COMPUTING ACTIVITIES

Columbia University Bulletin

1977-1978

Directory

Post Office Address of the University: Columbia University, New York, N.Y. 10027
This address should be preceded by division name and building address as given below; exception: the School of Public Health. The telephone area code is 212.

UNIVERSITY CENTER FOR COMPUTING ACTIVITIES

General information; additional copies of this bulletin: User Services Office, 115 Computer Center; telephone 280-3555

Reference Room: 109 Computer Center, telephone 280-4330

Technical Consultant: 115A Computer Center; telephone 280-3631

INFORMATION ON ADMISSION, DEGREE REQUIREMENTS, AND FEES, FOR DIVISIONS AND AFFILIATES OF THE UNIVERSITY OFFERING COMPUTING COURSES OR DEGREE PROGRAMS

Graduate School of Architecture and Planning, 400 Avery Hall; telephone 280-3510

Graduate School of Arts and Sciences, 106 Low Memorial Library; telephone 280-3808

Graduate School of Business, 105 Uris Hall; telephone 280-5567

Columbia College, 208 Hamilton Hall; telephone 280-2521

Program for Continuing Education, 103 Low Memorial Library; telephone 280-3331

School of Engineering and Applied Science, 530 Seeley W. Mudd Building; telephone 280-2931

School of General Studies, 509 Lewisohn Hall; telephone 280-2752

School of International Affairs, 106 Low Memorial Library; telephone 280-3808

School of Library Service, 516 Butler Library; telephone 280-2294

School of Public Health, Faculty of Medicine, 600 West 168th Street, New York, N.Y. 10032; telephone 694-3927

Summer Session, 103 Low Memorial Library; telephone 280-3331

Teachers College, 146 Horace Mann; telephone 678-3710

University Seminars, 606 Dodge Hall; telephone 280-2389

Computing Activities

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Foreword

This bulletin provides information on opportunities for computer study at Columbia University, as well as information about computing facilities available to the University community.

The resources of the University Center for Computing Activities (described under *Center Facilities and Services*) provide equipment and services to support the general-purpose computing needs of the University. A number of more specialized computing laboratories are also available (see *Other Computing Facilities*).

Three kinds of computer study are offered: courses that train specialists in the theory and practice of computing, those that teach students from other fields to apply computing techniques to their work, and courses that introduce students to the concepts of computing. Descriptions of these courses are given under *Computer Study* in this bulletin.

University Center for Computing Activities

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LEONARD L. LEAVY. *Assistant to the Director*

MICHAEL MARGITICH. *Assistant to the Director*

HOWARD ESKIN. *Associate Director for Computer Systems*

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Frank Ward
Victor Warren
Gail Webb
Sandra Wolf
Caroline Wueschner

Center Facilities and Services

The University Center for Computing Activities is maintained by the University as an educational, research, and service facility for University faculty members, research staff, students, and administrative offices. The facilities of the Center are available for:

1. Activities of the faculty and students of the University that are essential to, or appropriate for, a degree program in the University;
2. Research projects under the direction of the academic staff of the University that are consistent with the purposes of the University and that are subject to financial audit by the University administration;
3. Activities of students in the University that are in consonance with the educational aims of the University;
4. Computing activities related to the support of internal administrative functions of the University;
5. Activities of other accredited universities or colleges, or of other nonprofit research organizations, that are in consonance with the purposes of the Center and the University.

Through its facilities, the Center serves as a focal point for the computing activities of the University. Besides maintaining equipment, it provides many services that support the daily use of the computer.

Computing Systems

IBM 360 System

One of the several computing systems maintained by the Center for Computing Activities is an IBM 360 Model 91 coupled to a 360 Model 75. Both are very large and powerful machines, with the 91 particularly suited to scientific calculation. Columbia's 91 has two million bytes of high-speed core storage; the 75 has a half-million-byte high-speed store and two million bytes of lower-speed extended core storage. The 91 and 75 are attached by a hardware link and are normally controlled by a single unified supervisory system. The basis of the system is OS/MVT, locally modified for ease of use and administration, and run with ASP (Attached Support Processor), a control program that operates within OS and performs resource scheduling.

Available within the 91/75 system is Wylbur, a teleprocessing system developed at Stanford University, and APL/SV, an interactive system based on the APL language and supplied by IBM. Wylbur provides a facility for submitting jobs to ASP/OS from a remote low-speed terminal and retrieving results from the same terminal. It also provides extensive and sophisticated facilities for interactive file input, editing, search, and manipulation. APL is a self-contained interactive system providing an extremely powerful language for small and medium-scale problems. It is especially well suited to mathematical problems, but also has considerable string-handling capabilities.

The Open Batch system is intended to encourage student use of the Center by simplifying the running of small jobs under ASP/OS. The only requirements are that users be Columbia University students, their programs fit within certain constraints on resource utilization, and the work be educational in nature. Within the constraints specified, students should be able to compile and execute small programs written in most of the major languages supported by the Center.

Many Center users rely on traditional punched-card input and printed output; these input/output functions are normally performed by the user at self-service readers and printers.

Jobs with large output or long delays between input and output can be printed by the Center operations staff and the output picked up at the user's convenience. An increasingly large number of Center users are using remote terminals for job entry; a variety of terminals can be connected to the system, including high-speed remote work stations; lower-speed hard-copy, CRT, or graphic terminals; and small special-purpose computers. Most of these remote devices are obtained by user departments, although a modest number of "public" terminals are available at the Center.

The 360 system is used in support of research, instructional, and administrative activities of the University community. APL and the Open Batch System are primarily geared toward student use. The system is best suited, however, to the requirements of research, and it is anticipated that in the future more and more of the system resources will be made available to the research community as instructional and administrative users are accommodated on systems better tailored to their particular requirements.

DEC Systems

A PDP 11/50 with ninety-six thousand 16-bit words of memory is controlled by the RSTS/E operating system. Up to thirty-two on-line terminals can be accommodated on this interactive system. Small and medium scale problems can be solved using the interactive language Basic-Plus. The system is used almost entirely by students.

Interactive computing for both students and faculty is being expanded by the acquisition of a Decsystem-2050, a medium-scale computer especially designed for interactive computing. The system will have a quarter-million words of main memory, and will be controlled by the Tops-20 operating system. This system will provide a convenient user interface, file and program sharing, a relatively secure file system, and a wide variety of interactive languages and program packages. It will support sixty-four on-line terminals plus several remote-job-entry stations and on-line remote laboratory minicomputers.

IBM 370 Systems

Acquisition of an IBM 370/138 with one million bytes of main memory is expected to accommodate some of the administrative applications currently being run on other systems. The 138 will run under the VM/370 operating system. This system will soon be upgraded to a 370/148 with two million bytes of main memory. Planning and configuration of the 370 systems have been carried out with administrative applications in mind. It is anticipated that the 148 will accommodate most of the major administrative applications of the University.

Languages and Programming Aids

Programming languages available on the Center system include Algol, APL, 360 Assembler Language, Basic, Cobol, Fortran, PL/I, Snobol, and Utility Coder/360. (Multiple versions are maintained for some of these languages.) Of these, Fortran and PL/I are generally used for scientific applications; Snobol is used for text processing and non-numeric symbol manipulation; Utility Coder/360, Cobol, and PL/I are used for administrative applications. Most of the languages listed above are taught in one or more University courses.

The Center maintains an extensive collection of other programming facilities, including special-purpose programming systems, problem-oriented program libraries, and individual programs of greater or lesser generality. Included are standard utility programs, scientific application packages, a wide variety of packages for statistical analysis, several simulation and modeling packages, plotting facilities, and text-processing programs. Complete lists of available programs, their functions, and procedures for using them can be found in the Reference Room and in the *Guide to Facilities* (see Documentation, below).

User Services Office

The User Services Office, in 115 Computer Center, is the main source of information about procedures, accounts, and facilities provided by the Center. Here one can obtain introductory literature about the computing facilities, information about procedures to be followed for gaining access to the computer system, and pointers to more advanced information or assistance with problems. User Services Office hours are from 9 a.m. to 5 p.m., Monday through Friday.

Reference Room

The Reference Room, in 109 Computer Center, maintains a file of vendor manuals that pertain to the equipment used at the Center and has information about programs available at the Center and programs in use at other computer installations. Volumes may not be removed from the Reference Room. (Some vendor manuals are available for purchase.) Reference Room hours are from 9 a.m. to 5 p.m., Monday through Friday.

Documentation

The Center produces several documents designed to keep computer users, members of the University, and members of computer installations on other campuses abreast of developments at Columbia. *A Guide to Facilities,* which describes Center services and procedures, is available free of charge in the User Services Office. Major technical and administrative documentation appears in the *User's Manual* and the *Wylbur Manual;* copies are available in the Reference Room for reference or for purchase. As new programming facilities become available, their use is described in appendixes and revisions to these manuals, which are distributed without charge to Center users; a file of appendixes is kept in the Reference Room. The Center publishes the biweekly *Newsletter,* which includes articles of importance to Center users as well as descriptions of current Columbia computer research. The *Newsletter* is available without charge to anyone interested in computing at Columbia; a copy can be obtained in the Reference Room.

