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Notices
of the American Mathematical Society

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Calendar of AMS Meetings

THIS CALENDAR lists all meetings which have been approved by the Council prior to the date this issue of the **Notices** was sent to press. The summer and annual meetings are joint meetings of the Mathematical Association of America and the American Mathematical Society. The meeting dates which fall rather far in the future are subject to change; this is particularly true of meetings to which no numbers have yet been assigned. *Programs* of the meetings will appear in the issues indicated below. *First* and *second* announcements of the meetings will have appeared in earlier issues.

ABSTRACTS OF PAPERS presented at a meeting of the Society are published in the journal *Abstracts of papers presented to the American Mathematical Society* in the issue corresponding to that of the **Notices** which contains the program of the meeting. Abstracts should be submitted on special forms which are available in many departments of mathematics and from the office of the Society in Providence. Abstracts of papers to be presented at the meeting must be received at the headquarters of the Society in Providence, Rhode Island, on or before the deadline given below for the meeting. Note that the deadline for abstracts submitted for consideration for presentation at special sessions is usually three weeks earlier than that specified below. For additional information consult the meeting announcement and the list of organizers of special sessions.

MEETING #	DATE	PLACE	ABSTRACT DEADLINE	ISSUE
813	August 16–19, 1984	Eugene, Oregon	EXPIRED	August
814	November 2–3, 1984	Minneapolis, Minnesota	AUGUST 28, 1984	October
815	November 9–10, 1984	San Diego, California	AUGUST 31, 1984	October
816	January 9–13, 1985 (91st Annual Meeting)	Anaheim, California	OCTOBER 17, 1984	January
	March 22–23, 1985	Chicago, Illinois		
	April 12–13, 1985	Tucson, Arizona		
	April 19–21, 1985	Worcester, Massachusetts		
	January 7–11, 1986 (92nd Annual Meeting)	New Orleans, Louisiana		
	January 21–25, 1987 (93rd Annual Meeting)	San Antonio, Texas		
	January 6–10, 1988 (94th Annual Meeting)	Atlanta, Georgia		
	August 8–12, 1988 (AMS Centennial Celebration)	Providence, Rhode Island		

DEADLINES:	(*October* 1984 *Issue*)	(*November* 1984 *Issue*)
Advertising	*September* 13, 1984	*October* 11, 1984
News/Special Meetings	*August* 27, 1984	*September* 24, 1984

Other Events Sponsored by the Society

June 10–August 18, 1984, Joint Summer Research Conferences in the Mathematical Sciences, Bowdoin College, Brunswick, Maine.

July 22–August 4, 1984, AMS-SIAM Summer Seminar on Nonlinear Systems of PDE in Applied Mathematics, College of Santa Fe, Santa Fe, New Mexico. (Please note change of dates.)

July 16–August 3, 1984, AMS Summer Research Institute on Geometric Measure Theory and the Calculus of Variations, Arcata, California.

August 14–15, 1984, AMS Short Course: Environmental and Natural Resource Mathematics, Eugene, Oregon. This issue, page 508.

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Notices
of the American Mathematical Society

Volume 31, Number 5, August 1984

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Ad Hoc Committee on Resources for the Mathematical Sciences

The Ad Hoc Committee was charged by the National Research Council to report on the extent, nature, and adequacy of support for research in the mathematical sciences in the United States.

A summary of the report's findings was given in the address by E. E. David, Jr. at the Louisville meeting and published in the February 1984 *Notices*. The main text of the Ad Hoc Committee's report is published in this issue of the *Notices*. The report contains a number of Appendices: **Appendix A:** *The Mathematical Sciences Research Community*; **Appendix B:** *Federal Support: Trends, Analyses, and Data Sources*; **Appendix C:** *Ordering the Universe: The Role of Mathematics* by Arthur Jaffe; **Attachment 1:** *Report of the Briefing Panel on Mathematics*; and **Attachment 2:** *Report by the Subpanel on the Department of Defense of the Mathematics Briefing Panel.* Attachment 1 was published in the *Notices*, April 1983, pages 271–279. Other Appendices are scheduled for the October issue of the *Notices*.

