medicine</i>	3
JW 608	<i>Introduction to Documentation</i>	3
JW 609	<i>Computer Documentation</i>	3
JW 622	<i>Writing Copy for Industrial Public Relations</i>	3
JW 624	<i>Writing Product-Information Copy</i>	3
JW 630	<i>Basic Technical Report Writing I</i>	3
JW 631	<i>Basic Technical Report Writing II</i>	3
JW 632	<i>Writing Technical Manuals</i>	3
JW 641	<i>Graphics Workshop</i>	3
JW 701	<i>Special Project in Professional Writing</i>	3

GRADUATE CERTIFICATE PROGRAMS IN FIELDS OF SPECIALIZATION

Certificates in specialized journalism are available to students completing five courses with grades of B or higher. Courses must be taken in a prescribed sequence arranged with an advisor. Students enrolled in the certificate program must meet the same rigorous standards of performance required of those working for M.S. degrees. At any time during enrollment, or following the awarding of the certificate, students in this program may transfer into the master's degree program if their performance has been satisfactory and they meet the standards for admission set by the department. Transfer into the master's program, however, may not mean automatic acceptance of all courses which students have taken while working toward certificates. Acceptance of cred-

its depends upon the area of specialization in which students plan to work for degrees.

ENGLISH AND HUMANISTIC STUDIES AND MODERN LANGUAGES

Advanced courses and seminars in the humanities may be offered from time to time for graduate students in the sciences, engineering, specialized journalism, management, and the social sciences.

UNDERGRADUATE COURSES

HU 008R Reading and Writing in English as a Second Language 6:0:0

English as a second language at the high-intermediate level. Development of grammatical control in writing and improved comprehension of college-level texts. Practice in listening and speaking; intensive preparation in language skills for academic and professional purposes. Graduate students may register with permission of department. Admission by placement examination.

HU 009 Introductory Composition 6:0:0

Intensive course in reading comprehension and composition skills for native speakers of English who have not been adequately prepared for college composition. Emphasis on development of control over standard written English and fluency in writing. Admission by placement examination.

HU 101 Writing and the Humanities I 3:0:3

Introduction to the humanities and to effective techniques of college-level writing. Examination of basic concepts, forms and techniques of philosophy, art and literature, with emphases on fluency, precision and imaginative use of source materials in writing. Admission by placement examination.

HU 103 Writing and the Humanities I (English as a Second Language) 6:0:3

Introduction to the humanities and to effective techniques of college-level writing, designed for students for whom English is a second language. Examination of basic concepts, forms and techniques of philosophy, art and literature, with emphases on fluency, grammar, syntax, precision and imaginative use of source materials in writing. Admission by placement examination.

HU 200 Writing and the Humanities II 3:0:3

Introduction to the humanities and to advanced techniques in writing. Thematic emphasis on change and continuity in the humanities and an exploration of the interrelationship of the humanistic disciplines through study of great works of art, philosophy, literature and, in some sections, music. Advanced work in stylistic options and more complex forms of writing: the longer critical study, the formal report, the research paper. In some cases, this course may be presented as an introduction to literature, covering poetry, short stories, and novels. *Prerequisite: HU 101 or HU 103 or advanced placement. IS 140-141 (see Interdisciplinary Studies, below) may be substituted for the HU 200/SS 104 requirement.*

JOURNALISM AND TECHNICAL WRITING, COMMUNICATIONS

HU 105 Advanced Composition 3:0:3

Lucid expository writing. Gathering and organization of factual material into larger units of composition. Methods of research and uses of library. Topics based on models of expository prose. Long paper. *Prerequisite: HU 101 or HU 103.*

HU 106 Writing for Publication: The Magazine Article 3:0:3

Development of students' interviewing and writing skills to produce medium-to-long-length magazine articles. With instructor's help, students develop story ideas on technical or non-technical subjects, complete the necessary library

research and personal interviews and write pieces for specific publications. Students are encouraged to publish their work, although this is not a specific course requirement. Students also examine editorial practices of various popular, business and technical magazines and learn how successful magazine articles are put together. *Prerequisite: HU 101 or HU 103.*

HU 108 News Writing 3:0:3

Workshop to guide students in all basic news writing techniques. Writing of leads. Style and structure of news stories. Methods of news gathering. Writing of different types of news stories—meeting, speech, interview, human interest, interpretation. *Prerequisite: HU 101 or HU 103.*

HU 109 Feature Writing 3:0:3

Theory and practice of writing short or moderate-length magazine articles on general subjects. Principles and practices of writing in readable style. Guidance in selecting interesting topics, in market study, in slanting, in dramatizing, in outlining and writing minimum of three articles. *Prerequisite: HU 101 or HU 103.*

HU 110 Basic Report Writing I 3:0:3

Fundamentals of report writing applied to short, informal papers written by scientists and engineers in actual business situations; technical correspondence, memoranda, trip reports, periodic reports and new-product information sheets. Summaries, process and technical descriptions, instructions, analyses. Effective style, organization of material and mechanics. Students learn to coordinate tables, graphs, and other illustrative matter with textual matter. *Prerequisite: HU 200.*

HU 111 Basic Report Writing II 3:0:3

Writing the longer technical forms commonly used in industry. Technical proposals, sections of manuals, letter reports, formal reports, technical sales literature, and semi-technical and technical articles for trade journals. *Prerequisite: HU 110.*

HU 112 Advance Copyediting Techniques 3:0:3

Improvement of students' editorial skills through intensive practice in writing headlines, decks and subheads for both general and industrial publications and through assignments in editing, revising and rewriting copy intended for a variety of publications. Writing leads and reorganizing garbled copy. Newspaper and magazine page layout and makeup. *Prerequisite: HU 101 or HU 103.*

HU 113 Writing for Advertising and Public Relations 3:0:3

Writing effective advertising copy and publicity releases with emphasis on the industrial side. Students write product ads, brochure copy, product data sheets, news releases, short articles for trade journals, copy for house organs and speeches. Preparation and implementation of a typical advertising campaign and arrangements for press conferences. Layout of ad copy and accompanying color, design, typographic and illustrative features. *Prerequisite: HU 101 or HU 103.*

HU 115 Reporting and Writing about Science and Technology 3:0:3

How to interview scientists and engineers and how to present the information obtained in formats understandable to the layperson. Students write both news and feature stories—and are encouraged to publish their best pieces. *Prerequisite: HU 101 or HU 103.*

HU 116 Introduction to Computer Documentation 3:0:3

Computer systems and software documentation. The history of computer documentation, the role of documentation specialists, basic concepts and techniques, types of manuals, planning and management documentation. *Prerequisite: one technical writing course and basic familiarity with computers. This course cannot be used to satisfy the HU/SS elective requirements. Prerequisite: HU 101 or HU 103.*

HU 119 Public Speaking 1½:1½:2

Training and practice in speaking before groups, preparation of materials for oral

presentations, discussion and interviewing techniques, extemporaneous speaking. Not open to students who were required to take HU 008. Students who take HU 120 or HU 121 may not take HU 119. *Prerequisite: Placement in HU 009, HU 101, HU 103, or HU 200 as a result of the English Composition Placement Examination.*

HU 120 Public Speaking and Pronunciation 1½:1½:2

Training and practice in speaking before groups, preparation of materials for oral presentations, discussion and interviewing techniques, extemporaneous speaking, pronunciation and speaking of English. This course is only for intermediate English as a Second Language students who are required to take HU 008 as a result of the English Composition Placement. Students who take HU 119 or HU 121 may not take HU 120. *Corequisite or prerequisite: HU 008.*

HU 121 Public Speaking 3:0:3

Training and practice in speaking before groups, preparation of materials for oral presentations, discussion and interviewing techniques, extemporaneous speaking. Not open to students who were required to take HU 008. Students who take HU 119 or HU 120 may not take HU 121. *Prerequisite: Placement in HU 009, HU 101, HU 103, or HU 200 as a result of the English Composition Placement Examination.*

HU 125 Reporting and Writing for the Wire Services 3:0:3

Reporting, writing and editing the news under the pressure of tight deadlines (often the same day). Many assignments require field research as this course attempts to simulate a wire-service reporter's daily experiences. Trips to AP and UPI headquarters are arranged. Reporting accuracy, thoroughness and good journalistic style stressed. Wire-service history and editorial practices covered. *Prerequisite: HU 101 or HU 103.*

HU 130 Creative Writing I 3:0:3

The art and craft of writing poetry, fiction and drama. Students experiment with all genres. Students' own work

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stressed. Weekly written assignments discussed and criticized. *Prerequisite:* HU 101 or HU 103.

HU 131 Creative Writing II 3:0:3

Advanced art and craft of writing poetry, fiction and drama. Application of individual talents to specific forms. Development of intelligent critical responses to all forms of literature. Weekly written assignments, plus one longer writing project: a story, play or small collection of poems. *Prerequisite:* HU 130 or permission of instructor.

HU 135 Introduction to Corporate Communications 3:0:3

Intensive study, through a review of case histories and writing assignments requiring field research, of all aspects of editorial work in the communications department of a medium-sized or large corporation. Students research, write and edit copy for press releases, newsletters, proposals, house organs, community-relations campaigns, brochures and annual reports. Business correspondence, short nontechnical memos and reports, formats for minutes of meetings and job descriptions. *Prerequisite:* HU 101 or HU 103.

HU 141 Graphics and Productions Techniques 3:0:3

Graphic design and production techniques and procedures for technical writers and editors. Magazine layout and production of technical reports, manuals and proposals. Composition methods, copy preparation and processing, page makeup, mechanics, printing processes, magazine imposition. Workshop atmosphere. *Prerequisite:* HU 101 or HU 103.

HU 150-151 Special Projects in Communications each 3:0:3

Independent work in an area of communications selected by student in consultation with instructor. For majors only. *Prerequisite:* HU 101 or HU 103.

HU 155 Special Topics in Journalism 3:0:3

Courses on special topics in journalism are offered from time to time by depart-

ment staff or by visiting scholars. Specific titles and prerequisites are announced prior to registration. May be repeated for credit. *Prerequisite:* HU 101 or HU 103.

HU 160 Writing the News for TV and Radio 3:0:3

The special formats required for writing news for TV and radio. Rewriting of newspaper articles and wire copy in styles necessary for these formats. Practice in broadcasting news and writing newscasts under pressure. *Prerequisites:* HU 108 or permission of instructor.

HU 161 Writing and Producing Documentaries for Broadcast 3:0:3

Working in teams, students research, write and narrate documentary radio and television broadcasts on pressing social, economic, political, scientific and technological issues, with emphasis on local topics. Production as well as journalistic side of broadcasting. Study of classic models at the Museum of Broadcasting. *Prerequisite:* HU 101 or HU 103.

LITERATURE

(See also *Literature in Translation and Interdisciplinary Studies*, below)

HU 203 Literature of Western Civilization III 3:0:3

Intellectual and cultural, moral and spiritual values of the modern world in novels, drama, philosophy, poetry. Literature of the Romantic revolt, Goethe, Dostoevski, Brecht, Sartre, Solzhenitsyn, American and European poetry. *Prerequisite:* HU 200 or IS 140-141.

HU 211 English Literature from Beowulf to 1800 3:0:3

English literature from Beowulf through Chaucer, the Elizabethans and the Jacobean to 1800. *Prerequisite:* HU 200 or IS 140-141.

HU 212 English Literature from 1800 to Present 3:0:3

English literature from the Romantics to the present (Wordsworth, Byron, Dick-

ens, Tennyson, Shaw, Conrad, Beckett and others). *Prerequisite:* HU 200 or IS 140-141.

HU 213 Science and Literature 3:0:3

With emphasis on the modern period, examination of the literary merits of scientific and imaginative literature devoted to and affected by science. Readings in such authors as Charles Darwin, T.H. Huxley, Bertolt Brecht, Sinclair Lewis, Arthur Koestler, Heinar Kipphart, James Watson, Kurt Vonnegut and Isaac Asimov. *Prerequisite:* HU 200 or IS 140-141.

HU 222 Shakespeare 3:0:3

Representative tragedies, comedies, histories. Cultural, social and literary influences. Textual problems, recent criticism, Elizabethan theater. *Prerequisite:* HU 200 or IS 140-141.

HU 251 American Literature to 1880 3:0:3

The puritan and neoclassic periods through the romantic movement and the rise of realism. Jonathan Edwards, Paine, Irving, Poe, Hawthorne, Emerson, Thoreau, Whitman, Twain, James and others. *Prerequisite:* HU 200 or IS 140-141.

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. *Prerequisite:* HU 200 or IS 140-141.

HU 262 Contemporary American Novel 3:0:3

The contemporary American novel as affirmative expression of the human situation. Technical and philosophical analyses of such writers as Golding, Salinger, Updike, Roth, Vonnegut, Clarke, Bellow and others. *Prerequisite:* HU 200 or IS 140-141.

HU 264 The Short Story 3:0:3

Themes, structure, techniques of short stories by writers as diverse in style and

philosophy as Chekhov, Twain, O. Henry, Mansfield, Lardner, Faulkner, Thurber and Hemingway. *Prerequisite:* HU 200 or IS 140-141.

HU 281 Comedy 3:0:3

Nature and uses of humor as viewed by playwrights, psychologists, philosophers. Theories of comedy from Aristotle to Freud. Plays from Aristophanes and Moliere to Giraudoux and Shaw. Humor from Tarleton to Chaplin and Benchley. *Prerequisite:* HU 200 or IS 140-141.

HU 283 Modern American Drama 3:0:3

Technical and philosophical analyses of O'Neill, Miller, Anderson, Hellman, Williams, Inge, Albee and others. Some contemporary American films may be included. *Prerequisite:* HU 200 or IS 140-141.

HU 291 Short Fiction 3:0:3

Major writers of the novella (long short story). Study of the relationship between literature and ideas in such writers as Saul Bellow, Albert Camus, Joseph Conrad, Ernest Hemingway, Franz Kafka, Thomas Mann, Alexander Solzhenitsyn, Nathanael West. Class discussions, cinematic presentations of some works and theater visits are integral to course. *Prerequisite:* HU 200 or IS 140-141.

PHILOSOPHY AND COMPARATIVE RELIGION

HU 341 Introduction to Philosophy 3:0:3

An initial inquiry into problems, methods and terminology of Western philosophy through study and discussions of selected philosophical texts. *Prerequisite:* HU 200 or IS 140-141.