Instruction

Throughout the calendar year, the Center offers a series of tuition-free noncredit courses in the use of digital computers. These courses are open to faculty members, members of the research staff of the University, and students who are regularly enrolled in the University. Priority in the filling of class quotas is given to individuals who are pursuing or preparing to pursue a project at the Center. Application forms for admission to Center courses are available in the User Services Office. Questions should be telephoned to 280-4007. Applications are due one week in advance of the first session of the course. A non-refundable registration fee is required.

The courses are scheduled, and their content planned, in response to the immediate and changing requirements of the users of the Center, and changes in the computer systems and programming languages available at the Center are reflected in class schedules. Classes are usually announced by the Center at the beginning of the term in which they are offered. Typical course offerings include *Introduction to computing, Programming fundamentals, Job control language, Wylbur,* and *Introduction to computing for the social sciences.*

Programming and Consultation Services

The Center provides a variety of consultation services to the University community. A student consulting service is available to students with problems in basic coding and operating procedures; this service is available from 9 a.m. to 5 p.m., Monday through Friday, in the Self-

Service I/O Area. Senior consultants in Room 115A help users with more complex problems, other languages, library programs, and general questions about Center facilities. Some problems may require that an appointment be made with a member of the Center staff who has special expertise in the problem area. To illustrate the scope of services provided, the following might be cited: advice on setting up a project, choice of the appropriate language or library program, adaptation of programs obtained elsewhere, and advice on coding data. Consultants will not, however, do programming or coding for the user.

An additional service is available for instructional projects. If requested, a consultant will come to a class meeting to give a lecture suited to the particular needs of teacher and students, and to instruct the class in current Center procedures.

Each project is expected to secure its own programming support, as well as to provide for keypunching or other related services. The Center maintains a file of programming and keypunching services available for hire. The Center does not attempt to seek out such services and cannot guarantee the quality of the work performed.

Note: The Statistical Consulting Service, in 618 Mathematics, is maintained by the Department of Mathematical Statistics in order to assist researchers on problems of statistical design of experiments or statistical analysis and inference. Inquiries and requests for appointments should be directed to the department secretary, telephone 280-3653.

The Computer Services Office of the Center for the Social Sciences, in Rooms 204 and 205 International Affairs, offers consulting on problems related to statistics and computer programming. The office also houses several Wylbur terminals available to students and faculty. Office hours are 9 a.m. to 6 p.m. daily, with consulting available after 1 p.m.; telephone 280-3621.

Access to Center Facilities

Computer systems are available for use throughout the calendar year.

Columbia faculty members and students with computer applications that make modest demands on system resources can usually avail themselves of one of the services for which there is no direct charge: 360 Open Batch, APL/SV, RSTS/Basic, or some limited-use functions of the Decsystem-2050. Use of these facilities requires the assignment of an authorized user account, but usage is not directly charged to the student or faculty member. The only requirements are that the work be educational in nature and that it not exceed the resources allocated to these services. Application forms and procedural information are available in the User Services Office.

For use that is not strictly educational in nature, use by other than Columbia faculty and students, use that exceeds the resource limitations on the services mentioned above, or use that requires other system facilities, special authorization must be obtained and arrangements must be made for covering computing costs. Authorization is granted in one of five categories:

1. Research projects, which must be sponsored by a member of the regular academic faculty holding the rank of assistant professor or higher. Forms from faculty members with clinical, research, visiting, or adjunct appointments must indicate the cosponsorship of the department chairman, dean, or director.
2. Thesis projects, which must be sponsored by the student's thesis adviser or by another member of the regular academic faculty holding the rank of assistant professor or higher.
3. Instructional projects, which must be sponsored by the instructor of a regular University course.
4. External projects supported by funds not administered by the Office of the Controller of Columbia University. Requests for projects from organizations that have not obtained project authorization in the past must be approved by the Director of Computing Activities.

5. Administrative projects, that is, projects originating in administrative offices of the University, or projects that are fundamentally administrative but originating in academic departments. Administrative projects must be approved by the Director of Computing Activities, telephone 280-3031.

Authorization must be obtained for:

1. Research, Thesis, Administrative, or External projects: *(a)* before the start of the project; or *(b)* when the authorization period of an existing project has lapsed or its support status, sponsorship, or scope has changed.
2. Instructional projects: at the beginning of the term in which the associated course is offered.

Charges for the use of Center facilities are applied to an account associated with each project number. If a project is supported by a contract or grant or receives funds from outside the University (external sponsorship), arrangements for covering computer costs must be made during the processing of the application for a project number. This is ordinarily done by submitting a requisition mortgaging funds for computer use. A project supported by the University receives funds from a University pool. Application for such funds is made to the relevant department chairman or dean.

Decision on a properly sponsored and supported application is made within a week after the return of the form to the Center. Notification of authorization and the project number are mailed to sponsors.

Users with authorized project numbers must apply separately for access to the Wylbur system. Most users can be authorized to use Wylbur, but special application procedures are required since Wylbur use by some projects may be impractical. Authorization includes the assignment of on-line direct-access space for user files, and of unique identifiers for access to the system. University pool funds may not be used to pay for on-line Wylbur space.

For all of the various types of authorizations described above, application forms and procedural information may be obtained in the User Services Office.

Statement of Nondiscriminatory Policies

Columbia University admits students of any race, color, national and ethnic origin to all the rights, privileges, programs, and activities generally accorded or made available to students at the University. It does not discriminate on the basis of race, color, national and ethnic origin in administration of its educational policies, admissions policies, scholarship and loan programs, and athletic and other University-administered programs.

Consistent with the requirements of Title IX of the Education Amendments of 1972, as amended, and Part 86 of 45 C.F.R. (to which Columbia University is subject), the University does not discriminate on the basis of sex in the conduct or operation of its education programs or activities (including employment therein and admision thereto). Inquiries concerning the application of Title IX and Part 86 of 45 C.F.R. may be referred to Ms. Beverly C. Clark, the University's Equal Opportunity Officer (309-C Low Memorial Library, New York, N.Y. 10027, telephone 212-280-3554), who has been designated as the University's Title IX Coordinator, or to the Director, Office for Civil Rights (Region II), 26 Federal Plaza, New York, N.Y. 10007.

Other Computing Facilities Associated with the University

Although the University Center for Computing Activities provides the equipment and services to support the general-purpose computing needs of the University community, activities at the Center are only a part of the computer work that is being conducted by University members and affiliated or cooperating institutions. A number of other computing facilities, including both hardware and local support services, address more specialized needs.

The Department of Biological Sciences operates a Computer Graphics Facility in Schermerhorn. It consists of an Adage AGT/50 interactive graphics computer which is connected by a high-speed hardware link to the University's central 360/91. Graphics applications are further supported by a variety of graphics peripheral devices and remote-job-entry terminals to the Wylbur system. Current applications include three-dimensional nerve tracing, molecular model building, automated crystallographic analysis, x-ray diffraction and electron microscopy image processing. The Facility also has a PDP-11/45, a GT/40 Graphics Computer, several storage-tube graphics terminals, and a picture digitizer. This summer the facility will be moved to the new Fairchild Life Sciences Center, and in addition the communication link will be upgraded to allow high-speed data transfer between the PDP-11 and the 360/91.

The Graduate School of Business has extensive facilities in Uris Hall for student use of time-sharing and remote-job-entry terminals connected to the central facility. During the first term of study, every M.B.A. candidate is given an intensive course in computer technology, including programming in Basic, and receives further assistance in programming when courses require computer use.

The Chemical Engineering Research Laboratories have a Hewlett-Packard 2100 in Prentis Hall. Peripheral equipment includes a 15-megabyte disk, a tape drive, a printer, a teletype, a high-speed paper tape reader and punch, a Zeta incremental plotter, a 300-channel cross bar scanner system with digital interface for 10 Hz sampling rate, and a 112-channel high-level multiplexer with 45 KHz sampling capability (a dual-channel digital to analog capability). The system is used for on-line data acquisition and control of steady state and transient heat transfer experiments.

The Department of Chemistry has a Nova 1220 in Havemeyer Hall for real-time data capture and analysis of laser light scattering data. The mini-system is configured to allow transmission of data via Wylbur for batch-processing analysis on the central /91 and /75. Three PDP-8s are used for real-time data analysis—one for nuclear magnetic resonance spectroscopy, one for cross beams laser data, and the other in conjunction with automated x-ray equipment. The Department also has a Nicolet 20K 20-bit word dedicated computer for use in Fourier analysis of nuclear magnetic resonance data. An additional dedicated computer is in use with a Finnigan 3300 quadrapole mass spectrometer.