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The opinions, findings, conclusions, and recommendations expressed in the report are those of the authors and do not necessarily represent the views of the supporting organizations and agencies.

Copies of the report may be obtained from the Board of Mathematical Sciences, 2101 Constitution Avenue, Washington, D.C. 20418

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Renewing U. S. Mathematics: Critical Resource for the Future

Report of the National Research Council's Ad Hoc Committee on Resources for the Mathematical Sciences

I. Background

The Ad Hoc Committee on Resources for the Mathematical Sciences was established in June 1981 by the National Research Council's Assembly of Mathematical and Physical Sciences[1] to review the health and support of mathematical research in the United States. Preliminary evidence presented to the Assembly by its Office of Mathematical Sciences had suggested that in the nation's major universities external support for mathematics had lagged considerably behind corresponding support in other fields of science. The evidence was sufficiently dramatic that the charge to the Committee contained more emphasis on financial support than is usual for a review of the health of a scientific field. Committee members with a range of scientific interests and experience were chosen to ensure that this review would be carried out with a broad perspective.

Early in our Committee's deliberations, we came to three important realizations:

- Mathematics is increasingly vital to science, technology, and society itself.
- Paradoxically, while mathematical applications have literally exploded over the past few decades, there has been declining attention to support of the seminal research which generates such benefits.
- Opportunities for achievement in mathematical research are at an all time-high, but capitalizing on these will require major new programs for support of graduate students, young investigators, and faculty research time.

These perceptions guided the activities of our Committee as we pursued our charge.

II. The Mathematical Sciences

A. Strengths and Opportunities

The period since World War II has been one of dazzling accomplishments in mathematics. The flourishing of the discipline has run hand-in-hand with burgeoning applications, which today permeate the theoretical fabrics of other disciplines and constitute important parts of the intellectual tool kits of working scientists, engineers, social scientists, and managers. These developments were nurtured by cooperation between the universities and the federal government, and fueled by a national commitment to strengthening scientific research and education. The injection of federal funds into universities, combined with a pervasive sense of the importance of research, attracted numbers of the best young minds in the country into science and mathematics and propelled the United States into world leadership in the mathematical sciences.

The field expanded and diversified enormously during this period. Mathematical statistics matured. Operations research was born. Mathematics in engineering flowered with prediction theory, filtering, control, and optimization. Applied mathematics extended its reach and power, and the discipline of mathematics grew at a breathtaking pace.[2]

Since World War II, the impact of mathematics on technology and engineering has been more direct and more profound than in any historical period of which we are aware. When we entered the era of high technology, we entered the era of mathematical technology. Historically, the work of Wiener and Shannon in communication and information theory highlights the change. The mathematical underpinnings of the computer revolution, from von Neumann onward, and the sophisticated mathematical design of the fuel-efficient Boeing 767 and European Airbus airfoils further exemplify the increased impact of applied mathematics.

The discipline of mathematics also advanced rapidly and contributed to the solution of problems in other fields of science. Fundamental questions in algebra, geometry, and analysis were addressed with ever-increasing conceptual generality and abstraction; new interactions between parts of contemporary mathematics and physics, as in gauge field theory, remind us of the payoff of mathematics for other sciences. Indeed, in the span of little more than the past two years we have seen four Nobel Prizes awarded to U. S. scientists for largely mathematical work, much of it employing mathematical structures and tools developed

[1] Now the Commission on Physical Sciences, Mathematics, and Resources.

[2] In addition, computer science developed from roots in mathematics and electrical engineering, then spun off to become a separate discipline. It is important in reading this report not to confuse computer science with the mathematical sciences. The relationship of the fields is discussed in Appendix A.

over the last few decades: Chandrasekhar in astrophysics, Cormack in medicine (tomography), Debreu in economics, and Wilson in physics.

Major research opportunities for the future exist in the study of nonlinear phenomena, discrete mathematics, probabilistic analysis, the mathematics of computation, the geometry of three- and four-dimensional manifolds, and many other areas.[3] The infusion of mathematics into society will continue and accelerate, creating further opportunities and increased demand for mathematical scientists.