HU 344 Introduction to Logic 3:0:3

Principles and problems in syllogistic and propositional logic. Introduction to first order predicate logic. Some discussion of the history of logic, informal fallacies and relations between logic and language. *Prerequisite:* HU 200 or IS 140-141. *Prerequisite for engineering*

and computer science majors only: HU 341, HU 348, HU 349 or LA 139.

HU 346 Ethical Theories 3:0:3

A study of one or more major ethical theories. The nature of human action, distinctions between good and bad, virtue, sources of obligation, freedom of action, human valuation and conscience. *Prerequisite:* HU 200 or IS 140-141. *Prerequisite for engineering and computer science majors only:* HU 341, HU 348, HU 349 or LA 139.

HU 347 Ethics and Technology 3:0:3

An examination of some basic ethical theories of human action and how these relate to technological making and using. Use will be made of case studies of various ethical problems as well as some classic ethical texts. *Prerequisite:* HU 200 or IS 140-141. *Prerequisite for engineering and computer science majors only:* HU 341, HU 348, HU 349 or LA 139. *Crosslisted with LA 140.*

HU 348 Great Philosophers I 3:0:3

Selected works of such philosophers as Plato, Aristotle, the Stoics, neo-Platonists, St. Augustine, Maimonides, St. Thomas Aquinas. *Prerequisite:* HU 200 or IS 140-141.

HU 349 Great Philosophers II 3:0:3

Philosophy from the Renaissance to the 19th century, emphasizing the rationalist tradition (Descartes, Spinoza, Leibniz), the empiricist tradition (Bacon, Locke, Hume) and Kant. *Prerequisite:* HU 200 or IS 140-141. *If preceded by HU 348, this is considered an advanced philosophy course for engineering and computer science majors.*

HU 352 Philosophy of Science 3:0:3

Central problems in theories of science and scientific methodology. Relation between science and philosophy; scope and objectives of natural sciences, role of mathematics in science; observation and experimentation; laws, theories, explanations; causality and induction. *Prerequisite:* HU 200 or IS 140-141. *Prerequisite for engineering and computer science majors only:* HU 341, HU 348, HU 349 or LA 139.

HU 353 Philosophy of Technology 3:0:3

The nature and meaning of human making and using activities, examined by means of a critical reading of various conceptual, anthropological, ethical-political and metaphysical-epistemological studies. *Prerequisite:* HU 200 or IS 140-141. *Prerequisite for engineering and computer science majors only:* HU 341, HU 348, HU 349 or LA 139.

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. The changes in the social roles of music. *Prerequisite:* HU 200 or IS 140-141.

HU 375 Modern Music 3:0:3

Music from 1850 to present: Wagner, Strauss, Mahler, Debussy, Stravinsky, Ives, Schoenberg, Berg, Weber, Varese. Revolt against romanticism; breakdown of traditional tonal-harmonic system. Polyharmony, polytonality, pantonality, melodic fragmentation, aleatory and electronic music as expressions of the 20th century. Jazz, modern popular music and music of other cultures. *Prerequisite:* HU 200 or IS 140-141. *Prerequisite for engineering and computer science majors only:* HU 371.

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. *Prerequisite:* HU 200 or IS 140-141.

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, decora-

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tive and tectonic forms to express contemporary civilization. *Prerequisite:* HU 200 or IS 140-141. If preceded by HU 382, this is considered an advanced art course for engineering and computer science majors.

SPECIAL TOPICS

The following special topics courses are offered from time to time by the staff of the department or by visiting scholars. Specific titles and prerequisites are announced before registration. May be repeated for credit.

HU 300 Special Topics in Humanities 3:0:3

Prerequisite: HU 200 or IS 140-141. *Prerequisite for engineering and computer science majors only:* depending on the nature of the course, HU 200 or IS 140-141; HU 341, HU 348, HU 349, or LA 139; or HU 371, HU 382 or HU 383.

HU 301 Special Topics in Literature 3:0:3

Prerequisite: HU 200 or IS 140-141.

HU 302 Special Topics in Philosophy 3:0:3

Prerequisite: HU 200 or IS 140-141. *Prerequisite for engineering and computer science majors only:* HU 341, HU 348, HU 349, or LA 139.

HU 303 Special Topics in Music and Fine Arts 3:0:3

Prerequisite: HU 200 or IS 140-141. *Prerequisite for engineering and computer science majors only:* HU 371, HU 382 or HU 383.

MODERN LANGUAGES

Note: Students must begin a language sequence at the level of their proficiency. Normally students who have had two years of a language in high school would begin with the third semester of a language in college. If in doubt about the level of proficiency, a student should consult the appropriate instructor in the department.

GERMAN

ML 111 German I: Foundation Course 3:0:3

For students with no previous training in German. Development of proficiency in reading, comprehension, speaking. Early practice in reading original German prose and representative poems.

ML 112 German II 3:0:3

Continuation of foundation provided by ML 111. Reading of original German prose; selections from Hesse, Kastner, Zweig and others. *Prerequisite:* ML 111 or equivalent.

ML 113 German III: Readings in German Literature Since 1800 3:0:3

Reading and discussion of prose, lyric poetry and drama to acquaint students with outstanding writers, ideas, movements in German literature. May be taken by students who have had secondary school training in German. *Prerequisite:* ML 112 or equivalent.

ML 114 German IV 3:0:3

Continued reading of significant German writing with critical and aesthetic evaluation. Also selected reading in philosophical and scientific subjects. Practice in conversation. *Prerequisite:* ML 113 or equivalent.

ML 215 Goethe's Faust, Part I* 3:0:3

Background and genesis of Goethe's drama. Reading and discussion of Part I, examining its aesthetic, moral, ethical values. *Prerequisite:* ML 114 or equivalent.

ML 216 Goethe's Faust, Part II* 3:0:3

Reading and discussion of Part II, examining its modern cultural implication. Consideration of Goethe's contribution to science. *Prerequisite:* ML 215.

FRENCH

ML 131 French I: Foundation Course 3:0:3

For students with no previous training in French. Development of proficiency in reading, comprehension, speaking. Early practice in reading original French prose and representative poems.

ML 132 French II 3:0:3

Continuation of foundation provided by ML 131. Reading of modern French prose and poetry. *Prerequisite:* ML 131 or equivalent.

ML 133 French III: Readings in French Literature Since 1800 3:0:3

Reading and discussion of prose, lyric poetry, drama to acquaint students with outstanding writers, ideas, movements in French literature. May be taken by students who have had secondary school training in French. *Prerequisite:* ML 132 or equivalent.

ML 134 French IV 3:0:3

Continuation of ML 133. Reading of cultural, philosophical, scientific subjects. Practice in conversational French. *Prerequisite:* ML 133 or equivalent.

SPANISH

ML 161 Spanish I: Foundation Course 3:0:3

For students with no previous training in Spanish. Development of proficiency in reading, comprehension, speaking. Early practice in reading original Spanish prose and representative poems.

ML 162 Spanish II 3:0:3

Continuation of foundation provided by ML 161. Reading of modern Spanish prose and poetry. *Prerequisite:* ML 161 or equivalent.

ML 163 Spanish III: Readings in Spanish Literature Since 1800 3:0:3

Reading and discussion of prose, lyric poetry, drama to acquaint students with outstanding writers, ideas, movements in Spanish literature. May be taken by

students who have had secondary school training in Spanish. *Prerequisite: ML 162 or equivalent.*

ML 164 Spanish IV 3:0:3

Continuation of ML 163. Reading of cultural and philosophical subjects. Practice in conversational Spanish. *Prerequisite: ML 163 or equivalent.*

INTERDISCIPLINARY STUDIES

IS 140 Language and Communication 3:0:3

Types of language and modes of communication, including animal (bee, chimpanzee) and human communication, language development in children and the "languages" of music, art, literature and engineering (the Brooklyn Bridge). Readings, films, group projects and reports, museum visits, expository and creative writing. IS 140 and IS 141 may be substituted for the SS 104 and HU 200 requirement.

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 140 and IS 141 may be substituted for the SS 104 and HU 200 requirement.

GRADUATE COURSES

SPECIALIZED JOURNALISM

JW 511† Technical Writing about Digital Electronics 3½:0:3

Designed for students with no background in electronics, this course provides the fundamentals required for writing about digital electronics.

Throughout the course emphasis is placed upon recognizing standard circuits, developing timing diagrams and writing functional descriptions. A three-tier approach is used in the written functional descriptions: high-level block diagram, intermediate block diagram, and detailed circuit analysis.

JW 600 Introduction to Specialized Journalism 2½:0:3

A course designed to familiarize the student with the career opportunities available and the writing requirements demanded in these major fields of specialization: financial and business journalism, industrial and trade magazine journalism, medical journalism, industrial public relations and advertising, scientific and engineering writing. Students will be required to research and write articles in each of these areas.

JW 601 Style for the Professional Writer 2½:0:3

Designed to strengthen the student's command of usage, style, grammar, punctuation, precision, logical structure and color through intensive copyediting practice.

JW 602 Proposal Writing 2½:0:3

Solicited and unsolicited proposals in both the government and private sectors are covered, as are the different types of proposals. Topics include writing and editing, ability to work as a team member and to cope under heavy pressure, knowledge of graphics and production and procedures in proposal writing. Emphasis on the elements of a typical proposal, such as statement of the problem, technical discussion, how the team will organize to perform the task, fiscal information, technical competency of the company to perform the task and key personnel. The student will be required to prepare an outline and then to write a proposal on a specific topic worked out with the instructor as the major course assignment.

JW 603 Reporting on Science, Technology and Medicine 2½:0:3

Emphasis on spot-news reporting and the Sunday-supplement feature aimed at a general newspaper audience. The longer

interpretive pieces done for this course will 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 writer's responsibilities to sources and readers are also considered.

JW 607 Writing News for Radio and Television 2½:0:3

This course is designed to train students to write news for the electronic media. The focus will be on science and business news stories. The course will entail intensive practice in writing for radio and television, and will teach students accepted format and style of media news writing. The course will also acquaint students with the requirements and limitations of the media and how these must be taken into account in news writing. Students will use video and audio technology in the course.

JW 608 Introduction to Documentation 2½:0:3

An introduction to the field of technical documentation in general and to computer documentation in particular. Includes

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a brief history of documentation and management needs in the documentation area, particularly techniques, production and core studies.

JW 609 Computer Documentation 2½:0:3

An overview and introduction to computer systems and software documentation. Topics include the history of computer documentation, market trends in the field, role of the documentation specialist, basic concepts and techniques, types of manuals, planing and management documentation. *Prerequisite: one technical writing course and MG 602: Computers in Management.*

JW 620 Financial and Business Reporting 2½:0:3

For students who intend to go into financial and business reporting or financial public relations, this course will be conducted as a workshop. Students will cover the business and financial scene as if they were reporting for a business periodical or the financial section of a newspaper. Hard business news reporting and interpretive pieces will be stressed in such areas as economic trends, marketing, corporate activities, the stock market, government regulations, industrial technology, labor-management relations, energy, industry and the environment and advertising. Course will familiarize the student with the corporate annual report, the investment company's research report, stock analysis reports, the financial press release. Financial and business publication 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 relation 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 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 relation officials and research scientists.

JW 627 Writing Copy on Pharmaceuticals and Drugs 2½:0:3

Course is geared to preparing students for expanding opportunities in writing copy for pharmaceutical and drug companies. Intensive practice in writing new-product data sheets, bulletins and other technical literature generally used by "detail men"; research reports, progress reports and other technical papers based on information supplied by the instructor and gathered on trips to local pharmaceutical companies; technical speeches; advertising and public relations copy. A major paper will be assigned as a term project.

JW 628 Writing Industrial Advertising Copy 2½:0:3

Covers the objectives of industrial and technical advertising and how to achieve them through the three basic ingredients of the magazine ad: copy, artwork and layout. Emphasis is on the principles of writing effective copy and heads, the process of media selection for a given ad (product promotion, institutional), the preparation of an ad campaign, how to set up booths for industrial displays and exhibits, conducting the direct-mail campaign, the value and preparation of sales literature and an analysis of business-publication advertising today. The roles of the company advertising manager and the agency's account executive and their interrelationship are delineated. Completion of a special project and several ad-writing assignments will be required.

JW 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 let-

ters, 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 632 Writing Technical Manuals
2½:0:3

Intensive practice in preparing industrial and military technical instructions 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 trouble-shooting charts) are emphasized in practical writing situations. Assembling of a parts list is covered. The writing of military training manuals is also included.

JW 641 Graphics Workshop 2½:0:3

A workshop devoted to the actual production of technical graphics--charts, graphs, newsletters, etc. *Prerequisite:* JW 604 or equivalent.

JW 701 Special Project in Professional Writing 2½:0:3

Students, working in conjunction with a faculty member, will pursue a course of independent study dealing with a special facet of professional writing. They will be expected to gather the bulk of their information firsthand, that is, from personal contact with their sources, in addition to conducting the usual literature search. The end result of this project will be an original, thought-provoking interpretive report to be submitted to the department for faculty review and approval.

JW 702 Special Topics in Journalism 2½:0:3

This special topics course will be offered from time to time by faculty members, visiting scholars and professionals. The special titles and prerequisites will be announced prior to registration. May be repeated for credit.