The Department of Civil Engineering and Engineering Mechanics has a Hewlett-Packard Fourier Spectrum Analyzer in the Seeley W. Mudd Building. The system is used for computer structural dynamic tests, on-line spectral analyses, and experimental data reduction and processing.

The Department of Electrical Engineering and Computer Science has a Data General Super Nova and a PDP-7 in its Computer Laboratory on the twelfth floor of the Seeley W. Mudd Building. Peripheral equipment for the Super Nova includes a disk, a teletype with paper tape reader, a line printer, and a digital cassette recorder. Other digital laboratory equipment is also available. Until the spring of 1972 this laboratory was used primarily for research, with emphasis on the areas of programming languages, operating systems, and artificial intelligence. With the creation of two senior independent study courses, however, the Super Nova is beginning to be used for instructional purposes as well. For further information contact Professor Bashkow, telephone 280-2195 or 280-3104.

The Lamont-Doherty Geological Observatory is a research establishment that brings together the tools of physics, chemistry, biology, mathematics, and geology for study of the earth. Students at the Observatory are also candidates for advanced degrees in one of the departments of the University. To service its research needs, the Observatory has both laboratory-based computer systems and systems designed for shipboard use on the research vessels *Vema* and *Robert D. Conrad*. A PDP-11/70 has recently been installed as the main computer system for the Observatory. In addition, two Data General Novas are dedicated to processing of digital marine seismic data. PDP-11/20 computers are in operation on both vessels and are used primarily to assist in the acquisition, processing, and graphic display of oceanographic data while the ships are at sea. In addition, the PDP-11/70 is linked via telephone lines to the central 360/91. Through cooperative arrangements with the NASA Institute for Space Studies, programs such as those in meteorology also have access to the IBM 360/95 at the Institute. For further information on the program offered by the Observatory contact Lamont-Doherty Geological Observatory, Columbia University, Palisades, N.Y. 10964 (telephone: area code 914, 359-2900).

The Division of Nuclear Science and Engineering has, in the Engineering Terrace, an SEL 810B, an Imlac graphics processor, a PDP-8, and a PDP-11 for general research calculations.

The staff of the College of Physicians and Surgeons engages in a number of computer-based projects, many of which make use of the University's central computer, but some of which make use of smaller local machines. A PDP-8/9 is used for radioisotropic brainscan analysis. A PDP-8 is used for radiological physics, another for research in amino acids, and another for analysis of ophthalmological data. A Linc-8 is used for electroencephalographic and experimental epilepsy studies. A PDP-11/45 is used with the Unix time-sharing system for cancer research. A PDP-11/10 connects the William Black Medical Building with the University's central facility for transmission of programs and data. Another PDP-11 is used for experiments in computer-assisted instruction. A network of four PDP-11s supports research projects related to cardiovascular and pulmonary diseases, and another is used for anesthesiological data. A PDP-12 is used for electrophysiological analysis. Two Prime 300s support work in the Department of Surgery, while another Prime 300 is used for pediatric research. An HP2100A is used for clinical investigation in obstetrics and gynecology, with an HP21MX being used for patient management.

The New York Psychiatric Institute uses an IBM 360/44 for statistical analysis and a PDP-12 for laboratory analysis. The Presbyterian Hospital has two IBM 370/145s for administrative systems, patient care data, and laboratory analyses.

The Department of Physics makes use of a variety of computers in its research laboratories for both on-line and off-line purposes. The Nevis Laboratories in Irvington, New York, house the department's extensive facilities in high-energy and medium-energy nuclear physics, including a 500 MeV synchrocyclotron. The computing facilities at the Nevis Laboratories include an IBM 360/44, an EMR 6130, a PDP-11, and a PDP-15. An automatic film measurement system is available for the analysis of particle reactions in bubble chamber photographs. The system consists of a high precision digitizing device coupled to a 360/65. A PDP-11/70 data acquisition system is used by Columbia experimenters at Brookhaven National Laboratories. The Columbia Astrophysics Laboratory in Pupin Hall has two Data General Nova 820s used in connection with the orbiting solar observatory, and a Nova 1210 for the optical astronomy program. The Intermediate Energy Nuclear Physics Group in Pupin Hall has an interacting system of computers consisting of a PDP-8, a PDP-9, and a PDP-11/10. The computers are used both on-line and off-line in an experimental research project on exotic atoms. The George B. Pegram Nuclear Physics Laboratory uses a PDP-4 and a PDP-8 for data acquisition in nuclear orientation and angular correlation experiments using a ^{3}He-^{4}He dilution refrigerator. The PDP-4 is also used for analysis and plotting of data obtained in orientation, angular correlation, double-beta decay, and Mössbauer experiments. The Columbia Radiation Laboratory in Pupin Hall uses three PDP-8s and a Data General Nova 1220 for research in low-temperature, molecular, atomic, and solid-state physics.

The Department of Psychology has a PDP-8 used for real-time control of learning laboratory experiments, as well as for preliminary data analysis. Another PDP-8 is used for

control of human visual experiments. A Linc-8 is used for control of psychophysical and physiological experiments, and for processing of analog and digital data. A CRT is used for visual display of psychophysical stimuli.

The Center for the Social Sciences, in the International Affairs Building, operates as a research laboratory that promotes and facilitates empirical research in the social sciences at Columbia. It provides services to students and scholars in the social sciences throughout the University. The Center is prepared to: help identify and secure sources of research support; locate and obtain appropriate sources of data from archives here and elsewhere (e.g., ICPSR at the University of Michigan); provide assistance and advice on the use of computers and statistical methods for empirical analysis; offer non-credit instruction on the use of computer systems; and coordinate laboratory materials for research and methods resources. In addition, the Center carries on a program of research based on grants or contracts. For information on data archives and computer services, contact Ms. Pnina Grinberg, 201 International Affairs Building, telephone 280-3038.

The Institute for Space Studies is a theoretical research institute of the Goddard Space Flight Center, National Aeronautics and Space Administration. The program of the Institute stresses theoretical research in areas of the earth sciences and astronomy of special interest to the physicist, meteorologist, and geologist. Cooperative arrangements exist between the Institute and the University Committee on Atmospheric and Space Science, the Lamont-Doherty Geological Observatory, and the Departments of Geography, Geological Sciences, and Astronomy. The Institute's computing facility, including an Amdahl 470/V6, an IBM 360/95, and a variety of peripheral devices, may be used by University members associated with these cooperative programs.

The Teachers College Center for Computing and Information Management Services (CCIMS), 244 Horace Mann, offers computing support to both academic and administrative activities of the College. Support is biased toward the autonomous use of computing facilities by the individual student. Toward that end, CCIMS offers a broad spectrum of service to students, ranging from training and instruction to machine usage. CCIMS hardware includes a Burroughs B4700 computer with card, tape, and disk peripherals; keypunches; and off-line card manipulation devices. Details on all services, on schedules of operation, and on any charges are available in the CCIMS offices (telephone 678-3484).

Computer Study

For students interested in becoming specialists in the theory and practice of computing, a variety of degree programs is available in the University.

The Department of Electrical Engineering and Computer Science of the School of Engineering and Applied Science offers degree programs in computer science at all levels. Programs lead to the B.S., M.S., professional, Eng. Sc.D., and Ph.D. degrees. These programs provide instruction and stimulate research in the theoretical properties, organization, and application of computers. Concentrations in programming languages, computer system analysis and design, and linguistics and automata theory are possible.

The Department of Mathematical Statistics offers a major and a concentration toward the B.A. degree program in Columbia College or the B.S. degree program in the School of General Studies. The Departments of Mathematical Statistics and Mathematics cooperate in offering a graduate program in computing science in the Graduate School of Arts and Sciences. Although previous work in computing is desirable, it is not necessary for participation in the program. The course of study is arranged in consultation with a member of the Interdepartmental Committee on Computing Science. To earn the M.A., M.Phil., or Ph.D. degree in computing science, the student must meet the requirements of one of the participating departments.

At Teachers College, the Department of Mathematics, Statistics, and Computing in Education offers courses dealing with: man/computer communication; administrative uses of computing; and instructional uses of computing. These courses do not presuppose a mathematics background or employ extensive mathematics. Degree programs lead to the M.A., Ed.M., M.S., Ed.D., and Ph.D. degrees.

This bulletin includes the courses most directly related to computer science available under these programs. Students interested in the programs described above should obtain a copy of the bulletin of the appropriate school for information on admission, courses of instruction, and degree requirements.

In addition to those departments offering degrees in the computing disciplines, many departments offer single courses or programs of study that emphasize the interactions between computer science and the subject discipline of the department or school. A majority of these courses are designed to prepare the student to apply computer technology to his or her field of study. This bulletin also lists such courses, and attempts to include any course bearing a strong relationship to computer science and technology.

The courses are grouped into three major categories: introductory courses, courses in applications and related areas, and computer science courses.

Introductory courses have few prerequisites and assume no knowledge of computing. Although they may be designed for students in a particular school or department, they are generally of potential interest to a much wider audience.

