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THE MASTER'S DEGREE PROGRAM IN APPLIED MATHEMATICS

The Applied Mathematics Program at APL began as the Numerical Science Program in 1966. During its development and particularly in recent years, the program has undergone significant changes, guided by the philosophy discussed here.

ORIGIN OF THE PROGRAM

Initial Courses

In 1964, The Johns Hopkins University opened an Evening College Center at APL and offered the Master of Science Degree in Electrical Engineering. The initial offerings in the program included a course in applied mathematics (nine credits) and one in probability and stochastic processes (six credits), both two-semester courses. The following year additional mathematics courses were given, and in 1966 a mathematics program leading to a master's degree in numerical science was started. The program was immediately successful, attracting many students and permitting expanded course offerings. From the beginning, courses in computer science were included; in 1966 a hybrid course, Numerical Analysis and Computer Science, was started, followed in 1967 by a dedicated course, Computer Science, and in 1969 by Introduction to Computer Art and Science. In 1971, the master's degree program in Computer Science was introduced, and all computer science courses were offered under that program. Computer Science quickly became the most popular degree program offered at APL, and with its growth enrollments in the Numerical Science Program declined significantly.

Early Direction of the Program

Under the auspices of the Evening College, the Numerical Science Program was developed and managed by a committee consisting of Chairman Richard B. Kershner, Robert P. Rich, and Vincent G. Sigillito, all from APL. They selected and approved new courses, recruited new teachers, and oversaw the academic aspects of the program.

In the early years, the student body and the faculty consisted primarily of APL staff members; as the program grew and the course offerings expanded, the student body became more diverse and teachers were drawn from other divisions of Johns Hopkins and from other technical organizations in the area.

AFFILIATION WITH THE G. W. C. WHITING SCHOOL OF ENGINEERING

On 1 July 1983, the responsibility for part-time programs in engineering at Johns Hopkins was transferred from the Evening College to the G. W. C. Whiting School of Engineering. At that time, program committees, with representatives from APL and the Homewood Campus of Johns Hopkins, were formed for each of the part-time programs. Operating under the auspices of the Whiting School, the committees are responsible for establishing program admission and program degree requirements, selecting courses to be offered, recruiting and evaluating instructors, overseeing the academic aspects, and planning and pursuing the long-term development of the programs.

The Homewood representatives on the Numerical Science Program committee were faculty members from the Mathematical Sciences Department. From the outset, the interaction between the APL and Homewood faculty members was beneficial for the Numerical Science Program, providing for more diverse guidance and development of the program, while strengthening the ties between APL and Homewood. As a direct result of that interaction, APL teachers have taught courses at Homewood in the Mathematical Sciences Department, and Mathematical Sciences faculty have taught courses at APL in the Numerical Science Program.

Since the affiliation with the G. W. C. Whiting School of Engineering, the program has been changing, and the program committee has tried to expand the program by gradual introduction of new courses. With a greater variety and selection of courses, the program will attract more students and permit further expansion of the course offerings. Since 1985, new courses have been introduced at a rate of about one each semester. The strategy has been successful thus far; overall enrollments have been increasing each year.

In 1988, at the request of the committee, the name of the program was officially changed from Numerical Science to Applied Mathematics, a designation the committee and faculty members felt was more appropriate and descriptive.

Another change during 1988 was the program's expansion to The Johns Hopkins University Montgomery County Center, where two applied mathematics courses, Matrix Theory and Numerical Analysis, were offered during the fall semester. The program committee intends to expand the course offerings at the Montgomery County Center according to student demand and the availability of qualified instructors. With the many professional employees from industry and government in that region, there is a need for part-time continuing education in applied mathematics.

OVERALL PHILOSOPHY

The Continuing Professional Programs of The Johns Hopkins University provide educational opportunities at convenient times and places easily accessible to part-time students. The programs are tailored to the special needs and abilities of those students, and sustain the excellence characteristic of Johns Hopkins. The success of the programs requires a clear understanding of the students and potential students, of the field of study represented by each program, and of the problems inherent in and opportunities offered by relative autonomy and a part-time faculty.

Students

The students tend to be conscientious and highly motivated; they work hard at their jobs, however, and are often tired when they get to class. At times, the pressures of job and family make it difficult for them to find time for homework. In addition, many have been out of school for some time and have to regain good study habits. Still, they bring their motivation and conscientiousness to the classroom and to their class assignments. Their motivation is usually oriented specifically toward material they view as important to their careers; that puts healthy pressure on teachers and the program committee to encourage and use the students' comments to ensure that individual courses, as well as the overall program, continue to meet the students' needs.