THE FOLLOWING COURSES ARE OFFERED IRREGULARLY IN RESPONSE TO STUDENT DEMAND:

Journalism and Technical Writing, Communications:

- HU 114 Libel Law and Ethical Issues in Journalism
- HU 136 Writing Annual Reports
- HU 140 Proposal Writing
- HU 142 Writing Operation and Maintenance Manuals

Literature:

- HU 201 Literature of Western Civilization I
- HU 202 Literature of Western Civilization II
- HU 258 American Thought
- HU 272 Contemporary American Poetry
- HU 295 Literary Interpretation and Criticism
- HU 297 English Language

Philosophy and Comparative Religion:

- HU 345 Advanced Logic
- HU 354 Social and Political Philosophy
- HU 363 World Religions
- HU 364 Philosophy of Religion
- HU 365 Science, Technology and Religion

Music and Fine Arts:

- HU 389 Art of Asia

German:

- ML 115 Conversation and Composition
- ML 121 Scientific German I
- ML 122 Scientific German II
- ML 213 German Drama from 1800 to Present
- ML 214 Contemporary German Literature
- ML 217-218 German Thought from Kant to Present I,II
- ML 220 German Civilization

French:

- ML 135 Conversation and Composition
- ML 235-236 French Thought from Rabelais to Sartre I,II
- ML 237 Contemporary French Literature
- ML 238 French Civilization

Russian:

- ML 151 Russian I: Foundation Course
- ML 152 Russian II
- ML 153 Russian III: Readings in 19th-Century Russian Literature
- ML 154 Russia IV
- ML 155-156 Contemporary Russia Literature and Civilization

Spanish:

- ML 265-266 Culture of Latin America I, II
- Literature in Translation:**
- ML 311 Currents of Unrest in 20th Century: German Literature (in English translation)
- ML 312 Currents of Unrest in 20th Century: French Literature (in English translation)
- ML 313 Currents of Unrest in 20th Century: Russian Literature (in English translation)
- ML 318 The Hebrew Bible

ML 319 The Jewish Heritage

Linguistics:

- ML 381 Language and Society
- ML 382 Introduction to the Study of Language
- ML 383 Advanced Topics in Study of Language

Interdisciplinary Studies:

- IS 145 The American, This New Man
- IS 146 Brooklyn History and Culture

Specialized Journalism:

- JW 606 Oral Technical Presentations
- JW 623 Publications Management and Budgeting
- JW 624 Writing Product-Information Copy
- JW 629 Writing the Marketing Report
- JW 631 Basic Technical Report Writing II
- JW 640 The Video Documentary

English and Humanistic Studies:

- HU 521 Seminar in Oral English
- HU 522 Seminar in Written English

FACULTY

Duane DeVries, Associate Professor of English and Head of Department
B.A., Kalamazoo College; M.A., Ph.D., Michigan State University
Dickens, the nineteenth-century English novel, expository writing

Victor Bobetsky, Professor of Modern Languages
B.S., M.A., Columbia University
German language and literature, interdisciplinary studies

Anne Eisenberg, Professor of Humanities and Communications
B.A., Barnard College; M.A., University of Iowa; Ph.D., New York University
Linguistics, technical writing, reading

Bernard Rechtschaffen, Professor of Modern Languages
B.S., M.A., Ph.D., New York University
Comparative literature, science and literature

Wolhee Choe, Associate Professor of English
B.A., Adelphi University; M.A., Ph.D., City University of New York
Nineteenth-century English literature, literary theory, English as a second language

LIBERAL ARTS

Sylvia Kasey Marks, Associate Professor of English
B.A., M.A., University of Michigan;
Ph.D., Princeton University
Samuel Richardson, the eighteenth century English novel, public speaking

Lowell L. Scheiner, Associate Professor of Humanities and Communications
B.A., City College, City University of New York; M.A., Columbia University; M.S., Columbia University (Graduate School of Journalism)
Technical writing, journalism

Jane Robinett, Assistant Professor of Humanities and Communications
B.A., Goshen College; M.A., Ph.D., University of Notre Dame
Software documentation, twentieth century poetry, Latin American literature, computer ethics

Barbara Bartholomew, Instructor of Communications
B.A., San Diego State University; M.S., Polytechnic University

Constantine Contogenis, Instructor of English and Speech
B.A., M.A., City University of New York

ASSOCIATED FACULTY

Michael Alfano, Visiting Assistant Professor of Philosophy
B.A., Seton Hall University; M.A., Ph.D., Fordham University
Phenomenology, history of philosophy, applied ethics

ADJUNCT FACULTY

Richard L. Amper, Jr., Adjunct Instructor of Communications
B.A., University of Missouri

Andrew Appel, Adjunct Assistant Professor of Music
D.M.A., Julliard School of Music

Glenn P. Beck, Adjunct Instructor of English
B.A., John Carroll University; M.A., Purdue University

Allen M. Cobrin, Adjunct Instructor of Communications; B.A., City College, City University of New York; M.A., Columbia University

Manning Dandridge, III, Adjunct Instructor of English; B.A., M.A., State University of New York at Stony Brook

Reva Ehrlich, Adjunct Assistant Professor of Speech
B.A., M.A., Brooklyn College, City University of New York; M.A., Queens College, City University of New York; Doctor of Arts, St. John's University

Barbara Feknous, Adjunct Instructor of English; B.A., Vassar College; M.A., New York University

Reva T. Field, Adjunct Instructor of English
B.A., M.A., Adelphi University

Peter Fusco, Adjunct Instructor of English; B.A., Hunter College, City University of New York

Erin Hayes, Adjunct Instructor of English; B.A., University of Wisconsin, Madison; M.A., City College, City University of New York

Linda Lerner, Adjunct Instructor of English; B.A., M.A., Brooklyn College, City University of New York

Evelyn Londyn, Adjunct Assistant Professor of French; B.A., Hunter College, City University of New York; M.A., Columbia University; Ph.D., New York University

Barbara Lynch, Adjunct Instructor of Speech; B.A., State University of New York at Oneonta; M.A., Teachers College, Columbia University

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

Alison Menzie, Adjunct Assistant Professor of English; B.A., Ph.D., University of Liverpool

Susan Moger, Adjunct Instructor of Communications; B.A., Carleton College; M.A.T., Wesleyan University

Alan M. Nadler, Adjunct Instructor of English; B.A., Queens College, City University of New York; M.A.T., University of Iowa; M.F.A., Columbia University

Hans Ostermann, Adjunct Instructor of Modern Language; B.A., M.A., Hofstra University

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

Nanci Milstein Shapiro, Adjunct Instructor of Art; B.A., M.A., State University of New York at Binghamton

William Tilley, Adjunct Instructor of English; B.A., Hofstra University; M.F.A., Columbia University

Suzanne Darrow-Kleinhaus, Adjunct Instructor of Technical Writing; B.A., Hofstra University

Mary Buhl Dutta, Adjunct Instructor of English; B.A., Barnard College; M.A., Columbia University

Susan M. Goulding, Adjunct Instructor of English; B.A., M.A., Adelphi University

Claudia M. Caruana, Adjunct Instructor of Technical Writing; B.S., M.S., Syracuse University

Adrienne C. Baker, Adjunct Instructor of Technical Writing; B.A., Hunter College, City University of New York; M.A., University of Arizona

Sharon Kraus, Adjunct Instructor of English; B.A., University of Illinois at Urbana-Champaign; M.A., New York University

EMERITUS FACULTY

John G. Cavanna, Professor Emeritus; Ph.D., University of Minnesota

Clifford Osborne, Professor Emeritus; M.A., University of Denver

ENDNOTES

- 1 *IS 140-141 may be taken in place of HU 200 and SS 104. See the Humanities and Social Sciences requirements in the Degree Requirements section at the front of this catalog.*
- 2 *IS 140-141 may be taken in place of HU 200 and SS 104. See the Humanities and Social Sciences Requirements in the Degree Requirements section at the front of this catalog.*
- 3 *IS 140-141 may be taken in place of HU 200 and SS 104. See the Humanities and Social Sciences requirements in the Degree Requirements section at the front of this catalog.*

SOCIAL SCIENCES

UNDERGRADUATE PROGRAMS

Majors in social sciences take a core curriculum in contemporary liberal arts, together with course concentrations chosen from history, history of science, economics, anthropology and sociology, and psychology. The core curriculum was conceived to meet the increasing need for specialists in the social sciences who are familiar with computers, the physical sciences, mathematics and the humanities. Students are offered specialized training in the social sciences in a setting at the Polytechnic noted for scientific and technical excellence. Degrees are interdisciplinary, with emphasis on developing integrated historical, economic, behavioral and cultural perspectives on human society.

Social science degrees are useful in the following areas: teaching at all levels; applied research on problems involving race, poverty, and education; urban and national planning; management, personnel operations and market research; environmental impact evaluation; foreign policy assessment; law; social work; and medicine. Social science degrees also provide an excellent basis for further education and advanced professional training. Graduates are employed in government agencies, foundations, private industry, and independent practice.

The department is also responsible for the social science courses which provide general education and professional training for scientists and engineers at Polytechnic. Solid backgrounds in the social sciences prepare students for leadership in industry, education, and government.

HISTORY AND HISTORY OF SCIENCE AND TECHNOLOGY

Courses in history emphasize elements of social and economic change in various geographic areas and periods since the European Renaissance. Methods and conclusions of related work in economics and the behavioral sciences are applied. Basic sequences in the history of western civilization familiarize students with political, economic, social, cultural and intellectual developments in European history since the Middle Ages. Students are also introduced to original documents and differing scholarly interpretations, and to the study of the non-Western world.

Science and technology have been pivotal in modern historical development and social change, especially in our own epoch, and are emphasized in all introductory courses. An introductory course on the modern world, SS 104, stresses the conflicts of ideologies in the twentieth century and developments in non-Western societies. Students analyze and discuss the best historical scholarship in a variety of special courses, and methods of instruction include formal lectures, discussions, colloquia, films, and tutorials leading to independent research.

Students who major in the history of science and technology benefit from one of the most comprehensive programs available in the New York area. Career openings for history and history of science and technology may be found in government, law, medicine, teaching, public relations, and all fields of media and communications.

ECONOMICS

Economics courses guide students in developing critical understanding of contemporary economic ideas and their roots, and in analyzing economic institutions and problems. These courses pose, in their theoretical and historical con-

texts, important questions of domestic and international public policy.

Majors in economics receive thorough grounding in the tools of economic analysis, mathematics, and statistical methods. Concentration in economics prepares students for careers in governmental service, business and graduate work, not only in economics but in any of the social sciences. Theoretical training is applied to actual economic problems and circumstances.

BEHAVIORAL SCIENCES ANTHROPOLOGY, SOCIOLOGY, PSYCHOLOGY

Introductory courses in anthropology, sociology, psychology and environmental psychology broaden students' understanding of social processes and human behavior, and prepare them to meet professional and administrative problems with insight and sophistication.

Advanced courses examine contemporary American society and its impact on the individual, the variety of social and cultural forms which have unfolded in the course of history, and their implications for the contemporary world as new nations enter the historical mainstream. Other courses analyze language, learning and the modification of behavior, with experiments in perception, learning, and communication. Students become acquainted with a range of behavioral methods of scientific study, from participant observation and structured interviewing to opinion sampling, psychological testing, and controlled laboratory experiments.

PSYCHOLOGY

Courses introduce students to psychology as the science of behavior, which can be empirically investigated. The department offers advanced courses in applied, social, environmental, cognitive, developmental, personality, comparative, physiological, learning and

abnormal psychology. Social Science majors with a concentration in psychology take a two-semester experimental psychology sequence, which offers fundamental methods and concepts in the empirical investigation of human and animal behavior in laboratory as well as field settings. Other psychology courses allow ample opportunities for students to design and complete individual research projects under the supervision of instructors. A concentration in psychology enables students to pursue graduate training in psychology and other fields including psychotherapy, social work, marketing research, personnel management, organizational behavior, and social impact assessment, or to enter management training programs and paraprofessional work in such settings as youth centers, etc.

An understanding of psychology is of particular use to engineers who must design devices and controls for safe and easy application by human beings. For engineers who become managers, psychology is useful in teaching the principles of human interaction.

REQUIREMENTS FOR THE BACHELOR'S DEGREE IN SOCIAL SCIENCES

Core Curriculum	Credits
Polytechnic Requirements:	
HU 101 and HU 200*; SS104	9
Mathematics courses	8
Sciences and technology courses	12
Core courses: Liberal Arts & Social Sciences	28
	57
Concentrated Studies in the Major:	
Electives	33-42
Humanities electives	6
Social Sciences electives	6
Free electives	24-15
Total credits for graduation	126

* IS 140-141 be taken in place of HU 200 and SS 140.

Core Curriculum

For a full description of courses available in the "Contemporary Liberal Arts Core Curriculum" refer to that section in this catalog. These courses may be used to fulfill requirements for Bachelor of Science degrees in social sciences.

Concentrations for Majors in Social Sciences

Social science majors may choose from the following courses to fulfill requirements for their concentrations. (Students not majoring in Social Sciences should consult their departments for special concentration requirements in Social Sciences.)