Applications and related areas include specialized courses that deal with relationships between computer technology and other disciplines, including the application of computer techniques to particular research problems. Such courses are of potential interest to the student of computer science as well as to the student of the subject discipline.

Computer science courses are designed for students with specific interest in some aspect of the discipline that is growing out of the development of the computer. The subject matter of this discipline can be subdivided as follows: theoretical properties of computation and information structures; organization and design of hardware and software systems; and application techniques.

Not included is the large array of courses in which the computer is used as a routine computational aid, or where programming techniques are taught as a minor part of the subject matter.

Key to Course Listings

The capital letter at the beginning of each course number indicates the University division for whose students the course is primarily offered:

A Architecture
B Business
E Engineering & Applied Science
G Graduate School of Arts & Sciences
K Library Service
P Public Health
Q Continuing Education
S Summer Session
T Teachers College
U International Affairs
W Interfaculty

The first digit of the course number indicates the level of the course, as follows:

SCHOOL OF LIBRARY SERVICE

6 Basic course for the M.S. degree
8 Advanced course, open to both M.S. and D.L.S. degree candidates
9 Seminar designed for D.L.S. degree candidates

TEACHERS COLLEGE

3 Course for graduate credit
4 Course for intermediate graduate credit
5 Course for advanced graduate credit

ALL OTHER DIVISIONS LISTED IN THIS BULLETIN

1 Undergraduate course
3 Advanced undergraduate course
4 Graduate course open to qualified undergraduates
6 Graduate course
8 Advanced graduate course
9 Graduate research course or seminar

The letter following a course number designates the term in which the course is given: *x*, autumn term; *y*, spring term.

Two consecutive course numbers joined by a hyphen indicate a course which runs through both terms (e.g., *Architecture A6103x-A6104y*). The first half is prerequisite to the second half unless the course description says otherwise.

The number of points of credit that a course carries *per term* is given in boldface type in the right margin of the course-title line.

The course-title lines of *courses not given* in the current academic year are enclosed in brackets.

Room Assignments and Course Changes

Room assignments and course changes for most schools are published in a separate bulletin which is distributed at registration.

The days, hours, and room assignments for all courses given in the Graduate School of Architecture and Planning are posted in Avery Hall at the time of registration.

Detailed course schedules for the Graduate School of Business, including instructors, sections, hours, and terms, are published in a separate announcement which is available to students about four weeks before registration.

Class hours, room assignments, and course changes for the School of Engineering and Applied Science are published in a separate bulletin, which is distributed at registration

Hours for courses in the School of Library Service are available on request from the School.

The University reserves the right to withdraw or modify the courses of instruction or to change the instructors as may be necessary.

The University reserves the right to withhold the privilege of registration or any other University privilege from any person with unpaid indebtedness to the University.

Introductory Courses

School of Engineering and Applied Science

Computer Sci. E1801x or y. Introduction to digital computation. 3 pts

Since each of the four sections of this course is limited in size, section approval must be obtained in Room 1312 Seeley W. Mudd prior to registration.

Nomenclature: elements of computer structure and languages. The Fortran language. Computational algorithms, numerical solutions and introduction to numerical methods, computational errors. Student programs are run at the University Center for Computing Activities.

Computer Sci. E4811x or y. Digital computers: engineering applications. 3 pts

Not open to students who have taken *Computer Sci. E1801* or the equivalent.

Computer programming: use of procedure-oriented language. Simple applications: single and multiple parameter design equations, implicit solutions. Methods and solutions for typical engineering problems; analysis flow charts, program details. Introduction to simulation techniques. The laboratory is devoted to detailed discussion of the coding and running of student programs; a computer is available for use.

School of Public Health

Public Health P6120. Computer fundamentals and programming. 4 pts
Three lectures, two laboratory sessions a week.

Prerequisite: the instructor's permission.

Computer organization, available hardware, telecommunications; introduction to Job Control Language, tape and disc management; basic programming, flow charting, PL-I; interactive languages, heuristic algorithms, with computer exercises drawn from statistics and applied mathematical problems in health.

Program in Continuing Education

Computing Systems Q0001x or y. The nature and use of digital computers.
Five sessions, Tu 6-8 p.m., plus laboratory hours to be arranged.
***x*: Oct 25-Nov 29, excepting Nov 8; *y*: dates to be announced.**

An introduction to modern digital computers and to their impact on modern society. Elementary concepts of computer programming. Applications, capabilities, and limitations of the computer as a tool in science, the humanities, education, and industry. The laboratory will give participants the opportunity to operate a computer terminal and to experiment directly with a variety of programs such as simulation models, computer-directed instruction modules, tools for business and research, and simple experiments in machine learning. No previous exposure to computers is required.

Computing Systems Q0301x or y. Elementary computer programming.
Five sessions, Th 6-8 p.m., plus laboratory hours to be arranged.
***x*: Oct 27-Dec 1, excepting Nov 24; *y*: dates to be announced.**

Computing Systems Q0001 is a natural predecessor, but not a prerequisite, for this course.

Fundamentals of computer programming, using a time-sharing system, the programming language Basic, and a mixture of lectures and computer-directed instructional modules. Students have access to a minimum of five hours' hands-on experience in the laboratory. Topics include: program structure; loops; lists and tables; numerical operations; processing character strings; functions and subroutines; techniques for optimal use of time-sharing. No previous exposure to computers is required; no knowledge of mathematics beyond high-school algebra is assumed.

Summer Session 1977

Computer Sci. S1801J. Introduction to digital computation. 3 pts
TuTh 1-4:10.

Nomenclature: elements of computer structure and languages. The Fortran language. Computational algorithms, numerical solutions and introduction to numerical methods and computational errors. Student programs are run at the University Center for Computing Activities.

Computing Science S4001K. Fundamental programming concepts, I. 3 pts
MTuWThF 1-3:30.

Introduction to the Basic programming language. Flow charting. Testing and debugging. Systems of programs. Programming solutions to problems in the humanities, the sciences, and the social sciences. Students are able to run all assigned problems on a teletype input to a time-shared system.

Computing Science S4002L. Fundamental programming concepts, II. 3 pts
MTuWThF 1-3:30.

Prerequisite: *Computing Science S4001* or the equivalent.
A continuation of *Computing Science S4001*. Basic components and organization of a digital computer system (hardware and software). Some features of other programming languages. Artificial intelligence. An introduction to the theory of algorithms.

Teachers College

Teachers College TX4030y. Computing literacy—an introduction to computing in education. 2-3 pts
Tu 5:10-6:50.

Formerly *TI3608*.
An introduction to computers and programming. Administrative, instructional, and research applications of computers. Appropriate as an only course in computing or as a preview of specialized courses.

Teachers College TX4031x. Programming I—concepts and methods. 3 pts
Tu 5:10-6:50.

Formerly *TI3885*.
Laboratory fee.
Fundamental thought constructs of man-computer communication are introduced by means of a well-structured flowchart language.

Teachers College TX5031y. Programming II—the practice of programming.
Th 5:10-6:50 3 pts

Formerly *T14885*.
Prerequisite: *TX4031*.
Laboratory fee.
The environment, process, and product of programming explored through supervised programming experience with a major compiler.

School of International Affairs

International Affairs U4316x. Computers as a tool in decision making. 1½ pts

Pass/fail only.
This course provides an acquaintance with the capabilities and limitations of the digital computer as a tool for problem analysis and decision making. Offers insight into the nature of computers and their application to business, research, and government. Lectures and discussion are augmented by readings and by computer-directed instruction and experimentation.

Interfaculty

Computing Science W3001x or y. Introduction to computing science, A. 3 pts
x: MW 1:10-2:25; y: MW 6:10-7:25 p.m.
Primarily, but not exclusively, for students in the humanities and social sciences.
Laboratory fee.
Basic programming skills and their use in such applications as teaching, literature, law, and political science. Emphasis on learning to recognize the kinds of problems amenable to computer solution. Data simulation, learning machines, and compilers. Problems for solution on a computer teletype in the language Basic.

Computing Science W3002y. Computing and finite mathematics. 3 pts
MW 1:10-2:25.
Prerequisite: one term of calculus or the instructor's permission.
Recommended preparation: *Computing Science W3001* or the equivalent.
Laboratory fee.
Introduction to mathematical programming methods for utilization in the natural sciences and social sciences. Emphasis on equation solving and linear programming. Computer arithmetic. Economic models. Fortran.

[Computing Science W3003. Introduction to computing science, B. 3 pts.]
Prerequisite or corequisite: one term of calculus.
Primarily for students in the mathematical or natural sciences.
Laboratory fee.
Fundamental programming concepts such as decisions, loops, subscripted variables, and subroutines. General data processing methods like sorting and searching. Also, mathematical methods, batch Fortran, artificial intelligence, machine language. Various applications in the natural sciences; problems for solution on a computer terminal.