B. Prospects for the Future

There are reasons to be quite concerned about the future, in spite of current vitality and past achievements. In mathematics, the country is still reaping the harvest of the investment of human and dollar resources made in the mid-to-late 1960s. Investments since that time have not been adequate to assure renewal of the field, to provide the seminal work supporting expanded applications, or to pursue the remarkable opportunities in prospect.

During the past few years, concern about the future of mathematics has been reflected in an unprecedented probing and searching within and by the mathematical sciences community. The state of mathematics, its applications, and its future promise have been assessed in:

- the report of the COSEPUP Research Briefing Panel on Mathematics presented to OSTP and NSF [see *Notices*, April 1983],
- its supplementary report to DOD and the DOD-University Forum,
- reports to the NSF Advisory Committee for the Mathematical Sciences by J. Glimm [see *Notices*, January 1983], on the future of mathematics, and I. Olkin and D. Moore, on statistics,
- the G. Nemhauser/G. Dantzig report on research directions in operations science,
- the report of the NSF/DOD Panel on Large-Scale Computing in Science and Engineering,
- reports of the NRC Committees on Applied and Theoretical Statistics and on the Applications of Mathematics.

In all of these the theme recurs: in mathematics itself and in its capabilities for application there is a multitude of major opportunities, but the resources, people, and money are not available to capitalize on them.

Our Committee has found the support situation in mathematics to be worse than the preliminary evidence suggested:

Since the late 1960s, support for mathematical sciences research in the United States has declined substantially in constant dollars, and has come to be markedly out of balance with support for related scientific and technological efforts. Because of the growing reliance of these efforts on mathematics, strong action must be taken by the Administration, Congress, universities, and the mathematical sciences community to bring the support back into balance and provide for the future of the field.

[3]These research opportunities are discussed in detail in Chapter II.

III. The Weakening of Federal Support

A. How It Happened

In many ways, the history of support for mathematical research resembles that of other sciences: a rapid buildup of both federal and university support through the 1950s; some unsettling changes in the early-to-mid-1960s; then a slackening of federal support in the late 1960s and early 1970s, because of increased mission orientation of federal R&D and reductions in federal fellowships; and finally, more than a decade of slow growth.

However, mathematics faced special problems, owing to its concentration at academic institutions and its dependence for federal support on two agencies: the National Science Foundation (NSF) and the Department of Defense (DOD).[4] In the mid-1960s, increased focus on mission-oriented research (a change accelerated by the 1969 Mansfield Amendment) caused DOD to drop nearly all of its support of pure mathematical research and parts of basic applied work as well. Then dramatic reductions in federal fellowships beginning in 1971 removed virtually all federal support of mathematics graduate students and postdoctorals. Compensation for these two types of losses could only be made at NSF, but at NSF constant dollar support of mathematical research decreased steadily after 1967. **We estimate the loss in federal mathematical funding to have been over 33% in constant dollars in the period 1968–1973 alone; it was followed by nearly a decade of zero real growth, so that by FY1982 federal support for mathematical sciences research stood at less than two-thirds its FY1968 level in constant dollars.**[5]

While federal support for related sciences also dipped in 1969-1970, these sciences received (constant dollar) increases in NSF funding in the years 1970–1972 and thereafter, as well as support from other agencies; mathematics did not.[6] This

[4]The two agencies account for 93% of support. Today, the role of the Department of Energy in supporting work at the interface of mathematics and computation is of ever-increasing importance, however.

[5]FY1968 was not a peak budget year for mathematical research. It is the year in the period 1966–1970 for which we have the most accurate data.