History

SS 101	History of Western Civilization I (1500-1815)
SS 102	History of Western Civilization II (1815-1914)
SS 109	The Birth of Modern Europe
SS 110	The Renaissance and Reformation
SS 120	History of Tsarist Russia to the Revolution
SS 121	History of the Soviet Union
SS 123	History of the United States: From Settlements to Reconstruction
SS 124	History of the United States: From Reconstruction to the Cold Wars
SS 126	African-American History
SS 128	History of Jazz
SS 151	Introduction to Politics
SS 154	Russia, China, and the West
SS 161	Politics and Film
SS 221	The Contemporary U.S.S.R.
SS 226	Problems of American Foreign Policy
SS 229	Growth of the United States Constitution
SS 345	Colloquium in 20th Century Thought
SS 347	Colloquium on Imperialism
SS 348	Colloquium on the History of Socialism and Communism

History of Science and Technology

SS 133	Archaeo- and Ethnoastronomy
SS 135	History of Science and Technology: Antiquity to Galileo
SS 136	History of Science and Technology: Galileo to Darwin
SS 137	History of Science and Technology: Faraday to the Present
SS 138	Technology, Science, and Contemporary Society
SS 330	History and the Environment
SS 332	Science and Technology in America
SS 333	Medieval and Renaissance Engineering
SS 338	Galileo Galilei: The Man, His

	Research, the Times
SS 354	Technological Forecasting
SS 357	Technology Transfer to Developing Countries
SS 358	Human Resource Development in Advanced Developing Countries
SS 602	Seminar in the History of Science
SS 615	Guided Reading in the History of Ideas
SS 616	Guided Reading in the History of Science
SS 625	History of Technology: Antiquity through Early Industrial Revolution
SS 626	History of Technology: Industrial Revolution to the Present
SS 635	History of Psychology

Behavioral Sciences (Anthropology, Sociology, and Psychology)

SS 175	Introduction to Sociology
SS 177	Social Problems
SS 178	Minorities in the New World
SS 182	Man and the Environment
SS 185	Anthropology: Physical
SS 186	Anthropology: Cultural
SS 125	African-American History
SS 203	Learning
SS 204	Physiological Psychology
SS 210	Environmental Psychology
SS 213	North American Indians
SS 214	Social Psychology
SS 215	Abnormal Psychology
SS 216	Personality Development
SS 217	Psychology of Human Development
SS 279	The Sociology of Human Disease
SS 310	Genes, Gender, and Society
SS 354	Technological Forecasting
SS 357	Technology Transfer to Developing Countries

Psychology

SS 189	Introduction to Psychology
SS 203	Learning
SS 204	Physiological Psychology
SS 205	Applied Psychology
SS 206	Human Cognition
SS 208	Experimental Psychology I (required)
SS 209	Experimental Psychology II (required)
SS 210	Environmental Psychology
SS 214	Social Psychology
SS 215	Abnormal Psychology
SS 216	Personality Development
SS 217	Psychology of Human Development
SS 299	Organizational Behavior
SS 310	Genes, Gender, and Society
SS 635	History of Psychology

LIBERAL ARTS

Economics

SS 250	<i>Basic Economics</i>
SS 251	<i>Microeconomics</i>
SS 252	<i>Macroeconomics</i>
SS 254	<i>Economic Issues</i>
SS 255	<i>The Contemporary American Economy: Boom and Bust</i>
SS 257	<i>History of Economic Thought</i>
SS 262	<i>Collective Bargaining</i>
SS 263	<i>Labor Economics</i>
SS 264	<i>Urban Economics</i>
SS 265	<i>Money and Banking</i>
SS 267	<i>The Market for Engineers and Scientists</i>
SS 354	<i>Technological Forecasting</i>

GRADUATE STUDY

The Department of Social Sciences offers courses leading to the master of science degree in the history of science and technology and in environment-behavior studies. Courses in these programs are intended for students with a B.S. in a social science field, or for graduate students in science and engineering interested in pursuing the interdisciplinary links between their own specialties and the social sciences. Students are encouraged to apply for research fellowships, teaching fellowships, or partial tuition remission.

History of Science and Technology
- The master's program in the History of Science and Technology was the first of its kind to be offered in the New York City area. The need for advanced study of the growth of science and technology and their interactions with human society and values has become increasingly evident. Intense specialization has further heightened the need for understanding among the various branches of science and the humanities. In considering ideas, time, process, transfer and social changes in the history of science, students are able to explore the elusive connections which exist between science and engineering and the social sciences and humanities. Prospective teachers of science and engineering subjects are able to increase their effectiveness through knowledge of the history of their own and related disciplines. Polytechnic's libraries contain many important and rare

works on the history of science which may be used for original research.

A total of 36 units is required for the master's degree. Normally students start by taking introductory courses, SS 600 and SS 601, and then proceed to more advanced courses and seminars. In all cases programs are constructed in consultation with advisors, taking into consideration individual backgrounds and interests. The student will be encouraged to take nine units of work in related fields outside the program; for example, in philosophy, mathematics logic, Renaissance history or one of the sciences or engineering.

To qualify for degrees, students may elect to write either a comprehensive examination or a thesis embodying appropriate and substantive research. If students choose the former, examinations may be taken in the term in which courses are completed. A student choosing the thesis may apply up to 12 units of thesis course work toward requirements for the degree. Acceptance of a thesis involves an oral presentation and defense. In addition to these requirements, students must demonstrate reading knowledge of one foreign language - either French, German, Russian or Spanish.

Environment-Behavior Studies
- The Department of Social Sciences offers the master of science degree in Environment-Behavior Studies, an area which uses the methods and knowledge of the behavioral sciences to study the fit between human behavior and the built or natural environment.

This program is aimed at enabling students to become environmental professionals capable of addressing socio/technical problems in a variety of research and applied settings. Students with design, technical, or scientific expertise are especially encouraged to apply.

Students plan individualized programs in consultation with faculty advisors. Such programs consist of a series of basic courses and a number of electives to develop expertise in behavioral science research methods and areas of specialization which reflect students' own backgrounds and interests. Program requirements include completion of a master's thesis.

Full and part-time programs are offered at the Brooklyn campus.

Areas of Focus and Specialized Study include:

Behavioral Approaches to Architectural Programming and Evaluation.

The use of behavioral research and analysis techniques to evaluate the success and failures of a setting (interior or exterior spaces) in meeting designer goals and user needs.

Behavioral aspects of transportation planning, and behavioral analysis of energy use.

Application of behavioral methods and principles to problems in transportation planning and energy conservation.

Social Impact Assessment

The analysis and appraisal of the social effects of planned changes in areas such as transportation, energy, natural resources, housing and community development, education and health.

Laboratory Research in Environmental Effects

The use of laboratory techniques and facilities to study the effects of various environmental stresses on behavior under controlled conditions.

Certificate Program

Students may take a five course sequence for a certificate in Environment-Behavior Studies. The program is available as a minor for students in other programs, or for students applying directly for the certificate.

DEGREE REQUIREMENTS

Core Courses in Environment-Behavior Studies - (18 units):

SS 908	<i>Experimental Psychology I</i>
SS 909	<i>Experimental Psychology II</i>
SS 920	<i>Seminar in Psychology</i>
SS 926	<i>Environmental Psychology</i>
MA 552	<i>Applied Statistics I</i>

Thesis - (6 units):

SS 997	<i>Master's Thesis - 6 units.</i>

In addition to writing a thesis, students are encouraged to do practicum work in their areas of specialization.

Electives - (5 units):

Students may take up to 5 units of electives from a variety of departments, three of which must be chosen from advanced courses in Environment-Behavior Studies.

TYPICAL PROGRAMS

For a student whose primary interest is in "Behavioral Approaches to Architectural Programming and Evaluation," a typical program would include:

5 Core Courses

Advanced Courses:

Post Occupancy Evaluation	(SS 927)
Social Impact Assessment	(SS 925)
Human Factors in Engineering	(IE 765)
Practicum in Environment Behavior Studies	(SS 921)
Master's Thesis	

For a student whose primary interest is in "Social Impact Assessment", a typical program would include:

5 Core Courses

Advanced Courses:

Social Impact Assessment	(SS 925)
Environmental Impact Evaluation	(CE 767)
Environmental Health Engineering	(CE 751)
Practicum in Environment Behavior Studies	(SS 921)
Master's Thesis	

UNDERGRADUATE COURSES

HISTORY AND HISTORY OF SCIENCE AND TECHNOLOGY

SS 101 History of Western Civilization 1500-1815 3:0:3

SS 102 History of Western Civilization 1815-1914 3:0:3

SS 101 and 102 provide an introduction to the political institutions, theories and

practices, economic organizations and techniques, scientific, technological, and artistic heritages of Western society from approximately 1500 to 1914. (May be taken independently of each other.)

SS 104 Main Themes in Contemporary World History 3:0:3

Examination of the major ideologies, transformations, and tensions marking the contemporary age, from World War I to the last decade of the 20th Century. Readings, lectures, discussion, with feature and documentary films on such topics as: the World Wars and Cold Wars; the rise, and now the fall of, Communism in Eastern Europe and the U.S.S.R.; the development of American globalism; the awakening of the Third World and the end of European Imperialism; the scientific-technological revolutions in war and in peace; current crises. Required of all students at Polytechnic.

SS 109 The Birth of Modern Europe, The Early Phase, 800-1500 3:0:3

From the time of the first stirring of specifically Western European Civilization, through its initial expansion and consolidation in the High Middle Ages, to the beginnings of the next great expansion marked by a peculiar dynamism probably linked to the nature of its material, human, institutional and spiritual resources. How those resources evolved over the years, and how Europeans used them to create the foundations for the institutions and patterns of functioning that still characterize the West today. The nature of the historical processes behind the several cycles of growth, stasis and decay in given periods and places.

SS 110 The Renaissance and Reformation 3:0:3

Dynamic changes in intellectual and artistic values, political and economic approaches, social and religious institutions from late Middle Ages to counter-Reformation. Guided readings and research. Discussions of selected topics.

SS 116 History of Latin America 3:0:3

Early Mexico and Andean areas; Spanish conquests and establishment of hacienda

systems throughout Latin America. Wars of independence. Social, cultural and political developments of last century. Latin America and United States. *Prerequisite: SS 104*

SS 120 History of Tsarist Russia to the Revolution 3:0:3

Russian state and society from earliest times; structure and practice of Tsarism; Russia as "underdeveloped" society and special problems of modernization; Russia and the West; culture and literature with special emphasis on 19th Century fiction. Political, social, economic causes of Revolution in 1905. *Prerequisite: SS 104*

SS 121 History of the Soviet Union 3:0:3

Revolutions of 1917; Leninism in power; industrialization, collectivization, ascendancy of Stalin; Soviet Union and the West -- from alliance to Cold Wars; Khrushchev and de-Stalinization; Soviet impact on underdeveloped world; the Brezhnev era and the coming crisis of Soviet society. *Prerequisite: SS 104*

SS 123 History of the United States: From Settlements through Reconstruction 3:0:3

Indigenous civilizations in North America, culture, politics and society from European and African-American settlements through post-Civil War era. Interpretation of accessible "primary sources," which illuminate convictions, ideologies and activities of leaders as well as ordinary Americans from the 17th through the mid-19th century. *Prerequisite: SS 104*

SS 124 History of the United States: From Reconstruction through the Cold Wars 3:0:3

The transformation of the post-Civil War U.S. to a nation of global authority; interweaving of domestic struggles and foreign policies from the "Gilded Age", through the Progressive Era; the World Wars of the 20th century; the New Deal period and post-New Deal domestic policy conflicts. U.S. foreign policy in a world of revolutionary upheavals. *Prerequisite: SS 104*

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SS 126 African-American History 3:0:3

Roles 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 their future in a multi-cultural, multi-ethnic society. *Prerequisite: SS 104*

SS 128 A History of Jazz 3:0:3

History, appreciation and analyses of jazz as unique African-American art form. Social and historical roots and interactions with other musical traditions. Contemporary trends as expressions of 20th century society and culture. *Prerequisite: SS 104*

SS 133 Archaeo-and Ethnoastronomy 3:0:3

Early astronomical knowledge and its place and uses in all cultures (excluding only the astronomies of Graeco-Alexandrian antiquity forward; see SS 135) to keep track of the motions of celestial bodies. The two major emphases will be: one, the astronomical knowledge per se of several quite different cultures, along with the distinct observational instruments and techniques and the recording and calculating methods of each; and two, the ways in which these astronomies both reflected and reinforced the economic and social organization and the cosmological and religious beliefs of the cultures in which they were embedded. There will be instruction in elementary, naked-eye astronomy, exercises in designing simple instruments and, weather permitting, actual observation. Student work will include a term project.

SS 135 History of Science and Technology: Antiquity through Galileo 3:0:3

Science and technology from earliest time to Renaissance: neolithic and medieval technologies; achievements of ancient Greeks from pre-Socratics to Euclid; Copernican revolution; science and technology in expansion of Europe; influences of science on development of European thought.

SS 136 History of Science and Technology: Galileo through Darwin 3:0:3

Science and technology from the scientific revolution through Lavoisier to the origins of the Theory of Evolution. Galileo and Newton; the beginnings of evolutionary thought; the organization of scientific inquiry; the impact of scientific thought on society in the 17th, 18th and early 19th centuries; connections between technology and science.

SS 137 History of Science and Technology: Faraday through Present 3:0:3

Science and technology from early 19th century forward: the maturation of evolutionary thought and its consequences; the rise of the sciences of electricity and heat, relativity, quantum mechanics; the development of cell theory, genetics and biochemistry.

SS 138 Technology, Science and Contemporary Society 3:0:3

Mutual relationships of technology, science and society; emergence of "big science"; national styles in science and technology; social effects of recent technological and scientific developments; policy issues posed by restricted and unrestricted uses of technology and science.

SS 151 Introduction to Politics 3:0:3

Major issues in history of political philosophy: the state; nature of political obligation; scope of dissent. Origins and functions of American political system. Clashing ideologies of democratic society. *Prerequisite: SS 104*

SS 154 Russia, China, and the West 3:0:3

Impact of modernization on traditional societies of Russia and China. Attraction of Western ideologies — liberalism, socialism, communism and interaction with existing political cultures. Russian and Chinese revolutions compared. Differing visions and practices of Russian and Chinese communism. Sources of Sino-Soviet conflict. Russia and China as great powers; the end of the U.S.S.R.

SS 161 Politics and Film 3:0:3

Film viewed as document and instrument of social structures and relations. Film as facet of mass culture and mass communication and means of shaping and reflecting attitudes and values. Each of the historically framed subjects constitutes a separate course for credit. Topics include: Depression America; Fantasy & Reality; War: A Cross-Cultural Comparison; Weimar Germany in the Shadow of Fascism; The Fall of France, 1930-1940; Great Britain - the End of Empire; Russia in Revolution and Civil War; the Reconstruction of Europe, 1947-1962. Film screenings, readings, lectures and discussions. Lab fee required. Other topics offered as appropriate. *Prerequisite: SS 104*

SS 221 The U.S.S.R. Under Gorbachev 3:0:3

The U.S.S.R. under Gorbachev, 1985-1991, and the crisis that led to the collapse of Soviet Communism. The historical background: from Krushchev's de-Stalinization to Brezhnev's stability and stagnation. Gorbachev's "glasnost" and "perestroika" as reform strategies out of the crisis. The unforeseen consequences of the original Gorbachev reforms: The end of the U.S.S.R., culture, politics, and economy. Films, lectures, readings. *Prerequisite: SS 121 or SS 161 (if appropriate) (or instructor's consent).*

SS 226 Problems of American Foreign Policy 3:0:3

Formulations and applications of foreign policy from 18th century through post-Cold War; continental and overseas expansions, international rivalries: impacts of domestic influences; diplomacy of infant republic; Monroe Doctrine; Manifest Destiny; "White Man's Burden"; open-door policy; "dollar diplomacy"; World Wars and their settlements; Cold War and aftermath. *Prerequisite: SS 104*

SS 229 Growth of the United States Constitution 3:0:3

Growth and unfolding of American constitutional system stressing political and economic factors shaping the law. Students handle leading court decisions

and related legal texts. *Prerequisite:* SS 104

SS 330 History and Environment 3:0:3

Changing human environmental support systems and societal and technological responses at three critical historical junctures: the ancient world; the early modern period; and the twentieth century. Discussions focus on current environmental issues. *Prerequisite:* Any of the following: SS 135, 136, 137, 138, 175, 182, or consent of instructor

SS 332 Science and Technology in America 3:0:3

Colonial science. Indifference to basic science during the 19th century. Technology and industrialization. Recent accomplishments of American science and technology. Emergence to superpower status. *Prerequisite:* SS 104 and one 100-level history of science course (or consent of instructor)

SS 333 Medieval and Renaissance Engineering 3:0:3

Engineering and technological enterprise in the European High Middle Ages and Renaissance, roughly 1000 to 1600. This period was characterized by increasingly complex engineering tasks such as the building of the Gothic cathedral, the mining of ores, the extraction of metals, and the industrial production of chemicals (e.g. gunpowder). The course will consider examples from several categories, analyzing the technical procedures as well as some broader contexts involved; the means of financing, the political and institutional involvement, and the training of the artisan-engineer and his position in society. *Prerequisite:* at least one of the following: SS 101, 102, 109, 110 or one 100-level history of science & technology course.