Computing Science W4001x. Principles of computing science. 3 pts
TuTh 2:40-3:55.
Prerequisite: one year of calculus.
For students in the sciences and social sciences who need a working knowledge of computer methods and programming.
Numerical analysis developed and illustrated by Fortran IV programming. Topics include Fortran IV language, flow charting, debugging, error analysis, data simulation, algorithms for evaluating functions, numerical integration, matrix operations, solution of linear equalities and inequalities, curve fitting, sorting, game theory, artificial intelligence.

Applications

Graduate School of Architecture and Planning

Architecture A4530. Computers in architecture. 3 pts
Introduction to Fortran IV computer programming and to computer utilization in architecture. Recent developments in computer graphics. Both the potentials and limitations of computer usage in the profession are explored.

Planning A4210. Introduction to computer application. 3 pts
An introduction to basic computer terminology, equipment, use, and Fortran and Watfiv programming. An investigation and survey of the application of electronic data-processing in urban planning and municipal operations—data handling, information systems, data banks, and retrieval. The development and use of mathematical models; statistical analysis; methods and utilization of graphic output; critical-path scheduling and project management. Lectures are accompanied by demonstrations and student work in analysis, programming, and preparation of instruction decks. Auxiliary equipment and the equipment of the University Center for Computing Activities are utilized.

Graduate School of Business

Operations Management B6833. Computers and information systems management.
Focus on the key decisions managers make pertaining to computers and information systems. These decisions involve determining whether computers should be used at all, and if so, deciding how to use them properly. Terminology, concepts, and a descriptive view of practice are stressed. Topics covered include: an introduction to computer hardware and programming; the evaluation and selection of computer systems; charging, organizing, and staffing of the data processing function; the systems implementation process; data base systems; and social implications of information systems.

Operations Management B8818. Systems analysis and simulation.
Definition, testing, and design of complex human-machine systems. Development of a variety of managerial systems models, using simulation and heuristic techniques to plan, evaluate, and improve the system's configuration. Model-building techniques utilized in conjunction with empirical performance data to achieve realistic examples of how management employs these approaches to help achieve its objectives. Basic introduction to Management Information Systems (MIS).

Operations Management B8819. Systems modeling and management control.
Methods of information analysis as applied to the design and evaluation of management control systems. Practical utilization of such methodologies as general systems, information theory, and cybernetics theory provides the basis for examining fundamental process design problems. Special attention to management systems including the communication interface between human and machine and its relationship to control and automation. Performance characteristics of systems and relevant measures of effectiveness, with emphasis on economic considerations. Introduction to multiple criteria conflict resolution and multiobjective programming.

School of Engineering and Applied Science

C.E. E3121x. Structural analysis, I. **3 pts**
Methods for the analysis of structures by digital computer. Stability. Determinacy.

C.E. E4023x. Advanced structural analysis, I. **3 pts**
Prerequisite: *C.E. E3123* or the equivalent, and a working knowledge of Fortran.
Methods for the analysis of structures by digital computation.

E.E. E4212y. Computer methods of circuit analysis. **3 pts**
Prerequisite: senior standing.
Computer solution of large electronic circuits. Formulation. LU decomposition, pivoting and error considerations, sparse matrix techniques. DC analysis of nonlinear circuits: iterative algorithms, piecewise linear solution methods. Transient analysis of nonlinear circuits: explicit and implicit integration, companion network models, sparse tableau techniques, decomposition of large circuits. Sensitivity calculations. Computer determination of network functions.

Engr. Math. E4300y. Numerical methods. **3 pts**
Prerequisite: *Computer Sci. E1801* and *Engr. Math. E3101.*
Introduction to fundamental ideas of numerical analysis commonly used by engineers. Development is in the context of modern computing systems and includes methods of sub-routinizing algorithms and using libraries of programs such as those in the System 360 Scientific Package. Topics include numerical solutions of algebraic systems, eigenvalue problems, numerical integration, finite differences, difference equations and their solutions, solution of linear and nonlinear ordinary and partial differential equations, stability, consistency, and convergence.

Graphics E4005y. Computer-aided engineering graphics. **3 pts**
Prerequisite: *Computer Sci. E1801* or the equivalent.
Computer representation and manipulation of two- and three-dimensional digital descriptions of drawings and geometric systems. Digital geometric transformations. Homogeneous coordinates. Curve and spline fitting for use in graphs and contours. Data structures. Common software together with common graphic output devices are used.

[M.E. E6600x. Computation in mechanical engineering. 4 pts.]
Given in alternate years.
Prerequisite: *Computing Science G4401* or the equivalent.
Formulation of practical problems in mechanical engineering. Up-to-date solution methods; description and practice. Problems in dynamics, structures, heat transfer, fluid dynamics, elasticity, kinematics, shaft dynamics, and lubrication. One of the main objectives of the course is to put in good perspective the relation between analytical and numerical methods in the solution of real problems.

O.R. E6801x. Simulation. **3 pts**
Prerequisite: *Computer Sci. E4811* and *Engr. Math. E3602* or their equivalents.
The simulation of production, transportation, and other systems of operations research interest. Modeling the system, designing and programming a simulation experiment, and analyzing the results. Special programming languages. Generating random numbers and random variables. Monte Carlo; evaluation of integrals, variance reduction techniques. Statistical design and analysis problems.

Graduate School of Arts and Sciences

Biology G4293x. Mathematical methods in biology. **4½ pts**
Hours to be arranged.
Prerequisite: one year of calculus and the instructor's permission.
Introduction to computer programming using Fortran or other similar language. Review of basic calculus. The following topics are discussed, using various problems in modern biology as the examples considered. Elements of probability theory. Taylor series and iterative solution of equations. Difference and differential equations, numerical solutions by computer. Markov chains and linear algebra. Calculus and differential equations in several variables.

[Human Genetics and Development G4205. Computer programming for molecular biologists. 3 pts.]
Prerequisite: the instructor's permission.
Designed to prepare students in the use of the computer in research. Laboratory work stresses writing of programs to solve problems often encountered in genetics and molecular biology. Advanced compiler language such as Fortran and Basic.

Music G6610x-G6611y. Computer music. **3 pts**
M 1:10-3.
Prerequisite: *Music G6601-G6602* and the instructor's permission.
Synthesis of electronic music by digital computer. Students gain familiarity with a programming language and its use in the digital simulation of waveforms. The probject for each term is the programming and computation of an original work.

Political Science G4910x. Principles of quantitative political research. **3 pts**
Th 4:10-6.
Introduction to statistical analysis and data processing. Emphasis on the principles of statistical inference and the logic of hypothesis testing. A written research report is required.

Political Science G4911y. Analysis of political data.
Th 4:10-6.
Prerequisite: the instructor's permission.
Applications of multivariate statistical techniques to various types of political data. Emphasis on practical questions of research design and data processing. A written research report is required.

Sociology G4074x-4075y. Statistics for sociological research. **3 pts**
Th 9-10:50. Laboratory hours to be arranged.
For students without advanced mathematics preparation needing a computer-oriented approach.
Mathematical concepts necessary for literacy in quantitative sociology. Emphasis on probability, statistical inference, and the rudiments of matrix algebra. Computer techniques for statistical data analysis supplement the theoretical material.

[Sociology G6222. Computers in the social sciences. 3 pts.]
Introduction to the use of digital computers in social sciences research. Topics include punched-card machines, assembly language, higher-level languages, and programming packages. Laboratory assignments are drawn from social science research problems. Students are required to complete a project using the computer on a substantive problem.

School of Library Service

LS K6033x or y. Introduction to library automation and information science. **3 pts**

Prerequisite: *LS K6002.*
Basic introductory coverage of the principles and practices of library automation and of applications of information science of most general value to librarians. Laboratory and project work supplement class sessions.

LS K8033x or y. Information systems. **3 pts**

Prerequisite: *LS K6033* or the equivalent.
A survey of documentation programs and information systems, and their implications for traditional librarianship.

LS K8065y. Library and information networks. **3 pts**

Consortia, systems, and computer-communications networks as they relate to the library and information science fields. The course takes as its starting point the concept of interlibrary cooperation and illustrates the role of modern library cooperatives, especially those serving metropolitan, state, multi-state, and national constituencies. Emphasized are managerial, administrative, fiscal, and jurisdictional issues.

School of Public Health

Public Health P6121. Data analysis using computer statistical packages. 3 hours a week. **3 pts**

Prerequisite: *Public Health P6101* and *P6120,* and the instructor's permission.
Corequisite: *Public Health P6114* or the equivalent.
The uses of statistical computer packages; arraying and cleaning data; basic summary description and cross-tabulation; correlation; analysis of variance; regression and other multivariate procedures. The capabilities, selection, limitations, and use of statistical packages: SPSS, Crosstabs, and BMD; and utility package UC/360.

Public Health P8122. Data base design and management. **3 pts**
3 hours a week.