The balance between theoretical foundations and practical skills is different from that in a research-oriented program, and the problem of achieving and maintaining the balance is more difficult. Perhaps this difference is greater in mathematics than in physics or engineering.

Many students receive encouragement not only from spouses and children, but also from their employers, who often provide both paid leave for class work and financial help with tuition to students who take courses or pursue degrees in work-related subjects. Since employer support usually depends on accomplishment, it provides additional motivation to the student, who often already perceives the program as important to career development; in fact, a few students use the program to assist in a career change.

Faculty

All faculty participate part-time in the program; some are full-time faculty members at nearby colleges and universities, and some are employees of industries (such as Westinghouse) or laboratories (such as APL or the National Institute of Standards and Technology, formerly the National Bureau of Standards). Their motives are partly financial, because a modest stipend is paid for each section taught. Many are in the program chiefly because they like to teach and because they enjoy the challenge of mature students. The program makes it possible for teachers to choose their courses from semester to semester and even to propose new courses for committee approval. They tend, therefore, to be enthusiastic about their subjects and eager to make their own experience available to the students. Most teachers remain in the program for many years, teaching different courses as their interests and those of the students change. Two current faculty members, Louis W. Ehrlich (Fig. 1) and Ernest P. Gray (Fig. 2), have been teaching since the program started. Louis G. Kelly, who taught numerical analysis courses from the beginning of the program until he retired from teaching in 1986, wrote a book[1] based on material from his courses and his work experience.

Because teachers for specific courses are selected from the large pool of professionals available in the Baltimore–Washington area, it is usually possible to find highly qualified instructors even for new and specialized courses. This provides greater flexibility than if the members of only a single department were available, especially a department balanced for research strength rather than for teaching interest. One problem in selecting new instructors is that, although it is fairly straightforward to assess professional competence in advance, it is often difficult to predict teaching ability. For this and other reasons, students are asked to complete evaluation forms at the end of each course to assist the program committee in the choice of future instructors and to provide an indication of course quality and relevance.

Curriculum

The curriculum must be developed and constantly reviewed to meet the students' needs and to take advantage of the superb faculty without neglecting professional standards of depth and balance. The curriculum is based on a core of required courses. Each student designs a program to meet particular needs by selecting from a carefully constructed list of electives, including some from related programs such as Computer Science. The core requirements are for two semesters of numerical analysis and two semesters of either probability or statistics.

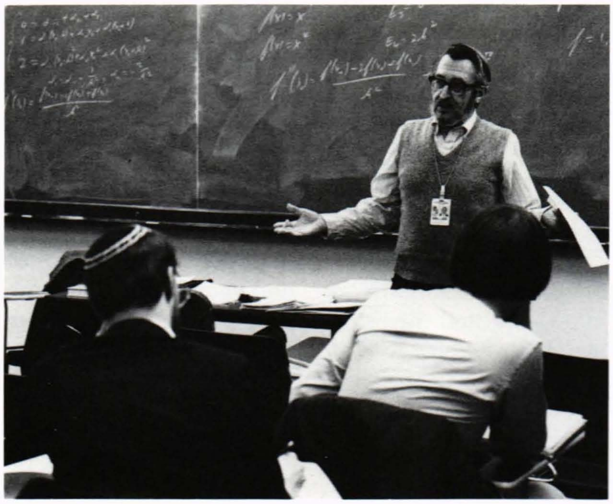


Figure 1—Louis W. Ehrlich, shown here teaching his class in numerical analysis, has been involved in the program since it began.

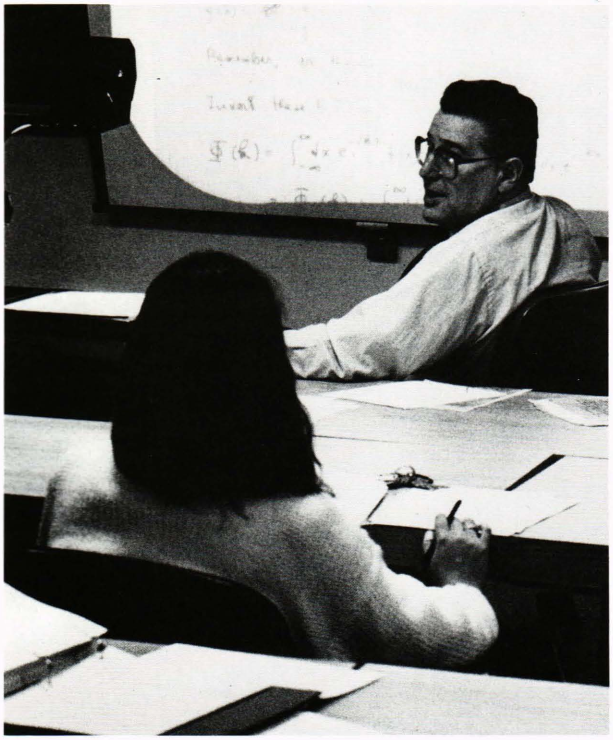


Figure 2—Ernest Gray, who has taught in the program since its inception, now teaches a two-semester course in mathematical methods.