SS 338 Galileo Galilei: the Man, his Research, the Times 3:0:3

The life and career of one of the pivotal founders of modern science, Galileo Galilei (1564-1642). The course will concentrate on Galileo's experimental/observational researches and the genesis and development of his mature conclu-

sions in physics and cosmology. His role in establishing new attitudes towards the investigation of natural phenomena, his conflict with the Church, the work of his predecessors and contemporaries and the setting: Italy in the late 16th and early 17th centuries. Students will have the opportunity of empirically investigating some of Galileo's experiments. Much of the reading will be from Galileo's writings in translation, but students who might enjoy exercising their reading knowledge of Italian will be encouraged to work from original primary and secondary sources. *Prerequisite:* At least one of the following: SS 101, 102, 109, 110 or one 100-level History of Science/Technology offerings.

SS 345 Colloquium in Twentieth-Century Thought 3:0:3

Contemporary ideas of Europe and America. Reading and evaluation of selected works in political theory, economic theory, philosophy of science, historiography, ethics, aesthetics, and mass cultures. *Prerequisite:* SS 104

SS 347 Colloquium in Imperialism 3:0:3

Principal theories of imperialism establishing their premises, their internal consistency, and their historical validity since dissolution of world empires after World War II. Students establish their own criteria judgements. *Prerequisite:* SS 104

SS 348 Colloquium in the History of Socialism and Communism 3:0:3

Socialist movements from founding of Second International to collapse in 1914 and revival in inter-war years. Communist movements from theoretical controversies within social democracy before World War I to Eurocommunism and the collapse of the U.S.S.R. Examinations of socialist theories and ideologies, national parties, international organizations: The end of communism and socialism? Interpretive materials and sources in translation. *Prerequisite:* SS 104

SS 354 Technological Forecasting 3:0:3

Introduction to problems associated with technology forecasting.; Short range, intermediate, and long-range forecasting methodologies. forecasting social and economic consequences of adopted innovations. Students will prepare a forecast on a topic of their choice. *Prerequisite:* SS 104 and one 100-level history of science course (or instructor's consent). May be repeated for credit.

SS 357 Technology Transfer to Developing Countries 3:0:3

Mechanisms of technology transfer. Ecological, social and economic factors in technology selection and utilization. Local efforts to adapt technology to local needs. National and international means to stimulate or block technology transfer. Technology and political influence. Case studies of technology transfer to newly industrialized countries. *Prerequisite:* SS 104 and one 100-level history of science course (or instructor's consent). Also listed under IE 357

SS 358 Human Resource Development in Advanced Developing Countries 3:0:3

Spectrum of technology-related human resource needs in emerging technology nations. Education of engineers, technicians and technically skilled workers. Uses of foreign personnel and foreign schools. "Brain drain" problems and their consequences. Designs of educational systems and curricula to suit national needs. Roles of technical assistance programs. Forecasting of human resource needs. May include field trip. *Prerequisite:* SS 104 and one 100-level history of science course (or instructor's consent). Also listed under IE 358

BEHAVIORAL SCIENCE (ANTHROPOLOGY, SOCIOLOGY, PSYCHOLOGY)

SS 175 Introduction to Sociology 3:0:3

Influences of culture and social structures on human behavior. Concepts of sociological analysis; types of human societies; social stratification; urban ecology; the social context of the envi-

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ronmental crises; and the human impact of technology.

SS 177 Social Problems 3:0:3

Social disorganization and deviant behavior in contemporary society; crime and juvenile delinquency; mental disorder; drug addiction; alcoholism; suicide; family disorganization; poverty; unemployment. Comparisons with cultures of other peoples and/or simpler societies. Discussions of conflicting theories of causes for deviance and social disorganization. *Prerequisite: one of the following - SS 175, 182, 185, 186.*

SS 182 Man and the Environment: Environmental Science I 3:0:3

Ecological understanding of interactions of human with non-human environments through relevant topics; ecosystem, human interaction with ecosystem, human societies as self-regulating systems, attitudes toward nature, case studies in ecological history, present environmental crises and attempts at resolutions.

SS 185 Anthropology: Physical 3:0:3

Biosocial bases of human conduct seen in evolutionary perspectives; elementary genetic, demographic and ecological models necessary for understanding of human behavior; biology as an evolutionary complex extending from prosimian revolution through neolithic revolution.

SS 186 Anthropology: Cultural 3:0:3

Social evolution from the hunting and gathering band through state society. Considerations of variation and developmental trends in several human institutions: kinship; economic organization; warfare; politics; religion; and technology. Demographic and ecological variables receive primary stress.

SS 189 Introduction to Psychology 3:0:3

Scientific study of behavior, learning, physiological psychology, sensory systems, developmental, educational, abnormal and social psychology. Lectures, class discussion, films/videos, demonstrations of experiments.

SS 203 Psychology of Learning 3:0:3

Response acquisition and maintenance in human beings and other animals. Concepts of reinforcement, extinction, schedules of reinforcement, generalization, discrimination training. Relationship of learning to emotion and motivation, transfer of training, retention and forgetting, concept learning, acquisition of skills. Theories of learning and application of learning to other areas of psychology. *Prerequisite: SS 189*

SS 204 Physiological Psychology 3:0:3

Relationships between physiology, anatomy, and behavior. Physiological, anatomical, and biochemical bases for memory, learning, motivation, sleep, arousal, and stress. *Prerequisite: SS 189*

SS 205 Applied Psychology 3:0:3

This course will show how various problems, particularly in work, can be solved through the judicious use of psychological principles. Phenomena addressed will include human-machine interaction and other engineering-behavior interactions, smoking, study habits, memory, creative thinking, group interaction, raising children, influencing people, self-control, and specific problems brought up in class by students. Students will learn how to employ the method of behavioral analysis in gaining an understanding of various problems. They will select a problem, do a behavioral analysis and finally modify it as a class project. *Prerequisite: SS 189*

SS 206 Human Cognition and Information Processing 3:0:3

Human cognitive and information processing capabilities: Structures of memory and internal representations of knowledge, concept formation, and schemes, symbol manipulation, mental operations, consciousness, and problem-solving capabilities and strategies. Implications for learning, development, language acquisition, and Artificial Intelligence. *Prerequisite: SS 189.*

SS 208 Experimental Psychology I 3:0:3

Theory and methods of measurement of sensory functions in human and animal subjects. Examination of the concept of the threshold and problems of its measurement. Investigation of learning, both motor and verbal, and both simple and complex, including problem solving and creative thinking. Students will perform a series of experiments with human and animal subjects. *Prerequisite: SS 189.*

SS 209 Experimental Psychology II 3:0:3

Experimental and descriptive methods including quasi-experimental design and large-scale survey techniques used by social, environmental, and developmental psychologists to assess human behaviors in laboratory and naturalistic settings. The course focuses upon laboratory and observational methods used to assess environmental effects, attitude measurement, social impact assessment, and theory and psychometric bases of normal personality development and assessment. *Prerequisite: SS 189.*

SS 210 Environmental Psychology 3:0:3

Ways people use and are affected by their physical environments. Research in natural environments as well as built urban areas. Research on personal space, privacy, territoriality, crowding and design-behavior relationships. Field research to assess suitability of environments to human needs, using interview techniques, behavioral observations and unobtrusive measures. *Prerequisite: SS 189.*

SS 213 North American Indians 3:0:3

A survey of the cultures of selected Indian and Eskimo groups. After a general historical introduction primary emphasis will be placed on tribal social organization, technology, art, and language at the time of European contact. *Prerequisite: one of the following - SS 133, 185, or 186*

SS 214 Social Psychology 3:0:3

Behavior as function of social stimulation. Nature of socio-psychological inquiry, with particular emphasis on experimental methods. Biological bases of social behavior, socialization processes, effects of social stimuli on perception and communication, group processes, attitude change, interpersonal bargaining. Student participation in experiments. *Prerequisite: SS 189.*

SS 215 Abnormal Psychology 3:0:3

Types of abnormal behavior: neurosis, psychosis, psychosomatic reactions, character disorders. Developmental and social learning theories, biological, etiological models. Relations of methods of treatment of abnormal behavior to models of etiology. *Prerequisite: SS 189.*

SS 216 Personality Development 3:0:3

Methods and theory relevant to the study of personality. Personality development in terms of social learning, development, and cognition. Examples of personality research include studies of authoritarianism, achievement motivation, self-esteem, sex-role acquisition and stereotyping, family and life style choices, and effects of physiological variables including maturity and aging. *Prerequisite: SS 189.*

SS 217 Psychology of Human Development 3:0:3

Human development from birth to old age. Effects of age on thinking, learning, social behavior. Implications for teaching and educational programs. *Prerequisite: SS 189.*

SS 279 The Sociology of Human Disease 3:0:3

Human disease in context of social and biological adaptation. Disease profiles of the three major levels of social evolution—hunters and gatherers, low-energy agriculturalists, and states—considered from broadly conceived human ecological viewpoints. Recommendation: some background in biology and anthropology. *Prerequisite: SS 175 or 177 or 185 or 186.*

SS 299 Organizational Behavior 3:0:3

Behavior in industrial settings. Informal and formal group dynamics: Interpersonal relationships, supervision, leadership, communication theories, attitude measurement, creativity. Analyses of administration problems through case studies and simulated situations. *Prerequisite: SS 189.* Also listed under MG 301.

SS 310 Genes, Gender, and Society 3:0:3

Psychology, sociology, and anthropology of men and women's relationships to one-another and to society. Biological, societal, and psychological bases of sex-role differentiation and acquisition. Implications of historical, cultural, economic, and psychological factors for contemporary women's and men's lifestyles, roles, economic status, and political power. *Prerequisite: SS 189 or 185 or 186 or 175 or 177.*

ECONOMICS**SS 250 Basic Economics 3:0:3**

Basic micro and macroeconomics. Supply and demand. Markets and market structure. Income distribution. Market failures. National output. Aggregate supply and aggregate demand. Unemployment and inflation. Fiscal and monetary policy.

SS 251 Microeconomics 3:0:3

Advanced supply and demand analyses. Allocation of resources and distribution of income. Various market structures: perfect competition, imperfect competition, oligopoly and monopoly. Externalities. Government and the market. *Prerequisite: SS 250*

SS 252 Macroeconomics 3:0:3

Advanced national income analysis. Employment and unemployment, inflation and growth. The federal government and fiscal policy, the Federal Reserve Board and monetary policy. International trade and the balance of payments. *Prerequisite: SS 250*

SS 254 Economic Issues 3:0:3

An intensive study of a number of the following: Unemployment and inflation, urban fiscal crises, racial and sexual discrimination, pollution, poverty, imperialism and military spending. Production and consumption and the role of the state. *Prerequisite: SS 250*

SS 255 The Contemporary American Economy: Boom and Bust 3:0:3

The current economy: inflation, unemployment, growth and recession. Interest rates, money, the stock market, wages, productivity, profit rates and the balance of payments. Role of military expenditures. Legacies of the Vietnam and Gulf Wars. Evaluations of the Federal Reserve and government of the economy; spending, taxation, deficits and monetary policy. Supply side economics. Wage-price controls, unions and the future of economic planning. *Prerequisite: SS 250 or SS 252.*

SS 257 History of Economic Thought 3:0:3

Development of economic thought. Various schools of thought which anticipated and prefigured modern economic analysis. *Prerequisite: SS 250 or SS 252 or SS 251.*

SS 262 Collective Bargaining 3:0:3

Labor-management collective bargaining. Historical background, bases of power, day-to-day administration and bargaining. Intra-union bargaining, major substantive issues and problems, legislation, public policy implications, effects of technological progress, the strike and its alternatives, comparison with other bargaining settings (e.g. international negotiations). *Prerequisite: SS 250 or SS 251.*

SS 263 Labor Economics 3:0:3

Theoretical and empirical analyses of labor market phenomena. Trends in the size and composition of the labor force. Supply, Demand and marginal productivity theory. Influence of market and other institutional forces on wages. Unemployment. Allocation by relative wages and job opportunities. Legislation, wage controls, labor unions, technology and

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skill requirements. Discrimination. Demand determinism. *Prerequisite:* SS 250 or SS 251.

SS 264 Urban Economics 3:0:3

Contemporary American cities and changing functions. Interrelation of population with housing, jobs, transportation. Problems of public finance and services, land use, urban decay and renewal. Analytic tools to examine economic aspects and evaluate policy alternatives. *Prerequisite:* SS 250 or SS 251.

SS 265 Money and Banking 3:0:3

Nature of money, gold and paper standards, commercial banks and Federal Reserve system, financial institutions, balance of payments, exchange rates, international monetary order. Money, prices, inflation, business fluctuations. Domestic and international monetary policy. Problems and changes in the U.S. banking system. *Prerequisite:* SS 250 or SS 252.

SS 267 The Market for Engineers and Scientists 3:0:3

Growth of the technological professions; social implications of technological progress; applications of conventional supply-demand models; institutional forces beyond supply and demand; schooling and skills; roles of government; supply models; demand models; non-wage responses to shortages and surpluses; the method of job evaluation; earnings and employment studies; future prospects. *Prerequisite:* SS 250 or SS 252.