Prerequisite: *Public Health P6120* and the instructor's permission
Issues and techniques in managing large data systems. Fundamentals and applications of file organization; file systems hardware; input-output communication systems. Storage and retrieval of data: automatic indexing; multi-linked systems; sort and search algorithms. Issues of confidentiality and security.

Public Health P8123. Seminar in the applications of data base systems in health. **3 pts**
3 hours a week.

Prerequisite: *Public Health P8122* and the instructor's permission.
Critical analysis of existing information systems in health care planning, management, evaluation, and research, and discussion of possible additional areas of application. Evaluation and implementation of "turnkey" data base systems. Administrative, organizational, and personnel issues of data base design, management, and implementation.

Public Health P8126. Digital simulation in health systems. **3 pts**
3 hours a week.

Prerequisite: *Public Health P6113, P6114,* and *P6120,* and the instructor's permission.
Modeling of health systems by Monte Carlo simulation; classifications and techniques of simulation; selection and use of GPSS, Simscript, and Dynamo languages; validation, analysis of output, and techniques to reduce variance; critical analysis of selected articles in the literature. Applications to control of epidemics, patient flow in health facilities, operations of regional health programs, etc.

Public Health P8722. Seminar in computers and the evaluation of patient care. **3 pts**
2 hours a week.

Prerequisite: for first-term students, the instructor's permission.
Intensive analysis of the leading methods and systems for the evaluation of the quality of patient care and administrative programs in hospitals, with special attention to systems utilizing electronic data processing and methods of data gathering, processing, and reporting. Special emphasis on the question of effective reporting. The objective is to train the potential users of such a system to evaluate intelligently the alternatives of various systems offered for hospital purchase, or offered for the development of a special system in a hospital. Student presentations.

Public Health P8725. Computer technology and problem solving in the health sciences. 3 pts
2 hours a week.
This is a computer literacy, not a programming, course.
Introduces the principles and methods of computer science and explores their application in the health sciences (i.e., in clinical decision making, simulation of physiological and psychological processes, professional and patient education, biostatistical analysis). Students learn to formulate problems in their specific interest area, in a manner conducive to the development of computer-based solutions. Oral report and written paper required.

Public Health P9440. Use of the computer in epidemiology. 3 pts
2 hours a week.
Prerequisite: a background in statistics and methods, and the instructor's permission.
For advanced students approaching the writing of the dissertation who are either conducting or preparing to conduct their doctoral research. Students are exposed to all phases in the utilization of the computer for research analysis. Students are expected to run SPSS (Statistical Packages for Social Sciences) programs.

Summer Session 1977

Library Service S8065D. Library and information networks. 3 pts
TuTh 9-11:10.
Consortia, systems, and computer-communication networks as they relate to the library and information science fields. The course takes as its starting point the concept of interlibrary cooperation and illustrates the role of modern library cooperatives, especially those serving metropolitan, state, multi-state, and national constituencies. Emphasized are managerial, administrative, fiscal, and jurisdictional issues.

Teachers College

Teachers College TX5030x. The computer as an instructional aid. 3 pts
Tu 7:20-9 p.m.
Formerly *TI5101*.
Prerequisite or corequisite: *TX4030* or *TX4031*.
Laboratory fee.
Examination of a representative range of applications of computing to the instructional process including CAI, CMI, simulation, and other modes.

Teachers College TX5032x. Survey of administrative data processing systems for schools and colleges. 3 pts
Th 5:10-6:50.
Formerly *TI4618*.
Prerequisite or corequisite: *TX4030* or *TX4031*.
Laboratory fee.
Examination of a representative range of administrative systems applications for educational institutions, major costs and benefits associated with each, acquisition alternatives, and management considerations. Attention focused on a range of subsystems and packages illustrative of what is available.

Teachers College TX5033y. Analysis, design, and implementation of administrative data systems. 3 pts
Tu 7:20-9 p.m.
Formerly *TI4608*.
Prerequisite or corequisite: *TX4030* or *TX4031*.
Detailed examination of a representative EDP application, including analysis, user interface, documentation, testing, maintenance, and modification. Attention is focused on a single system as illustrative of a range of problems.

Interfaculty

Geography W3071x-W3072y. Quantitative techniques in geography. **3 pts**
TuTh 11-12:15.
Theory and techniques of measuring geographic distributions. Descriptive and analytical methods (regression, factor analysis) useful in dealing with areal associations and interactions. Instruction in the composition of "packaged" programs and their uses for displaying and analyzing spatial patterns. Additional selected programs (point pattern analyses, frequency distributions, and taxonomic procedures).

Related Subjects

School of Engineering and Applied Science

Computer Sci. E4850y. Computers and society. **2 pts**
Prerequisite: *Computer Sci. E1801* or *Computing Science W3001*, or the instructor's permission.
The impact of computers on political, social, and economic processes. Evaluation of the positive and negative contributions of computers. Case studies from banking, law, medicine, and television. Privacy and security of data banks. How society can direct the development of computer applications.
This course is part of the General Education Program.

Teachers College

Teachers College TI5885. Teaching computer programming in schools and colleges. **3 pts**
Summer 1977: MW 4:40-6:45.
Laboratory fee.
Teaching computer programming with special attention to formulating and computerizing problem solutions, to developing a reasonable pedagogical approach and to overcoming hardware/software shortcomings.

University Seminars (membership by election)

U.S. 461-462. Technology and social change (1962)

U.S. 467-468. Computers and their relation to man and society (1966)

Computer Science—Theoretical Properties of Computation and Information Structures

School of Engineering and Applied Science

Computer Sci. E4833x. Computer linguistics. **3 pts**
Concept of formal languages: regular context-free, context-sensitive, and type O languages; concept of automata; finite state push-down and linear-bounded automata. Turing machines.

Computer Sci. E6834y. Computer linguistics and automata theory, II. **4½ pts**
Prerequisite: *Computer Sci. 4833.*
Closure of families of formal languages under various operations. Time and space bounds for recognizing various classes of language undecidability: results for formal languages; automata over nonlinear structures; other topics as time permits.

Graduate School of Arts and Sciences

Computing Science G4101x. Theory of computability. 3 pts
TuTh 5:40-6:30.
Intuitive properties of algorithms. Recursive function theory. Recursions as programs. Computation of recursive functions by Turing machines. Basic decidability and undecidability results for programs.

[Computing Science G4102. Algebraic structure of algorithms. 3 pts.]
Prerequisite: a course in abstract algebra or the instructor's permission.
Historical background of automata and computability. Monadic program schemes as linguistic and algebraic entities. The structure of equivalence classes of program schemes. "Interpretation" as a functor between appropriate algebraic structures.

[Computing Science G4115. Computer arithmetic. 4½ pts.]
Prerequisite: *Computing Science W3002* and linear algebra, or the instructor's permission.
Representation of numbers, floating point vs. fixed point computation. Study of algorithms and accuracy of floating point arithmetic, rounding errors, double precision computation. Statistical study of the distribution of floating point numbers. Elementary number theory, prime factorization, polynomial arithmetic. Algorithms for efficient evaluation of polynomials and factorization.

[Computing Science G4203. Graph theory. 4½ pts.]
Prerequisite: a course in linear algebra or equivalent mathematical background.
General introduction. Trees, connectivity, factorization, graph operations. Extremal problems, Ramsey numbers. Planarity, genus, colorings. Kuratowski theorem, Euler theorem, Ulam conjecture, four-color problem.

Computing Science G4205x. Combinatorial theory. 4½ pts
MW 4:10-5:25.
Prerequisite: *Computing Science W3002* or *Mathematics V3202,* or the instructor's permission.
Permutations, combinations, generating functions, inclusion and exclusion, graphs, block designs, Polya's enumeration theory.

[Computing Science G4501-G4502. Algebra of computation. 4½ pts.]
G4501: a rapid survey of the various aspects of theoretical computer science, with intensive parallel reading.
G4502: a seminar with student participation.

[Computing Science G4801. Mathematical logic. 3 pts.]
Introduction to mathematical logic, emphasizing topics of interest to students in computing science. Propositional calculus, completeness, and decidability. Predicate calculus, completeness, and undecidability. Theorem-proving by resolution. Semantics of programming languages.

Computer Science—Organization and Design of Hardware and Software Systems

School of Engineering and Applied Science

Computer Sci. E3802y. Introduction to logic circuits. 3 pts
Open only to sophomores and juniors. Seniors should take *Computer Sci. E4802.*
Introduction to basic switching circuits, truth tables. Boolean algebra, the design of minimal complexity circuits, the covering problem, interactive circuits. Codes, binary arithmetic. The design of synchronous sequential circuits, flow tables, state minimization.

Computer Sci. E4802x. Switching circuit theory, I. 3 pts
Students who have taken *Computer Sci. E3802* may not register for this course.
Non-decimal number systems, codes. Specification of combinational switching functions using truth tables, Boolean algebra, and Karnaugh maps. Manipulation of algebraic expressions, synthesis of logical circuits using maps and Quine-McCluskey method. Introdution to sequential circuits, state diagrams, flow tables.