[6]Chemistry and physics constant dollar budgets at NSF dipped in 1969-1970, then increased by over 25% in the years 1970–1972, and continued to grow until the late 1970s.

resulted in the present imbalance between support for mathematics and related sciences:

Comparisons of Federal Support in Institutions of Higher Education for Three Fields of Science, 1980

	Chem.	Physics	Math. Sciences
Doctoral scientists in R&D	9,800	9,200	9,100
Faculty with primary or secondary activity in R&D	7,600	6,000	8,400
Faculty in R&D federally supported	3,300	3,300	2,300
Approximate annual Ph.D. production	1,500	800	800
Graduate research assistants federally-supported	3,700	2,900	200
Postdoctorals federally-supported	2,500	1,200	50

SOURCE: NRC Survey of Doctoral Recipients, National Science Board—Status of Science Review.

B. Why It Escaped Notice

Three things made it difficult for mathematicians and policy-makers to quickly grasp the full extent of the weakening of support for mathematics:

- After the sharp decline of 1968–1973, universities increased their own support for many things which earlier would have been carried by research grants. It was only after financial problems hit the universities in the mid-1970s that the severe lack of resources became evident.
- The growth of computer science support masked the decline in mathematics support because of the federal budget practice of carrying "mathematics and computer science" as a line item until 1976.
- The explosion of the uses of mathematics caused funding to flow into applications of known mathematical methods to other fields. These were often labelled "mathematical research" in federal support data. The category grew rapidly, masking the fact that support for fundamental research in the mathematical sciences shrank.

C. Its Consequences

The absence of resources to support the research enterprises in the country's major mathematical science departments is all too apparent. In most of them, the university is picking up virtually the total tab for postdoctoral support, research associates, and secretarial and operating support; as a result, the amounts are very small. Graduate students are supported predominantly through teaching assistantships, and (like faculty) have been overloaded because of demands for undergraduate mathematics instruction, which have increased 60% in the last eight years. The number of established mathematical scientists with research support, already small in comparison with related fields, has decreased 15% in the last three years. Morale is declining. Promising young people considering careers in mathematics are being put off.

Ph.D.'s awarded to U. S. citizens declined by half over the last decade. A gap has been created between demand for faculty and supply of new Ph.D.'s. It may well widen as retirements increase in the 1990s. There is the prospect of a further 12% increase in demand for doctoral mathematical scientists needed for sophisticated utilization of supercomputers in academia, industry, and government.

The most serious consequence has been delayed. In a theoretical branch of science with a relatively secure base in the universities, sharp reduction in federal support does not leave large numbers of scientists totally unable to do their research, as might be the case in an experimental science. There is a considerable time lag before there is a marked slowing down of research output. The established researchers and the young people who were in the pipeline when reduction began carry the effort forward for 15 or 20 years, adjusting to increased teaching loads, to decreased income or extra summer work, and to simply doing with fewer of most things. If the number of first-rate minds in the field is large at the onset of the funding reduction, an effort of very high quality can be sustained for quite some time.

This is what has been happening in the mathematical sciences in the United States for over a decade. The situation must be corrected.

IV. Future Support

A. The Needs of Research Mathematical Scientists

The research community in the mathematical sciences is concentrated heavily at academic institutions spread throughout the country. Over 90% of productive research mathematicians are on the faculties of the nation's universities and colleges. Their numbers equal those of physics or chemistry, some 9,000–10,000.

To pursue research effectively, mathematical scientists need:

(1) research time,
(2) graduate students, postdoctorals, and young investigators of high quality,
(3) research associates (visiting faculty),
(4) support staff (mostly secretarial),
(5) computers and computer time,

(6) publications, travel, conferences, etc.

During the fifties and sixties, these needs were effectively met by the injection of federal funds for research into universities. That spurred remarkable growth and propelled the United States into world leadership in the mathematical sciences. The erosion of support since the late 1960s has slowed momentum and decreased the rate of influx of outstanding young people into the mathematical sciences.

B. A Plan for Renewal

What has been described makes it evident that realization of the potential for mathematics and its applications requires a substantial increase in extra-university support. Because there is often an indirect relation between mathematical developments and their applications, significant support from industry will not be forthcoming. Thus, the role of government is crucial.