SPECIAL TOPICS AND GUIDED STUDIES

SS 302-306 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 and department's permission.

The following special topics courses are offered from time to time by the staff of the department or visiting scholars. The specific titles and prerequisites are announced prior to registration. May be repeated for credit:

SS 361 Special Topics in Social Sciences* each 3:0:3

SS 362	<i>Special Topics in History*</i>
SS 363	<i>Special Topics in History of Science and Technology*</i>
SS 364	<i>Special Topics in Economics*</i>
SS 365	<i>Special Topics in Psychology*</i>

GRADUATE COURSES

HISTORY OF SCIENCE AND TECHNOLOGY

SS 600† History of Science and Technology: Antiquity to the Scientific Revolution 2½:0:3

Biological and physical sciences from antiquity to Renaissance. Issues, aims and tools of historians of science working in these periods.

SS 601† History of Science and Technology: Scientific Revolution to Darwin¹ 2½:0:3

Biological and physical sciences from scientific revolution to Darwin. Issues, aims and tools of historians of science working in these periods.

SS 602† Seminar in History of Science 2½:0:3

Advanced problems in history of science: development of quantification, historiography of science, history of ecology, science and social thought. Main topic chosen by students and instructor. Training in methods of archival research. Required regular reports leading to a major paper. Course may be taken twice for credit with different topical emphasis and instructor's consent.

SS 616† Guided Reading in History of Science 2½:0:3

Independent studies of leading interpretive works and sources in history of science. Regular tutorial sessions and periodic student-faculty colloquia. Course may be taken twice for credit with different topical emphases and instructor's consent. Comprehensive written examination.

SS 625† History of Technology: Antiquity through Early Industrial Revolution 2½:0:3

SS 626† History of Technology: Industrial Revolution to the Present 2½:0:3

These two courses involve the evolutions of techniques and tools used in society's attempts to master the environment. Reciprocal relationships between technology and other facets of society's economic and social structures, political policies; general cultural manifestations. Technological bases of historical changes and interactions of science and technology. *SS 625 prerequisite:* SS 600 or equivalent. *SS 626 prerequisite:* SS 601 or equivalent.

SS 635† History of Psychology* 2½:0:3

Survey of psychology against background of periods in which principal modern schools and issues emerged. Early psychology as speculative discipline, essentially part of philosophy. Differentiation of psychology into various fields. *Prerequisite:* SS 189 or equivalent or SS 135-136 or equivalent.

SS 640-641† Environmental Studies Seminar* 2½:0:3

This seminar provides an opportunity to investigate environmental issues by focusing on a specific topic each year. The aim is to cultivate a more holistic understanding of human societies in their ecological settings. Attention is given to such factors as weather, technology, population, social organization and political structure. All students are responsible for a seminar paper. Guest participants on special topics. *Prerequisite:* SS 182 or other appropriate environment studies course or instructor's consent.

SS 672 Technological Forecasting
2½:0:3

Introduction to problems associated with technology forecasting. Short range, intermediate, and long-range forecasting methodologies. Forecasting social and economic consequences of adopted innovations. Students will prepare a forecast on a topic of their choice. *Prerequisite:* SS 104 and one introductory History of Science and Technology course (or instructor's consent). Also listed under MG 672.

SS 675 Technology Transfer Among Nations
2½:0:3

Social, ecological and economic factors in the selection, transfer and use of technology. Mechanisms of technology transfer and criteria of success. Case studies of successful and unsuccessful technology transfers. *Prerequisite:* SS 104 and one introductory History of Science and Technology course (or instructor's consent). Also listed under IE 757 and MG 757.

SS 676† Human Resource Development in Developing Countries
2½:0:3

Spectra of technology-related manpower needs in less developed countries. Education of engineers, technicians and skilled mechanics. Uses of foreign personnel, foreign schools, "brain-drain" problems. Economic consequences. Comparisons of educational system of Western, Eastern and developing countries. Designs of curricula to suit national needs. Roles of technical assistance programs. Forecasting of human resource needs. Also listed under IE 758.

SS 678† Human Resources Information Systems
2½:0:3

Design, selection, implementation, enhancement and operation of Human Resources Information Systems (HRIS) in organizations. Organizational, legal and political issues as well as hardware, software, applications and communications in HRIS. The uses of time-sharing, personal and minicomputers and mainframes. Focus on design and use of HRIS to facilitate objectives of human resource functions, as well as to support

entire organizations. Also listed under MG 626.

PSYCHOLOGY

SS 901 Guided Readings in Environment-Behavior Studies

Students will work closely with a faculty member to develop a reading list in a specific area of interest, read and discuss the reading material with faculty member, and present a term paper summarizing and critically analyzing literature on the topic. *Prerequisite:* SS 189

SS 905 Psychology: Applied
2½:0:3

This course will show how various problems, particularly in work, can be solved through the judicious use of psychological principles. Phenomena addressed will include human being-machine interaction and other engineering-behavior interactions, smoking, study habits, memory, creative thinking, group interaction, raising children, influencing people, self-control, and specific problems brought up in class by students. Students will learn how to employ the method of behavioral analysis in gaining an understanding of various problems. They will select a problem, do a behavioral analysis and finally modify it as a class project. *Prerequisite:* SS 189.

SS 906 Human Cognition and Information Processing
2½:0:3

Human cognitive capabilities including natural language and information processing. Memory, internal representation of knowledge, concept information, symbol manipulation, language acquisition, reasoning and problem solving. Artificial intelligence approaches to natural language learning and acquisition of cognitive skills. *Prerequisite:* SS 189 or equivalent course.

SS 908 Experimental Psychology I
2½:0:3

Theory and methods of measurement of sensory functions in human and animal subjects. Examination of the concept of the threshold and problems of its measurement. Investigation of learning, both motor and verbal, and both simple and complex, including problem solving and

creative thinking. Students will perform a series of experiments with human and animal subjects. *Prerequisite:* SS 189.

SS 909 Experimental Psychology II
2½:0:3

Experimental and descriptive methods including quasi-experimental design and large-scale survey techniques used by social, environmental, and developmental psychologists to assess human behaviors in laboratory and naturalistic settings. The course focuses upon laboratory and observational methods used to assess environmental effects, attitude measurement, social impact assessment, and theory and psychometric bases of normal personality development and assessment. *Prerequisite:* SS 189.

SS 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 formation, and social interaction. All students are required to perform one experiment on learning under guidance of the instructor. Available to undergraduate majors in social science. *Prerequisite:* SS 189 or equivalent.

SS 911 Psychology of Language and Communication
2½:0:3

Methodological problems in analysis of language, verbal behavior in animals, anatomical and physiological aspects of speech apparatus, operant and respondent conditioning of verbal behavior, semantics, statistical approaches and mathematical models, contextual factors, pathology of speech. All students are required to perform one experiment under guidance of instructor. Available to undergraduate majors in social science. *Prerequisite:* SS 189 or equivalent.

SS 912 Sensation and Perception
2½:0:3

Review of different sensory systems: vision, audition, taste, smell, touch, temperature sensitivity, vestibular and kinesthetic senses and their relations to nonsensory controlling stimuli such as states of organism, learning, social psychological variables. Techniques for

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obtaining psychophysical data on each sensory system and relations of these techniques to theories of discrimination. Available to undergraduate majors in social science. *Prerequisite: SS 189 or equivalent, or instructor's permission.* Also listed under BE 675.

SS 913 Physiological Psychology 2½:0:3

Physiological and anatomical bases of behavior. Memory, motivation, emotion, sleep reward mechanisms, psychosurgery and higher cortical functions. *Prerequisite: SS 189.* Also listed under BE 695

SS 920 Proseminar in Psychology 2½:0:3

Review and readings in major areas of psychology required of all master's candidates. Includes history and systems, sensation and perception, learning, developmental and abnormal psychology.

SS 921 Practicum in Environment-Behavior Studies

Under the guidance of their advisor, students will work in a field setting with environment-behavior professionals. The setting will be chosen to match the students' programmatic interests and to provide training which will be of value in their professional careers. Students will be expected to provide, at the end of the term, a written and oral presentation of the semester's project.

SS 924 Social Psychology 2½:0:3

Nature of socio-psychological inquiry, biological bases of social behavior, socialization processes, effects of social stimuli on perception and communication, group processes, attitude change, interpersonal bargaining. Students will conduct laboratory and field studies.

SS 925 Social Impact Assessment 2½:0:3

How physical changes in urban or rural settings affect social systems, group and individual behavior. Measuring quality of life and social responses to technology; uses of alternative futures paradigms. Students do an analysis of a problem in social impact and report findings to the class.

SS 926 Environmental Psychology 2½:0:3

Critical issues in person-environment relations, including privacy, crowding and environmental design. Work includes a term paper and a major research project, emphasizing applications of psychological research methods to practical design problems or specific environmental issues.

SS 927 Post Occupancy Evaluation 2½:0:3

Principles, approaches and methods for assessing how well built settings fit the needs of their users. A review of past research in a broad variety of settings (such as work environments, institutions, educational settings, recreational settings). Students will conduct and present an evaluation of an occupied setting.

SS 928 Advanced Topics in Environmental Psychology 2½:0:3

This course varies from year to year depending on the needs and interests of students and instructors. Potential subjects include: social impacts of transportation systems; stress and the environment; aversive environmental factors; laboratory assessment of environmental effects on animal learning; effects of pollution; human factors of software design; assessing the built environment including the office; applied behavioral analysis.

SS 997 Thesis for Degree of Master of Science* each 2½:0:3

Independent research project demonstrating scientific competence performed under guidance of advisors.

† Course may be taken for undergraduate or graduate credit.

FACULTY

Louis Menashe, Professor of History and Head of Social Sciences
B.A., City College of New York;
M.A., Ph.D., New York University
Russian social history, revolutionary thought and politics, Soviet and contemporary history, Soviet cinema and society

Marvin E. Gettleman, Professor of History
B.A., City College of New York;
M.A., Ph.D., Johns Hopkins University
History of the United States, American constitutional history, nationalism, modern radicalism, Asia, Central America, U.S. Foreign Policy

Helmut Gruber, Charles S. Baylis Professor of History
B.S., City College of New York;
M.A., Ph.D., Columbia University
History of socialism and communism, intellectual social and cultural history of 19th and 20th centuries, contemporary history

Frederick C. Kreiling, Professor of History of Science
A.B., Hofstra College;
A.M., Ph.D., New York University
History of science, environmental studies, music history

David Mermelstein, Professor of Economics
B.A., Amherst College;
Ph.D., Columbia University
Radical economics, current macroeconomic problems, comparative economic systems, urban fiscal problems

Kurt Salzinger, Professor of Psychology
B.A., New York University; A.M.,
Ph.D., Columbia University
*Behavior theory and learning, abnormal
psychology, language behavior*

Thomas B. Settle, Professor of History
of Science and Technology
B.A., M.A., Ph.D., Cornell University
*Galilean Studies, the Italian
Renaissance, engineering in Medieval
and Renaissance Europe*

Lester O. Burnas, Associate Professor
of Economics
B.E.E., City College of New York;
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, human cognition,
psycholinguistics and developmental
psychology*

I. Leonard Leeb, Associate Professor of
History
B.A., University of Pennsylvania;
Ph.D., Columbia University
*History of the Netherlands, colonialism
and imperialism, history of political
thought, contemporary history*

F. David Mulcahy, Associate Professor
of Anthropology
B.A., M.A., Ph.D., University of Mas-
sachusetts
*Marginal communities, human ecology,
cultural symbolism, language and culture*

Romualdas Sviedrys, Associate
Professor of History of Technology
B.A., Cornell University; Licenciado,
Universidad Nacional (Colombia);
Ph.D., Johns Hopkins University
*Technology forecasting and technology
assessment, history of technology and
science since 1750, technology transfer
to developing countries*

Richard E. Wener, Associate Professor
of Psychology
B.A., University of Wisconsin;
M.S., Ph.D., University of Illinois at
Chicago
*Environmental psychology, crowding,
assessment of the built environment,
software evaluation, clinical psychology*

Donald Phillips, Instructor in
Psychology
B.S., Polytechnic Institute of New York
*Experimental and physiological
psychology, physical anthropology,
paleontology*

ADJUNCT FACULTY

Barbara Bienstock, Lecturer in
Psychology
B.A., Ph.D., Queens College

Mark D'Amato, Lecturer in Economics
and Contemporary History
B.A., New York University;
M.A., Ph.D., The New School for
Social Research

Malcolm McCullough, Lecturer in
Psychology
B.S., Polytechnic Institute of New York;
Ph.D., Queens College

COOPERATIVE EDUCATION PROGRAM

The Cooperative Education (Co-op) Program provides students with practical work experience in industry, government and public service agencies. This experience contributes to the student's career decision making ability, motivates academic performance and provides a competitive advantage in the job market. Students can also earn a substantial salary while employed in a Co-op position.

The Co-op program alternates semesters of classroom study with semester of work. A student may Co-op for up to five work periods (semesters) and may require a five year undergraduate program depending on the number of semesters spent working. Each Co-op student designs a Co-op work-study program with the help of their academic advisor. Eligible students can begin co-oping in their sophomore year. Seniors and graduate students are not eligible for the Co-op program.

Students accepted into the program start interviewing with participating Co-op companies during the semester prior to the first scheduled work period. Companies select students based on their employment needs and the process is competitive. Co-op students are given work directly related to their career goals and level of academic experience. Co-op students are paid salaries based on their experience and academic level.

The Cooperative Education Program is a non-credit, optional program. Students participating in the program for at least two Co-op field experiences receive Co-op certificates upon graduation. Students who have a Co-op position and are not attending classes do not pay tuition during the work period; however there is a small registration fee for Co-op experience. (Fee is waived for summer Coop.)

ELIGIBILITY

Before applying for the initial Co-op work assignment, students must:

- Complete two full-time semesters at Polytechnic.
- Achieve and maintain a 2.5 grade point average.
- Have sophomore status (28+ credits) with no course deficiencies.
- Complete at least one technical course in the major as determined by their academic department.
- Successfully complete CP 101 (Career Development Seminar) and CP 102 (Communication in the Workplace).
- Obtain advisor approval for program participation (work-study plan signed by advisor).