Computer Sci. E4814x or y. Assembly language programming and operating systems. **3 pts**

Prerequisite: *Computer Sci. E1801* or *E4811.*

Stored program computers, components and organization. Assembly language programming for OS/360 computers. Linking from Fortran to Assembly language. The function of an operating system—how should the machine look to users and operators. Early operating systems. OS/360—concepts and facilities. Facility management and principal components of an operating system. Time slicing systems.

Computer Sci. E4815x. Programming languages and translators. **3 pts**

Prerequisite: *Computer Sci. E4814.*

The programming languages Snobol, Lisp, and Algol. The implementation of recursive functions, assemblers, and compilers. Introduction to the formal description of languages and syntax-directed compilation. Students are required to write programs to be run on the equipment at the University Center for Computing Activities.

Computer Sci. E4822y. Digital computer system analysis, I. **3 pts**

Prerequisite: *Computer Sci. E4802.*

Corequisite: *Computer Sci. E4814* or the instructor's permission.

Introduction to computer architecture. Basic organization, data flow. I/O schemes, instruction execution. Control timing. Magnetic core and semiconductor memory. I/O device attachment and interrupts. Arithmetic units.

Computer Sci. E6817y. Programming languages and translators, II. **4½ pts**

Prerequisite: *Computer Sci. E4814* and *E4815.*

Recommended preparation: *Computer Sci. E4816.*

A continuation of *Computer Sci. E4815.*

Techniques in computer language implementation. Application of formal language theory to design of compilers; implementation of language features such as nested procedures, reentrancy and recursion, code optimization. Run-time storage organization.

Computer Sci. E6818x. Computer operating systems. **3 pts**

Study of the design of large general purpose operating systems for digital computers. Topics include multiprogramming, multiprocessing, memory management, scheduling, virtual machines, paging, segmentation, protection. Existing systems are examined when feasible to exemplify the emerging general theory.

Computer Sci. E6823x. Digital computer system analysis, II. **3 pts**

Prerequisite: *Computer Sci. E4822* or the instructor's permission.

Detailed study of computer subsystems. Arithmetic unit: binary and decimal, serial and parallel. Storage: magnetic core, drum, thin film, read-only storages. Control: central processor and input-output, hardware and read-only-storage.

Computer Sci. E6827x-E6828y. Digital computer system design. **3 pts**

Prerequisites: *Computer Sci. E4814, E4822.*

A survey of significant variations in computer system structure and their influence on operating systems and user programs. Analytic and simulation models of computer systems are constructed with the intent of quantifying the impact of various architectural trade-offs on performance. Case studies include memory hierarchies (cache design), I/O systems (loop performance), and processor design (multiprocessor interference).

Computer Sci. E6831x. Switching circuit theory, II. **4½ pts**

Prerequisite: *Computer Sci. E4802* or some other introductory course in switching theory.

Brief review of multi-output combinational functions, symmetric, unate, and iterative functions. Reduction of incompletely specified flow tables. Asynchronous sequential circuits: flow table construction, state assignments to meet various objectives, delays, races, hazards, feedback. Alternative modes of operation such as synchronous circuits using M/S flip-flops, and speed-independent circuits.

Computer Sci. E6832y. Swtiching circuit theory, III. **4½ pts**

Finite state machines, state identification control and checking sequences. Information losslessness, regular expressions, linear sequential circuits. State assignments for synchronous sequential circuits, feedback, machine structure theory. Iterative circuits: completion signals, realizations in tree form, generalizing the full carry lookahead adder, 2-dimensional circuits applied to pattern detection. Reliability, redundancy, and testing of digital systems. Additional topics may be chosen from the current literature.

E.E. E4330y. Micro-processor-based digital systems. **4 pts**

Enrollment limited. Course approval must be obtained in Room 1312 Seeley W. Mudd.
May not be taken for credit in addition to *Computer Sci. E4822.*
Prerequisite: *E.E. E3301.*
Typical microprocessor organization. Machine and assembly language programming, emphasis on input/output. Introduction to logic gates and resistors, RAMs and ROMs, digital system support chips. Peripheral equipment interfacing techniques, software and hardware, are emphasized.

E.E. E6761x. Computer-communication networks. **4½ pts**

Focus on problems of message concentration or multiplexing, routing, and distribution encountered in geographically distributed digital data networks. Examples are drawn from both terminal-oriented and computer-oriented networks. Message store and forward systems using programmable concentrators are stressed. A thorough introduction to relevant aspects of queuing theory is offered to provide the necessary analytical background for the bulk of the course. Students are asked to read and report on the current literature in the field. The course concludes with a discussion of future computer communication systems and with a consideration of both technical and societal questions.

Interfaculty

[Computing Science W4051. Advanced programming language features. 3 pts.]

Prerequisite: two terms of computing science courses or the instructor's permission.
Introduction to APL. Array operations in APL and other languages. Designing advanced features into languages suitable for beginners. Structured programming and stepwise refinement. Analysis of subroutine and function calls. Default conventions and implicit declarations for compilation. Program self-documentation. Character information. Data structures. Illustrations of these concepts in various languages.

Computer Science—Application Techniques

School of Engineering and Applied Science

Computer Sci. E4816y. Data structures. **3 pts**

Prerequisite: *Computer Sci. E4814.*
Recursive programming: implementation of recursive programs in nonrecursive languages using push-down stacks; varieties of linear-linked lists; tree structures, their uses and processing; rudiments of analysis of algorithms.

Computer Sci. E6841y. Topics in artificial intelligence. **4½ pts**

Natural language processing: syntactic semantic and pragmatic analysis of natural language with a view toward implementation of computer systems for "understanding" English.

[Computer Sci. E6871. Simulation techniques. 3 pts.]

Prerequisite: *E.E. E4601* or the equivalent.
Principles and applications of simulation techniques. Simulation of continuous- and discrete-time, linear and nonlinear systems. Use of analog and digital computers to evaluate stability, sensitivity, and system performances.

Graphics E4100y. Interactive computer graphics. **3 pts**

Prerequisite: a working knowledge of Fortran and the instructor's permission.
Programming interactive graphics devices. Graphics hardware and software. Two- and three-dimensional representations. Applications to problems of design and visualization.

Graduate School of Arts and Sciences

Computing Science G4301x. Fundamental algorithms of computing science and algorithmic analysis, Part I. 3 pts
MW 11-12:15

Prerequisite: two terms of calculus, linear algebra, or the equivalent; knowledge of a higher level language (Fortran, APL, PL/I) and assembler language.
Data structures and their computer representation; sets, lists, stacks, trees, graphs, multilinked structures. Recursive programming and recursive data types. String processing and pattern matching. Storage allocation and garbage collection. Sorting and searching, hash coding. Expression evaluation.

Computing Science G4302y. Fundamental algorithms of computing science and algorithmic analysis, Part II. 3 pts
MW 11-12:15.

Prerequisite: two terms of calculus, linear algebra, or the equivalent; knowledge of a higher level language (Fortran, APL, PL/I) and assembler language.
Part II can be taken independently of Part I.
Emphasis is on algorithmic analysis. Models of computation. Analysis of sorting and searching methods. Algorithms on graphs: depth-first search, shortest path algorithms. Efficient pattern-matching. Matrix multiplication. Integer and polynomial arithmetic. The fast Fourier transform. Lower bounds on the numbers of arithmetic operations. Intractable combinational problems. Introduction to undecidability.

Computing Science G4401x-G4402y. Numerical analysis and digital computers, I and II. 3 pts
MW 2:40-3:55.

Primarily for research students in science and applied mathematics.
Prerequisite: a demonstrable knowledge of the Fortran programming language for the IBM System/360, ordinary differential equations, and the elementary concepts of linear algebra.
G4401: theory and practice of computation, with special reference to methods useful with modern electronic computers. Students use the IBM System/360 for the solution of problems. Interpolation, finite differences, numerical differentiation and integration, introduction to the numerical solution of ordinary differential equations, solution of simultaneous equations, inversion of matrices, determination of eigenvalues and eigenvectors.
G4402: numerical solution of partial differential equations, approximation of functions, solution of nonlinear equations, maximization techniques, analysis of errors.

Computer Science—Other Courses

School of Engineering and Applied Science

E.E. E3998x or y. Projects in electrical engineering and computer science. 0 to 3 pts

This course may be repeated for credit, but no more than 3 points may be used for degree credit.
Prerequisite: approval by a faculty member who agrees to supervise the work.
Independent project involving laboratory work, computer programming, analytical investigation, or engineering design.

E.E. E6001x-E6002y. Advanced project in electrical engineering and computer science. 1 to 4 pts

This course may be repeated for up to six points of credit.
Graduate level projects in various areas of electrical engineering and computer science. In consultation with an instructor, each student designs a project depending upon the student's previous training and experience. Students should consult with a professor in their area no later than the last day of registration for detailed arrangements.