Incremental budgetary increases of the usual sort cannot deal with the severe inadequacy of support. We estimate that the federal support needed to strengthen mathematical research and graduate education is about $100 million more per year than the FY1984 level of $78 million. Significant additional resources are needed in each of the six basic categories we identified earlier. The resources will:

- allow mathematical scientists to capitalize on the future opportunities provided by the dramatic intellectual developments now occurring,
- provide for the attraction and support of young people to help renew the field,
- sustain the work of established researchers.

As the framework for this, we have determined through analysis the elements of a program to renew U. S. mathematics. This program can be carried out through expansion of support to the $180 million level over the next five years. This National Plan for Graduate and Postdoctoral Education in the Mathematical Sciences has these features:

- Each of the approximately 1,000 graduate students per year who reaches the active level of research for a Ph.D. thesis would be provided with 15 months of uninterrupted research time, preceded by two preceding summers of unfettered research time.
- Two hundred of the 800 Ph.D.'s per year would be provided with postdoctoral positions averaging two years in duration at suitable research centers.
- There would be at least 400 research grants for young investigators (Ph.D. age three to five years).
- At least 2,600 of the established mathematical scientists who, with the young investigators, provide the training for the more than 5,000 total Ph.D. students and the 400 total postdoctorals would have sufficient supported research time not only to conduct their own research, but also to provide the requisite training for these young people.
- Support would be provided for associated research needs of the investigators.

We believe this plan to be consistent with the priorities set by the mathematical sciences research community through several self-studies in the last few years.

C. Implementation

It will be up to the Administration and Congress to decide what national priority to assign to these needs. We would remind them that what is at stake is the future of a field central to the country's scientific and technological effort. While the uses of mathematics in other fields have been supported, somehow the needs of fundamental mathematics were lost sight of for over a decade. Since there is about a 15-year delay between the entry of young people into the field and their attainment of the expected high level of performance, this decade of neglect alarms us. We urge immediate strong action, in the form of a five-year "ramping up" of federal support for the mathematical sciences (18% real growth annually, for five years). An effort to renew mathematics support has already begun at the National Science Foundation. This must be continued for five more years, with a parallel effort at the Department of Defense. This will bring support back into balance and allow for renewal, provided Department of Energy resources going to the mathematics of computation are significantly increased to sustain the initiative which we recommend in this field.

Appropriate utilization of present and future resources requires a well-thought-out and consistent set of priorities in the expenditures of funds. Recommendations of this type have recently been set forth in the COSEPUP Mathematics Briefing Panel Report prepared for OSTP and its companion report specifically for DOD, as well as recent reports of the NSF Advisory Committee for the Mathematical Sciences. We have built on these community efforts to systematically and consistently direct funding trends. The efforts must continue, to ensure the most efficient and fruitful utilization of resources.

Success will also depend on action and understanding within the nation's universities. For too long, they have been silent about the fact that the level of external support for research in their mathematical science departments is markedly out of balance with the general level of support for science and engineering in the country. The disparity is reflected in the working circumstances of their mathematical faculties and graduate students. As added resources become available, they must be used in part to ease the strain on the mathematical science departments, which embody mathematical research in the United States.

Still, the group which has the fullest agenda before it is the mathematical sciences research community. It is obvious to anyone that if a field gets into the sort of extreme situation we have described, the associated research community must bear much of the responsibility. We urge the mathematical scientists to greatly step up efforts to increase public awareness of developments in the mathematical sciences and of the importance of the broad enterprise to the nation; to set their priorities with long-term needs in mind, and to develop mechanisms for effectively presenting their needs to the universities, to the Administration and to Congress—all with a renewed commitment to the unity of the mathematical sciences.

I. Introduction

The reputation and achievements of the American mathematical community place the United States first among the nations of the world in mathematical sciences research. The tools—the concepts and techniques—which mathematical scientists have created, and continue to create, play a vital role in the advancement of science and technology in our country, as well as in its defense and economic development. As these tools are developed and refined, they also feed into a broader mathematical effort in the training of technical manpower and the general education of citizens. It is important to the country that mathematical sciences research remain vigorous and productive.

A. Vitality of the Mathematical Sciences

We shall assess the current strength of mathematical research by:

- discussing the accomplishments of the mathematical sciences, both historically and in terms of their potential contributions to society
- examining the health of the institutions and organization systems through which research is conducted.