Transfer Students are required to:

- Complete one semester of full-time study at Polytechnic University before beginning their first work period.
- Attend one semester of the required Co-op seminar, either CP 101 or CP 102.
- Achieve a 2.5 grade point average at Polytechnic University.
- Obtain departmental approval for program participation (work-study plan signed by advisor).

CO-OP SEMINARS

Co-op pre-employment seminars prepare students for entry into professional environments and are a prerequisite to participation in the work experience sequence.

CP 101 examines methods of discovering fields which are most fulfilling. Topics include self assessment, techniques of résumé writing, interviewing, making contact with prospective employers, planning for advancement, and other issues which help to bridge the gap between education and work.

CP 102 assists students in the development of communication skills in the workplace. Topics include corporate culture, ethics in the workplace, negotiation skills, communicating in a diverse work force and other topics that foster students' successful adjustment in the workplace.

Students entering work assignments after the freshman year can complete up to five field experience courses, CP 201 through CP 401; students entering after the sophomore year might complete up to four field experience courses. Types, complexities and challenges of field assignments vary depending on the student's academic preparation, ability, and interest. The initial field experience (CP 201) usually serves as an introduction to the technical work environment. Students are assigned work under supervisors, who are usually senior staff professionals. As students progress through subsequent field assignments, more complex tasks and duties are added:

COURSES

CP 101 Cooperative Education Seminar I 1:0:NC

CP 102 Cooperative Education Seminar II 1:0:NC

CP 201 First Co-op Field Assignment 0:0:NC

Prerequisite: CP 101, CP 102 or departmental approval

CP 201 First Co-op Field Assignment 0:0:NC

Prerequisite: CP 101, CP 102 or departmental approval

CP 202 Second Co-op Field Assignment 0:0:NC

Prerequisite: CP 201

CP 301 Third Co-op Field Assignment 0:0:NC

Prerequisite: CP 202

CP 302 Fourth Co-op Field Assignment 0:0:NC

Prerequisite: CP 301

CP 401 Fifth Co-op Field Assignment 0:0:NC

Grades of (S) "satisfactory" or (U) "unsatisfactory" are recorded upon completion of each course. Courses will not be computed in the grade point average (G.P.A.). These grades are based upon final reports and work evaluations written by students and evaluations submitted by supervisors.

Nominal registration fees are charged for each field assignment.

COORDINATORS

Ellen E. Dressner, Director of Student Development Program
B.A., Queens College; M.S., St. John's University

Jeanette Grill, Associate Director, Career Services and Cooperative Education
B.A., Molloy College;
M.S., Polytechnic University

Glennis Daniels-Bacchus, Coordinator of Job Development Program
B.A., Fordham University

Jane R. Garfield, Assistant Director, Career Services and Cooperative Education, Brooklyn Campus
B.A., Brandeis University;
M.A., New York University

Sari Goren, Assistant Director, Career Services and Cooperative Education, Long Island Campus
B.S., M.S., Brooklyn College;
M.S., Hofstra University

MILITARY SCIENCE

The department of military science administers the Reserve Officer Training corps program and provides college-trained officers for the United States Army Reserve. Best explained in the words of Dr. Lee S. Dreyfus: "The Reserved Officers Training Corps is not the presence of the military in the university, but rather the presence of the university in the military."

Through the Department of Military Science the United States Army gains officers with excellent educational backgrounds and contemporary ideas. Military science graduates have the chance to use their ideas in positions of leadership and enable the Army to remain aligned with our ever-changing society.

Military science enhances a student's education by providing unique leadership and management experience found in few college courses. It helps develop self-discipline, physical stamina and poise. Students develop qualities basic to success in any worthwhile career. They earn commissions as officers in the United States Army while earning their college degrees. As commissioned officers they serve on active duty or as citizen soldiers in the Reserve Forces upon graduation. ROTC graduates provide critical leadership to the U.S. Army, government and industry.

OFFICER EDUCATION PROGRAM

THE FOUR-YEAR PROGRAM

The four-year military science program is divided into two parts—the Basic Course and the Advanced Course.

Basic Course—The Basic Course is usually taken in the freshman and sophomore years. No military commitment is incurred during this time, and students may withdraw at any time through the end of their second year. (Except scholarship contracted students.) Subjects cover the following areas: first aid,

national defense, drill and ceremonies, physical conditioning, map reading, survival techniques, tactics, basic rifle marksmanship and leadership development.

Various social and professional enrichment activities are available in conjunction with the military science program. Necessary textbooks and materials are furnished without cost. Students who participate in the Basic Course are excused from physical education requirements.

All students in the Basic Course are organized into the cadet student battalion. Some Saturday or Weekend training is included in the coursework. Uniforms may be issued to Basic Course students who are active in military science program, but uniform wear is not mandatory.

Advanced Course—The Advanced Course is normally taken in the final two years of college. Instruction includes further leadership development, organization and management techniques, basic military hands-on skills, tactics, administration, military history and the military justice system. These subjects are taught in the classroom, in laboratories and during field training exercises. A paid six-week advanced camp is held during the summer between the junior and senior years. This camp permits the cadets to put into practice the principles and theories they have acquired in the classroom. It also exposes them to the conditions of Army life in a tactical and field environment.

All cadets in the Advanced Course receive uniforms, necessary military science textbooks and pay for Advanced Camp. Contracted U.S. citizens also receive a living allowance each school year.

To be selected for the Advanced Course, a student must:

1. Be a citizen of the United States. Permanent residents may participate in the Advanced Course and may possibly obtain a commission once they obtain U.S. citizenship.

2. Qualify for appointment as a second lieutenant prior to reaching 30 years of age.
3. Be approved by the Professor of Military Science.
4. Successfully pass a prescribed medical examination.
5. Successfully pass an educational level examination and a leadership assessment program.
6. Have successfully completed the two-year Basic Course or its equivalent. Minimum Basic Course requirements consist of successful completion MS 101, 102, 201 and 202.
7. Sign a contract with the U.S. Army agreeing to pursue the standards required for Commissioning.

THE TWO-YEAR PROGRAM

The two-year program is designed for undergraduate and graduate students who have not taken the Basic Course and have two years remaining in school. Students can take advantage of this opportunity by successfully completing a paid, six-week basic camp offered at Fort Knox, Kentucky, during the summer. Students may then enroll in the Advanced Course in their last two years, provided they otherwise meet enrollment requirements.

OBLIGATIONS

Cadets must successfully meet ROTC standards. Upon commissioning, students may fulfill their contract obligations by either serving on active duty or by becoming a member of a local United States Army Reserve or National Guard unit.

Based upon the current manning requirements, approximately two thirds of those students requesting active duty are selected for active duty. Therefore competition for these slots is intense. For

students interested in remaining in the local area and pursuing a civilian career, Reserve Forces duty would be their choice. This consists of one weekend drill per month and a two-week period of active duty each summer. Qualified students may be guaranteed Reserve Forces duty prior to committing themselves to the Advanced Course by electing to sign a guaranteed Reserve Forces duty contract.

The Professor of Military Science may designate outstanding cadets as Distinguished Military Graduates. Students so designated may apply for a commission in the Regular Army of the United States.

MILITARY SCIENCE SCHOLARSHIPS

The Department of Military Science offers two-, three- and four-year scholarships. The four-year scholarships are awarded on a worldwide competitive basis U.S. citizens who will be entering college as freshmen. The two- and three-year scholarships are awarded competitively to students who are enrolled in college and are academically aligned with military science.

Students who attend the Basic Camp of the two-year program may also compete for two-year scholarships.

All scholarships pay for tuition, a stipend for textbooks, lab fee, plus a living allowance each year the scholarship is in effect.

REQUIREMENTS FOR COMMISSIONING

1. Completion of the Basic Course or Equivalent
2. Completion of the Advanced Course
 - a. MS 301, 302, 303 (or approved history course determined by the Department Head), 304.
 - b. MS 401, 402, 403.
 - c. Advanced Camp.
 - d. Meet Army Physical Fitness Standards.
 - e. For Scholarship Students—one semester of a Foreign Language.

CREDITS TOWARD POLYTECHNIC DEGREES

BASIC COURSE

Students enrolled in any of the Basic course courses (MS 101, 102, 201, or 202) may substitute these courses for the mandatory physical education requirements.

ADVANCED COURSE

The number of military science credits which are applicable toward Polytechnic degrees depends upon the student's academic major and upon which courses the student chooses to replace with MS courses.

A student may substitute up to six credits from the four two-credit courses (MS 301, 303, 401 or 403) for free/technical electives as authorized by the individual departments.

PROFESSIONAL ACTIVITIES

The military science program offers a variety of social and professional activities:

Scabbard and Blade is the national military honor society, whose local chapter is active in service to the Military Science Department and to Polytechnic. An annual military ball is sponsored by the local chapter.

The Pershing Rifles promotes military ideals as exemplified by General John J. Pershing. The local chapter is active in drill and ceremonies, military training and in organizing ceremonial colorguards.

The Society of American Military Engineers promotes the national engineering potential for defense. The local student chapter is active in guest presentations in military and civilian engineering.

The National Association of Rigorous Training Units (Sappers) offers instruction in adventure training, such as mountaineering, rappelling, orienteering and tactics.

HOW TO ENROLL IN MILITARY SCIENCE (ROTC)

Students interested in the two-year program should contact the department early in their sophomore year for application deadlines. If students have any questions concerning the military science program, they should telephone (718) 260-3150. Students should visit the Department of Military Science during the registration period so that the desired course can be integrated with normal registration procedures.

BASIC COURSE

MS 101 Introduction to Military Science I 1:1:0

History and organization of the Reserve Officer Training Corps; organization and purpose of the United States defense establishment; the roles of key government organizations and officials in defense matters. Introduction to physical fitness training and planning, land navigation, and basic rifle marksmanship. The course also includes several lab periods or field trips which allow for application of skills taught. Extra credit field training exercises are available.

MS 102 Introduction to Military Science II 1:1:0

Development of self-confidence in students, as well as skill necessary to navigate using a map and compass, and continued development of physical fitness. First aid measures consisting of basic lifesaving steps are included in this course. Extra credit field training exercises are available: *Prerequisite: MS 101 or permission of department head.*

MS 201 Military Skills I 1:1:0

Basic skills associated with small unit leaders; tactics and communications skills; theoretical and practical applications of military marksmanship; basic marksmanship including the firing of the M16 rifle during an off campus field trip. Oral and written communication techniques and skills required of successful leaders. Students are required to participate in practical exercises which

SPECIAL PROGRAMS

apply all military skills from previous classes and several labs. Extra credit field training exercises are available. *Prerequisite: MS 101 and 102 or permission of department head.*

MS 202 Military Skills II 1:1:0

This course is a continuation of MS 201. A large portion is devoted to the study of leadership on an individual level. Principles and traits of leadership, human behavior and psychology, command, discipline, decision making, the leadership assessment program, and how to prepare to conduct performance-oriented training. The course also includes a field trip which applies all military skills and several laboratories previously taught. Extra credit field training exercises are available. *Prerequisite: MS 201 or permission of the department head.*

ADVANCED COURSE

MS 301 Leadership and Management Techniques 2:0:2 or nc as arranged

Theory and techniques used by successful leaders and managers are taught. Within the management portion, the interpersonal skills needed to lead and work with others are developed and practiced by individuals in small group practical exercises. *Prerequisite: Completion of the Basic Course or its equivalent and permission of the department head.*

MS 302 Leadership Skills I 2:2:0

Soldier skills, physical capabilities and high motivational attitudes required to meet demands of today's modern army officers. Cadets receive hands-on instruction on military equipment and practical work experience emphasizing their roles as group leaders. Students work as a team, building individual confidence as well as team reliance. A six-week leadership camp follows this course during the summer months. Students are required to attend various field training exercises to reinforce classroom training and to meet standards in land navigation and physical training. *Prerequisite: enrollment in MS 301.*

MS 303 American Military History 2:1:2 or nc as arranged

Interrelationship between the American military establishment and American society; development of the American military system; study of American wars—their causes, conduct and results; study of selected campaigns and battles; role of technology in evolution of tactics and strategy. This course includes a one-day trip to a local battlesite. *Prerequisite: none.*

MS 304 Leadership Skills II 2:2:0

This course is a continuation of MS 302. Students are required to attend various field training exercises to reinforce classroom training, plus a five-day training session conducted prior to Advanced Camp. Students must meet standards in required military skills to attend Advanced Camp. *Prerequisite: MS 302.*

Advanced Summer Camp nc

All candidates for commission through military science are required to successfully complete advanced camp, held at Fort Bragg, North Carolina. Stresses leadership and command responsibility, implemented by a command rotation system that places each student in varying positions of authority during the course of the normal military training and field operations. Emphasis on weapons training and field operations. Camp lasts six weeks and normally is attended between the third and fourth years of college. Students receive travel expenses and pay while at camp. *Prerequisites: MS 301, 302 and 304.*

MS 401 Military Law, Ethics and Professionalism 2:0:2 or nc as arranged

The military justice system to include jurisdiction, military crimes and rights of individuals, as well as the non-judicial and judicial options available to maintain discipline in the Army are examined. Ethics and professionalism in the military environment are discussed. Ethical reasoning and decision-making processes are developed and utilized in relation to case studies. *Prerequisite: Permission of the department head.*

MS 402 Applied Leadership 2:2:0

Leadership skills necessary for cadet officers to function in areas such as formal classroom instruction, planning and conducting field training exercises, and administration of the cadet battalion are stressed. The course is structured to permit formal instruction followed by a laboratory each week for practical application. Students are required to attend various field training exercises to reinforce classroom training. *Prerequisite: MS IV cadet standing.*

MS 403 Pre-Commissioning Seminar 2:2:2 or nc as arranged

Prepares senior cadets for commissioning as second lieutenants in the U.S. Army. Studies include effective communication emphasizing military correspondence and staff writing, interpersonal relations, personnel management, career planning, Army logistics and administration; duties of the junior officer. Students are required to attend various field training exercises to reinforce classroom training. *Prerequisite: MS IV cadet standing, permission of the department head.*

PHYSICAL EDUCATION AND ATHLETICS

The major goal of the Physical Education program is to offer a wide range of physical activities for the benefit and enjoyment of the student body. With guidance from their instructors, students can develop skill and success in a chosen activity while having fun and experiencing an optimum condition of physical fitness in terms of strength, agility, endurance and tension relaxation.