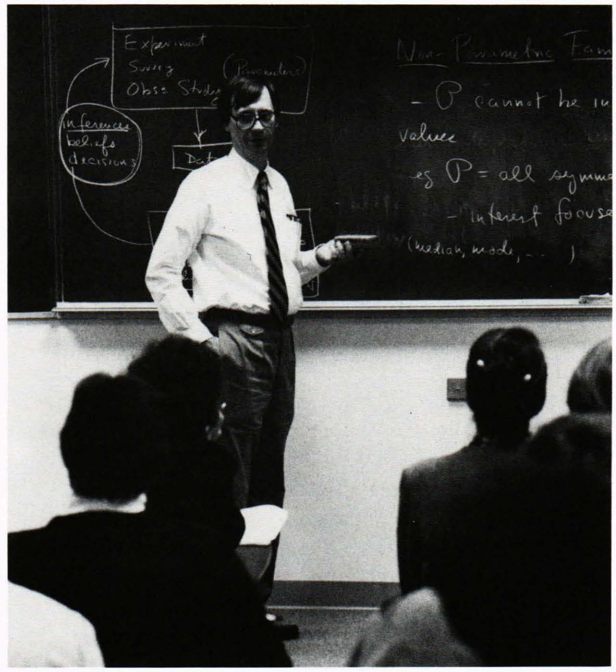


Figure 3—Charles Rohde, of the School of Hygiene and Public Health, teaches the core courses in probability and statistics.

The numerical analysis courses are intended to give students, most of whom use computers in their work, an appreciation of the advantages and dangers of solving numerical problems on computers. Courses in probability or statistics are required because so many applications of mathematics require the understanding and use of those subjects. They are taught by Charles Rohde (Fig. 3), Chairman of the Department of Biostatistics at the School of Hygiene and Public Health.

There are three areas of concentration within the program: Applied Analysis, Probability and Statistics, and Operations Research. The lists following give the courses applicable to each concentration. The areas of concentration are not distinct; some courses apply to several of them. Students may select their elective courses from one or more areas, depending on their interests and needs. We are increasing computer assistance in appropriate courses, such as those in numerical analysis, and making computers more available to students.

AREAS OF CONCENTRATION IN APPLIED MATHEMATICS

Applied Analysis

Real Analysis
Ordinary Differential Equations
Matrix Theory
Numerical Analysis I and II
Power Series Recursions: A General Approach to Numerical Algorithms and Analysis
Mathematical Methods
Functions of a Complex Variable
Fourier Analysis
Numerical Analysis III
Modeling Chaotic Systems

Probability and Statistics

Applied Combinatorics and Discrete Mathematics
Introduction to Operations Research: Probabilistic Models
Fourier Analysis
Probability and Stochastic Processes
Theory of Statistics
Modeling Chaotic Systems

Operations Research

Introduction to Optimization
Applied Combinatorics and Discrete Mathematics
Introduction to Operations Research: Probabilistic Models
Graph Theory
Theory of Statistics
Queueing Theory with Applications to Computer Science

The general emphasis throughout the program is on problem-solving skills and on practical knowledge reinforced by theory, rather than on theory illustrated by problems. This emphasis is naturally more appropriate in some courses than in others.

Prerequisites for individual courses are determined by the teacher, with approval of the program committee. Advisors and teachers have some freedom in counting previous experience in this regard.

The Program Committee

The program committee for Applied Mathematics, consisting of three members from APL and two mem-

A NEW COURSE IN THE APPLIED MATHEMATICS PROGRAM

An example of a course that has recently been added to the Applied Mathematics Program to update the curriculum in response to the computer revolution is Applied Combinatorics and Discrete Mathematics (also included in the Computer Science Program). Discrete mathematics, which has been called "the new mathematics of science",[2] differs from calculus-based mathematics, which deals with continuity and limits. In calculus, it is shown that the set of real numbers is infinite and forms a continuum; for example, given any two real numbers, one can always find another real number between them. In contrast, the set of real numbers that can be represented in a computer, although large, is finite and discrete. Discrete mathematics is the study of such sets of discrete objects; combinatorics is the study of methods of counting such sets. Discrete mathematics and combinatorics have applicability to computer science, operations research, and finite probability, so they are appropriate for a program in applied mathematics.