The first task is difficult, because much of mathematical research is unfamiliar to people outside the field and is therefore not easy to describe. Mathematical research baffles the general public. Precision and logic, so fundamental to mathematics, appear antithetical to exploration and discovery. Moreover, we often encounter mathematics first through seemingly arbitrary rules which foster the illusion that mathematical techniques or theorems were not searched out but were somehow always there, presumably handed down in one great mathematical utterance some time in the dim past.

Even the scientific or technological public, well aware that mathematics is ever-changing and discovered by people, is unfamiliar with large portions of the subject. A normally affable discussion takes place with regularity over whether the difficulties in understanding mathematics are inherent in the subject or result from the mathematicians' failing to make their subject comprehensible to outsiders. To deal with this communication problem, we have (i) included Appendix A, which describes the varied approaches to research in the mathematical sciences, delineates its boundaries, and discusses the size and other characteristics of the research community; (ii) augmented our discussion of the health of the field in the main text by including as Appendix C a paper by Professor Arthur Jaffe, *Ordering the Universe: The Role of Mathematics*, which talks about the importance of mathematics to science and technology.

The "invisible" character of much mathematical research also suggests that the field is small, but the academic research community is about the same size as that of physics or chemistry: 9,000–10,000 members. Indeed, its faculty component is larger than in those two fields. The scope and diversity of the mathematical sciences are vast. The field's rapid development and expansion keep pace with other sciences and technology. If one does not know what is "out there" in the newer parts of mathematics, it helps to remember that calculus, which seems rather advanced to the public, was at the frontier of mathematics in 1700. The development of mathematics in the ensuing 284 years has been as dramatic as the general development of science and technology.

Our discussion of the health of the institutional structures for mathematical research begins by reviewing their development through post-World War II university-government cooperation. We describe some serious problems, especially those confronting the major university departments. These centers of research are widely spread around the country and form the matrix which holds the mathematical research community together.

B. Support of Research

The discussion of support for the field is divided into two parts: an historical analysis of support up to 1982; and future planning.

What we found is complex and unusual. We identify a substantial support deficiency in mathematical sciences funding compared to its allied fields in the physical sciences and engineering. This deficiency resulted from events in the period 1968–1973 and doubled the negative impact of the slow squeeze that various other fields of science felt over the same period. We suggest how to deal with the built-in deficiency and provide funding adequate to capitalize on the exciting opportunities mathematics and its applications offer.

The country's mathematical research community finds itself in a deeply serious, highly unusual situation, despite its current vigor and past achievements. The field is not renewing

itself. It lacks the resources to perform the seminal mathematical work on which the future depends. Bold action, by a number of groups, will be required to maintain the health and quality of research and seize the remarkable opportunities currently available. Our recommendations focus on these points.

C. Scope of the Mathematical Sciences

The mathematical sciences research community includes:

- pure mathematicians, who create the discipline itself;
- applied mathematicians, who develop mathematical tools, techniques, and models to understand scientific phenomena or solve basic technological problems; specialists in numerical analysis and scientific computing;
- statisticians, who develop and apply mathematical techniques to analyze and interpret data for use in inference, prediction, and decision-making;
- mathematicians in operations research who develop and apply optimization techniques to management and decision-making;
- mathematical specialists in fields of engineering, e.g., communication and control theories;
- mathematical biologists, mathematical economists, etc.[7]

D. Relationship to Computer Science

Computer science is not a branch of the mathematical sciences. It makes pervasive use of mathematics; however, it has its own sources of funding and has been recognized as a separate discipline for more than a decade. Prior to that time, academic institutions and federal agencies frequently grouped the theoretical parts of computer science with mathematics under headings such as "mathematics and information sciences," "mathematical/computer sciences," or, in a few cases, "mathematical sciences." Residues of these practices exist today. In reading this report and in using older reports or data on science and science funding, it is essential to maintain the mathematical sciences/computer science distinction.[8]

There will continue to be important intellectual activity along the boundary between the mathematical sciences and computer science, especially in the areas of theoretical computer science and scientific computing.