Computer Sci. E6898x-E6899y. Topics in computer science. 3 or 4½ pts
***x:* 3 pts. *y:* 4½ pts.**

Selected topics in computer science varying from term to term. Examples are performance evaluation, theory of algorithms, advanced aspects of operating systems, and microprocessors.

Computer Sci. E9801x. Seminar in computer systems. **3 pts**
Open to doctoral candidates and to qualified M.S. candidates with the instructor's permission.
Advanced topics in computer theory (principally digital) such as programming, artificial intelligence, and machine structures.

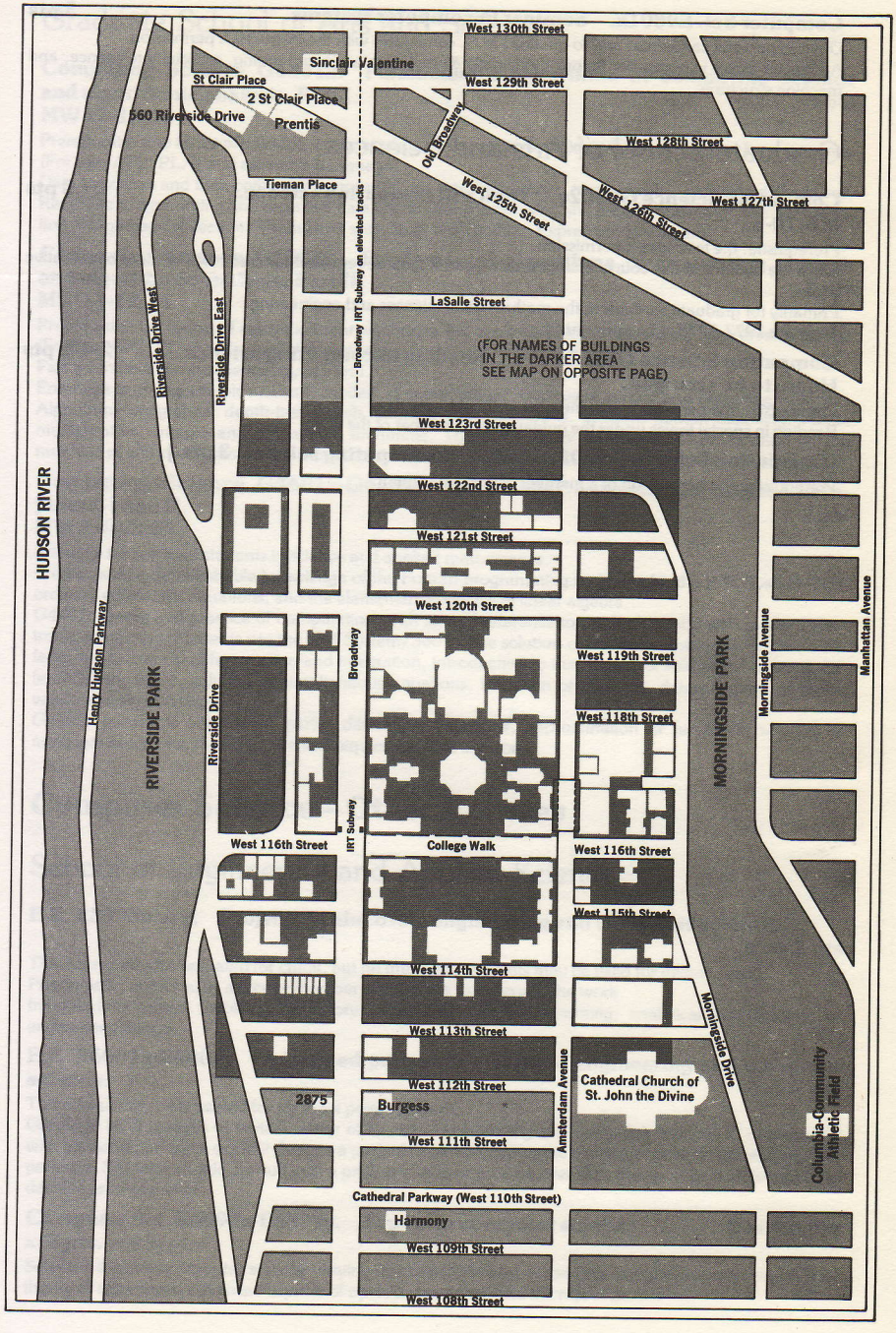
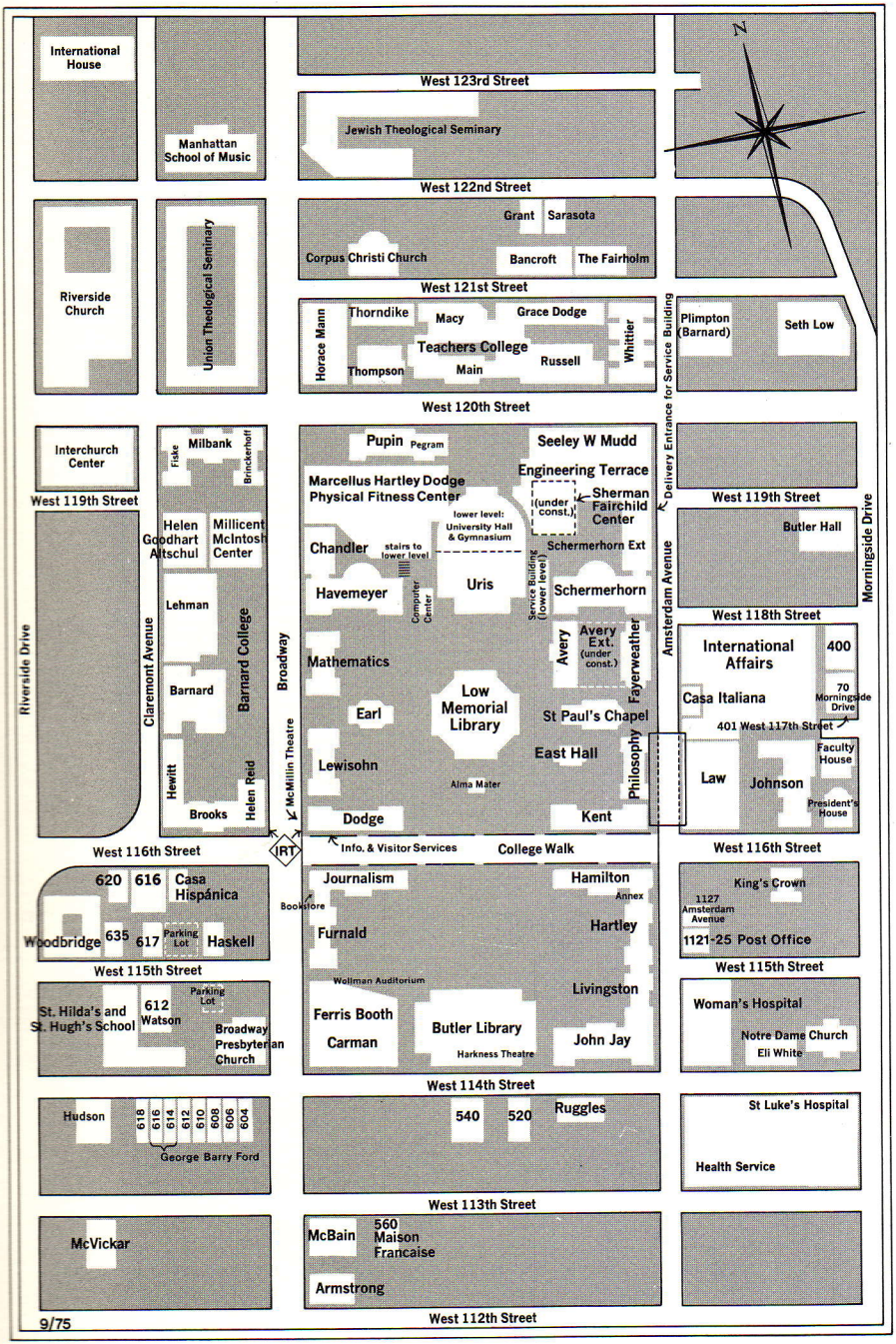
Graduate School of Arts and Sciences

Computing Science G6002y. Topics in computing science. **3 pts**
M 4:10-6.
Prerequisite: the instructor's permission.
Since the content of this course changes each year, it may be repeated for credit two or more consecutive years.
Primarily for graduate students in the mathematical sciences and engineering.
Topic for 1977-1978 to be announced.

Computing Science G8252x or y. Reading in computing science. **2-4½ pts**
Hours to be arranged.
Prerequisite: the permission of a member of the department.
Reading in special topics under the guidance of a member of the staff.

[Computing Science G9002. Seminar in computing science. 3 pts.]
Prerequisite: the permission of a member of the department.

The Morningside Heights Area of New York City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