One of the main objectives of the course is to teach the students to model problems involving sets of discrete objects and to reason combinatorially to obtain solutions to such problems. The course material is divided into two major topics: graph theory and enumeration. A graph is a non-numerical model showing relationships between discrete objects. (Examples of objects that can be represented as graphs are computer data structures, project scheduling networks, maps, and highway networks.) Although most students are familiar with various numerical models, many find the study of graphs to be quite different from their previous course work, primarily because of the non-numerical nature of graph theory. The enumeration portion of the course begins with consideration of basic counting methods involving combinations and permutations, then extends these to the development of solution methods for general combinatorial problems. This leads to a development of the theory and application of generating functions, a topic that is new to most students. Also studied are the derivation and solution of recurrence relations, which are the discrete analogs of differential equations and which often arise in computer science.

The course was designed to cover a broad range of topics applicable to many areas of mathematics and computer science. Students not only learn problem-solving skills, but also learn to reason combinatorially and analyze problems in ways different from those taught in most mathematics courses. To learn those problem-solving skills and thought processes, the students are exposed to many combinatorial problems as examples in class lectures and as homework. Although computers are neither required nor necessary, some students use them to solve or check solutions to homework problems.

Response to the course has been good from students in both the Applied Mathematics and the Computer Science programs; enrollments increase each time it is offered. Students have commented that they find the course challenging, at times frustrating (until they master the problem-solving techniques), enjoyable, and rewarding. Perhaps the best comment was expressed by one student who said he "enjoyed the course because it teaches you to think."

This course was one of several added to update the Applied Mathematics curriculum. Student response indicates that there is a need for such a course and that it is achieving its goal and the ultimate goal of all education—teaching students to think.

bers of the full-time faculty from the G. W. C. Whiting School of Engineering, meets formally twice a year, with informal interim communications as appropriate. It is responsible for the continuing quality and suitability of the program. In particular, the committee defines the core curriculum, approves new courses and retires those for which there is insufficient demand, and approves the selection of new faculty. The members also consider the adequacy and balance of the curriculum and review the contents of particular courses.

Comparison with the Full-Time Program

Although many of the differences between a Continuing Professional Program and the corresponding full-time research-oriented program have been mentioned, a summary may be helpful.

Part-time students are older and more mature than many full-time graduate students. For the vast majority, the master's degree will be their highest degree and will not be used as a step to the doctorate. The curriculum reflects this and is different from the research-oriented curriculum prevalent in full-time departments.

The faculty in the part-time program, themselves part-time in the program, are drawn from several widely dispersed organizations, and hence do not know each other as well as would members of a single academic department. They join the program to teach and do their research as part of their full-time jobs.

The classes in the part-time program meet at times and places convenient to students and faculty, most of whom must travel some distance to attend. Library and computer facilities are limited compared with those on campus. Student access to instructors and advisors is also much more limited than in a resident program.

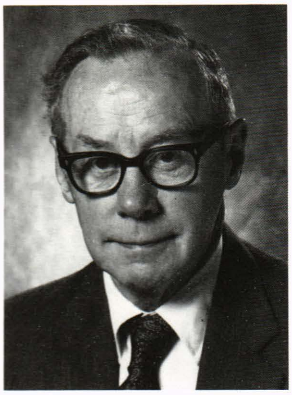
In summary, the Continuing Professional Program in Applied Mathematics is not an imitation (good or bad) of a full-time research-oriented program, but is carefully designed to suit the requirements of its particular student body.

REFERENCES

[1] Kelly, L. G., *Handbook of Numerical Methods and Applications*, Addison-Wesley, Reading, Mass. (1967).

[2] Ralston, A., "Discrete Mathematics: The New Mathematics of Science," *Am. Sci.* **74**, 611–618 (Nov–Dec 1986).

THE AUTHORS



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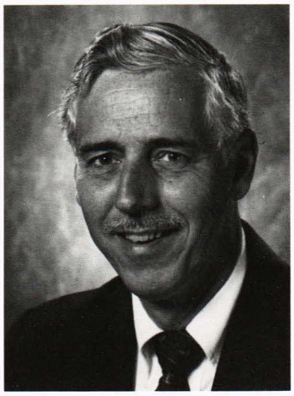

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