E. Relationship to Education

Research and education in mathematics have always been strongly coupled—they still are. Nearly all mathematical researchers also teach at the college level. Many are intensely involved in the early years of mathematics education. Concern for precollege mathematics and science education in the United States is great. The quality of today's mathematical education, at all levels, will determine the quality of tomorrow's research scientists. Literacy in science and mathematics must be the hallmark of any contemporary citizenry.

The full spectrum of mathematics education must be a high-priority item for the mathematical sciences research community. We have been forced to limit the scope of our inquiries and hence have not dealt in detail with the important topic of mathematics education. We are pleased to see the research community contributing to the national dialogue[9] and participating more directly in improving precollege education. Our report urges stepping up these efforts with the strong backing of the professional societies.

II. The Mathematical Sciences: Strengths and Opportunities

The period since World War II has been one of dazzling accomplishments in science and technology, especially in mathematics, which is riding the crest of a wave of development rare in intellectual history. This flourishing of the discipline has run hand-in-hand with burgeoning applications. These applications, unknown before the War, today permeate the theoretical fabrics of many disciplines and make up important parts of the intellectual tool kits of working scientists, engineers, social scientists, and managers.

The mathematical sciences have become enormously diverse. Over the postwar decades, mathematical statistics came to full maturity; operations research was born; discrete mathematics with combinatorial formulations came into prominent use; mathematics in engineering, concerned with control and operations, optimization and design, flourished; numerical analysis allied with computing touched many fields. Traditional applied mathematics also greatly extended its reach and power and the discipline of mathematics itself developed at a breathtaking pace.

We shall discuss in detail only a few of the important developments and promising directions, within the context of changes in the dynamics of the field as a whole.[10] Our comments are amplified by Appendix C, in which Professor Arthur Jaffe's paper, *Ordering the Universe: The Role of Mathematics*, examines in depth the

[7] See Appendix A for a more complete discussion.

[8] Ibid.

[9] For example, through the Conference Board of Mathematical Sciences' contributions to the National Science Board's Commission on Precollege Education in Mathematics, Science, and Technology.

[10] See the Introduction and Appendix A for a description of the scope of the mathematical sciences. Note that computer science is *not* included among them.

evolution of several areas. Professor Jaffe's personal perspective extends and enlarges upon our general remarks, given under these headings: (a) mathematics and technology, (b) mathematics in and as science, (c) trends, and (d) looking ahead.

A. Mathematics and Technology

The emergence of "high technology" brought our society into an era of mathematical technology, in which mathematics and engineering interact in new ways. Fifty years ago this was the pattern: mathematics made some tools directly for engineering but basically promoted the development of other sciences, which, in turn, provided the foundations for engineering principles and design. Mathematics and engineering now interact directly, on a broader, deeper scale, greatly to the benefit of both fields, and to technology. Here are six examples of the new pattern.

1. Communication

A mathematical work that marks the beginning of this new era is Norbert Wiener's classic paper, *Extrapolation, interpolation and smoothing of stationary time series* (Wiley, New York, 1949). Its ideas and results grew out of Wiener's work on gunnery problems during World War II, first appearing as a classified document which, because of its yellow cover and impenetrability to engineers, was affectionately known as "The Yellow Peril." Wiener's work, interpreted by his colleague, Norman Levinson, blended with the pioneering work of Kolmogoroff in the Soviet Union to form communication theory: the study of transmitting, coding, and decoding messages over noisy channels. Their results dealt with continuous signals and were augmented by the very different work of Claude Shannon, the founder of information theory. This collective work found significant application within the communications industry in areas as diverse as analog and digital voice, data, and image transmission; signal processing, in fields from radar interpretation to musical and physiological data analysis; and in data processing itself.

But such developments inevitably have other, far-reaching consequences. For example, the vast seismic oil exploration industry grew directly out of applying the Wiener/Levinson results to design and construction of equipment to filter noise and interpret seismic signals. Signal processing has played a vital role in exploratory geophysics, as it has in resolving bomb testing data, and in predicting earthquakes.