INTERCOLLEGIATE ATHLETICS

All full-time undergraduate students who are in good academic standing are eligible for team membership, and are encouraged to participate and win their varsity letter.

Polytechnic is a member of the N.C.A.A., E.C.A.C., and the I.A.C. and fields varsity teams in men's basketball, baseball, cross country, judo, lacrosse, soccer, tennis, wrestling, women's cross country, judo, tennis and volleyball.

INTRAMURALS

Intramural sports enjoy substantial success at Polytechnic. All students, both undergraduate and graduate, are eligible for competition in badminton, basketball, football, tennis, handball, hockey, paddleball, softball, volleyball, wrestling and other sports that may be offered. Winners of the intramural basketball and volleyball tournaments compete in the tri-state area college intramural championships.

PHYSICAL EDUCATION COURSES

The University and all of its degree granting departments strongly recommend and encourage all undergraduates to register for a minimum of two semesters of Physical Education.

Courses may be selected in any sequence. A student may elect to take the same course for more than one semester.

PE 101 Racquetball 0:2:0

Fundamentals for beginners, leading to interclass tournament play for novice and advanced players.

PE 102 Weight Training 0:2:0

Individualized weight training program developed on Nautilus and/or Universal weight training equipment. The Nautilus machines allow for rotary movement; they exercise specific muscles throughout the student's full range of motion.

PE 103 Team Sports 0:2:0

Basic skills, conditioning and strategy needed while participating in team and carry over sports, volleyball, basketball and badminton.

PE 105 Martial Art Karate And Judo 0:2:0

Fundamental principles and basic karate techniques including katas and light sparring, plus the principles of sport judo. Includes throwing techniques, matwork, and rules leading to tournament play.

FACULTY

Joseph Martini, Director of Physical Education and Athletics; B.S., Long Island University; M.S., Brooklyn College

Maureen Brazier, Associate Director of Athletics; B.A., Hunter College; M.S. Hunter College

Louis Zinser, Assistant Director of Athletics; B.S., University of Baltimore; M.S., Hofstra University

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AE Aerospace Engineering
CE Chemical Engineering
CH Chemistry
CI Civil and Environmental Engineering
CM Computer Engineering
CO Cooperative Education Program
CP Chemical Physics
CS Computer Science
EE Electrical Engineering
EP Electrophysics
EV Environmental Science and Engineering

HU Humanities and Communications
IE Industrial Engineering
IF Information Systems Engineering
LA Contemporary Liberal Arts Core Curriculum
MA Mathematics and Statistics
MC Management of Technology
ME Mechanical Engineering
MF Manufacturing Engineering
MG Management

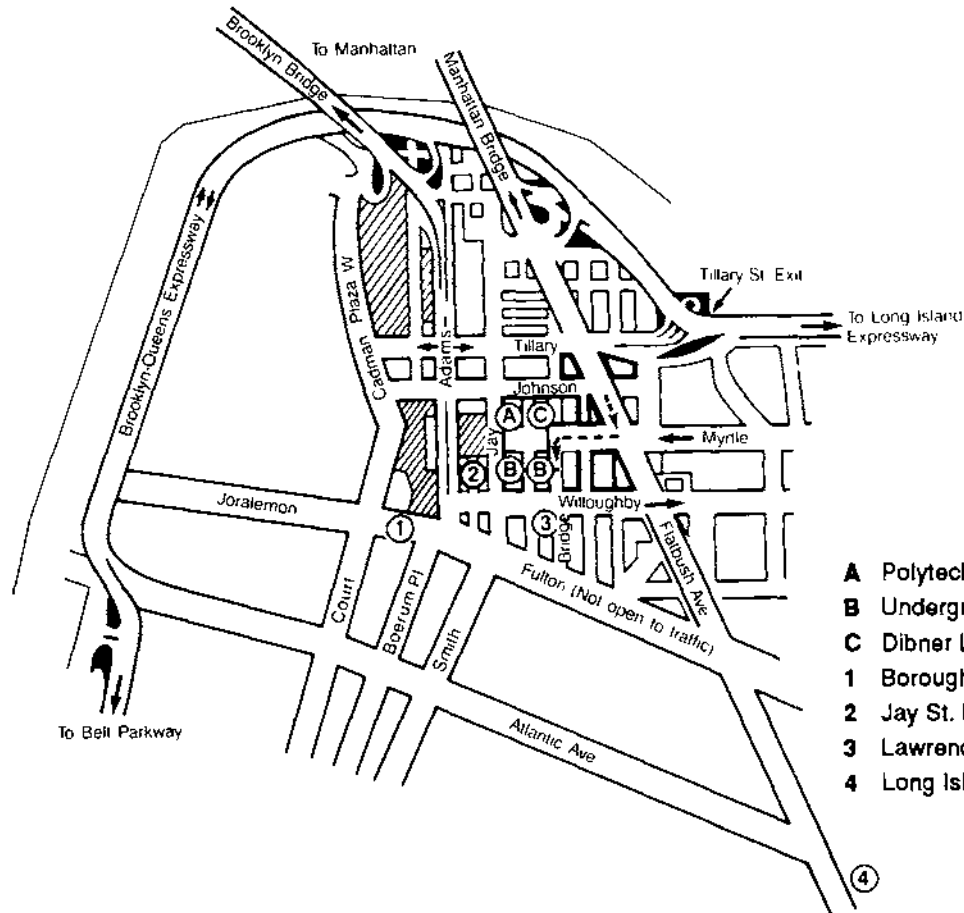
ML Military Science
MS Materials Science and Engineering (Metallurgy)
OR Operations Research
PE Physical Education and Athletics
PH Physics
PS Polymer Science and Engineering
SE Systems Engineering
SS Social Sciences
TM Telecommunications Management
TP Transportation Engineering

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The Routes to Polytechnic— Brooklyn Campus



- A** Polytechnic University
- B** Underground Public Parking
- C** Dibner Library/CATT Building
- 1** Borough Hall **2,3,4,5**, Subways
- 2** Jay St. Borough Hall **A,F,C**, Subways
- 3** Lawrence St. **R,M**, Subways
- 4** Long Island Railroad - Flatbush Ave.

from Manhattan

by subway—A, C or F train to Jay St.-Borough Hall; or the 2,3,4 or 5 subway to Borough Hall (walk to Fulton and make a left onto Jay) or the R or M to Lawrence St.

by car—take the FDR Drive to the Brooklyn Bridge, make the first left after the bridge onto Tillary and a right onto Flatbush.

* From Flatbush go right onto Myrtle and the second left onto Bridge St. Public parking is available on the lower levels of the SIAC and Brooklyn Union Gas buildings for \$10 a day.

Queens or the Bronx

by car—take the Brooklyn-Queens Expwy. to Tillary St. and then left onto Flatbush Ave. Continue from *.

Staten Island

by car—Take the Verrazano Narrows Bridge to the Brooklyn-Queens Expwy. to the Tillary St. exit. Make a left onto Flatbush Ave. Continue from *.

New Jersey

by car—From the George Washington Bridge take the Harlem River Drive to the FDR Drive or Holland Tunnel to Brooklyn Bridge. (Continue as from Manhattan)

Brooklyn or Long Island

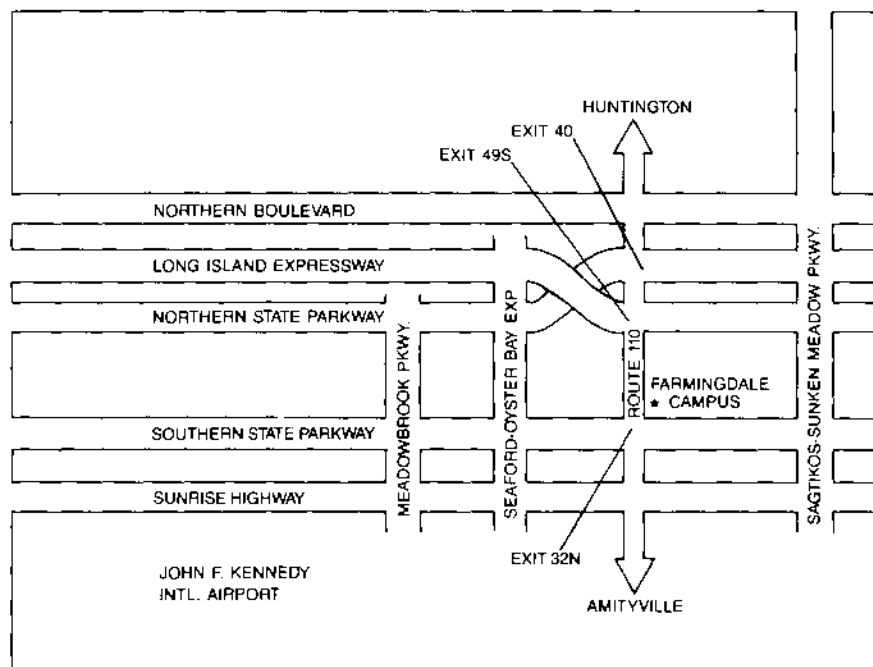
by train—Take the Long Island Railroad to Flatbush Ave. Then take a taxi, bus #B67 to Metrotech on Jay St., or the R or M subway to Lawrence St. It's about a one-mile walk from the LIRR station: go to the Fulton Mall and make a left, then a right onto Jay St.

by car—Brooklyn-Queens Expwy. to the Tillary St. exit. Go left onto Flatbush, continue from *.

Westchester

by car—Take the Major Deegan or Cross Bronx Expwy. to FDR Drive to Brooklyn Bridge or the Triborough, Whitestone or Throgs Neck Bridge to Brooklyn-Queens Expwy. to Tillary St. From there take a left onto Flatbush Ave., continue from *.

The Routes to Polytechnic— To the Long Island Campus at Farmingdale



Directions from:

New York City

- by train: Take the Long Island Railroad (LIRR) to the Amityville Station-taxi or buses available.
- by car: Take the Long Island Expressway to Exit 49 S. South on Route 110 four miles to campus on left.
Or, Northern State Parkway to Exit 40 S. then south on Route 110 for five miles to campus on left.
Southern State Parkway to Exit 32N, then north on Route 110 for one mile, campus on right.

New Jersey

- by train: Penn Central, or Commuter Lines to Penn Station, the LIRR as above
- by car: Same directions as from New York City.

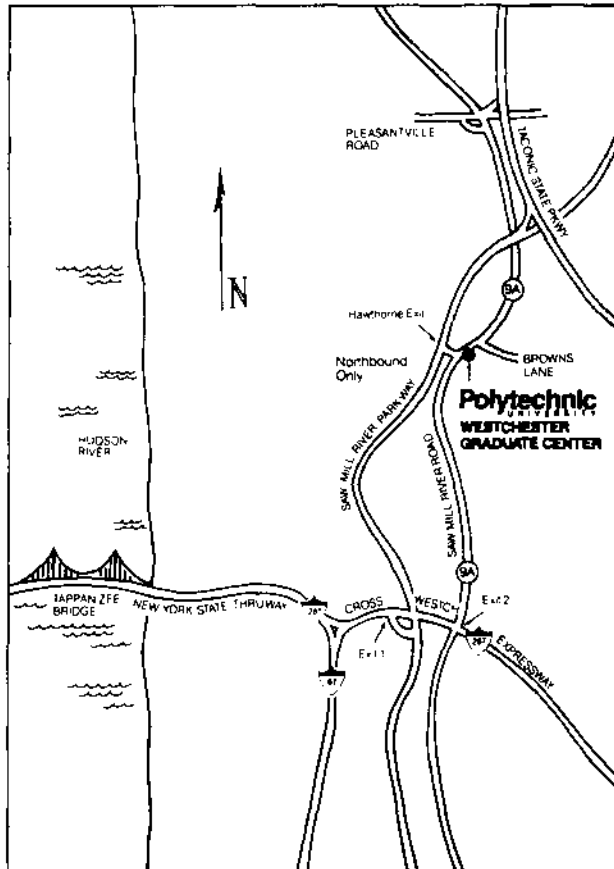
Westchester

- by train: To Grand Central, taxi or Shuttle (S) train to Penn Station, LIRR as above.
- by car: Whitestone or Throgs Neck Bridge to Cross Island Pkwy. (South) to Long Island Expressway East or Northern State Parkway East (then same as from NYC).

Eastern Long Island

- by car: Long Island Expressway to Exit 49S which is Route 110; the campus is four miles on the left. Or, Southern State Parkway to 32 North, (Route 110) for one mile, campus on right.

The Routes to Polytechnic— To the Westchester Campus



Directions from:

West

NY State Thruway East across Tappan Zee Bridge. Take Exit 8. Going east on Interstate 287, take Exit 1: Saw Mill River Pkwy. North. Go 3 miles and take the Hawthorne (route 9A) Exit to Saw Mill River Road. Turn left (north) on 9A, Polytechnic is on the right.

East

Going west on Interstate 287 take Exit 2: Route 9A-Saw Mill River Rd. Go north 3 miles, Polytechnic is on the right.

South

Going north on Saw Mill River Pkwy. take the Hawthorne exit to Saw Mill River Rd. Follow directions above for traveling from the west.

North

Take the Taconic State Pkwy. South to Pleasantville Rd. Go 1/4 mile west to Route 9A South. Go 4 miles. Polytechnic is on the left.

Polytechnic University is an equal opportunity institution. The University is diverse in its representation of various racial, ethnic, and economic backgrounds. It strives to maintain that diversity not only to comply with state and federal statutes, but also to provide an educationally desirable environment.

The University does not discriminate in admission, or access to, or treatment or employment in its programs and activities on the basis of race, color, religion, national origin, handicap, Vietnam veteran status, age, or sex. This statement is published in part to fulfill the requirements of Section 86.9 of title 45, **Code of Federal Regulations**, which implements Title IX of the Education Amendments of 1972.

Inquiries about the above policies may be directed to the Affirmative Action Office, Polytechnic University, Six Metrotech Center, Brooklyn, New York 11201.

The University is authorized under federal law to enroll non-immigrant alien students.

This catalog is not intended to be, and should not be regarded as, a contract between Polytechnic University and any student or other person.



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