2. Control

Recent years have seen a major extension of the calculus of variations by Bellman, Hestenes, Lefschetz, Pontrjagin, and others, leading to the development of the theory of optimal control. A critical innovation of Kalman's changed the paradigm for filtering by introducing matrix Riccati equations. Optimal control with the Kalman filter played an essential role in guidance and control in the Apollo Program. Continuous, discrete, stochastic, and distributed control methods are now valued engineering tools. Modern problems span the range from operational control of continuous process manufacturing of semiconductor chips to the stability of large space platforms.

3. Management

Industry and commerce now apply mathematics to operations and management, a relationship which evolved from operations research, which itself grew out of logistical analysis in World War II. The optimization techniques of linear programming using George Dantzig's simplex method (1947) improved management decisions in varied industrial and business contexts, from routing tanker fleets, to optimal use of factory machines, to organizing transportation systems. Later developments in nonlinear and integer programming, effective methods for finding maxima and minima of nonlinear functions, broadened the range of applications and contributed to the emergence of operations research and management science as ongoing fields of inquiry. Along with game theory and other concepts, these methods serve as valuable production tools in everything from oil refining and other chemical processes to clothing design and manufacture; they are tools in operations, from bus scheduling, to military tactics, to stock market activities.

4. Design

The fuel-efficient Boeing 767 and European Airbus airfoils have been designed using a process involving an entire spectrum of applied mathematics:

- new physical behavior, such as shock motion and shock/boundary layer interactions;
- a system of nonlinear partial differential equations that change character as flow speeds change from subsonic to supersonic, so that new features of the solution must be understood and calculated;
- new analytical approximations to solutions of the system;
- powerful new numerical methods;
- efficient coding and storage of these methods which enable design calculations to be done economically.

Mathematical formulations and analysis in fluid dynamics—developed since the time of Euler and the Bernoullis—played an essential role.

Mathematical design of this complex type is applied to magnetic data storage disks, nuclear reactors, semiconductor chips, automobile bodies and other products. More powerful analytical and numerical methods, along with cheaper calculational capability, will make mathematics even more important in design.

5. The Computer

The development of computer technology has been strongly influenced by mathematics. The art of computation, numerical analysis, has been an important part of mathematics since it was systematically explored by Newton, Euler, and Gauss. Its importance has increased because of the development of high-speed digital computers. Here, we want to stress the importance of mathematics to the evolution of the machines themselves.

In the 1930s symbolic logic flourished. Church, Gödel, Post, and others studied formalized languages, and the mathematical notion of computability emerged from their work and Turing's. Around 1935, Turing constructed his abstract model for a universal computing machine. These developments provided the intellectual framework for the creation of both the stored program computer (by von Neumann and his colleagues) and formal programming languages.

Computer science, in contrast to computer engineering, has a strong mathematical base. Mathematics underlies much of computer science and systems thinking: working out paradigms for artificial intelligence, from verifying the correctness of programs to the first robotic theories; developing the inner algorithms for operating system schedules, pagers, and dispatchers; providing the relational algebra and calculus of data bases. These are no accidents of history because understanding the capabilities of a tool which is essentially a calculator requires the kind of facility with precise forms of abstraction which characterizes mathematical thinking.

6. Alternative to Experimentation

Mathematics and computation are now forming a much larger place for themselves as an alternative to experimentation. This is a role that is not new to mathematics, but one that can now be played far more effectively using computational power. Mathematically prepared computational models are used to stimulate complex structures, systems, or organizations in a number of industrial research, development, and manufacturing settings. Calculational models are used to design, optimize, and study effective operations in place of building costly petrochemical pilot plants. A large computational system, programmed to solve tough nonlinear partial differential equations, can do much of the work of expensive-to-build and expensive-to-operate wind tunnels. Analysis of a large space station for controllability, structural integrity, and general dynamic behavior must be done before the station is sent aloft. Huge calculations, requiring processing at over a billion computer instructions per second, are currently used to test the logic flow on integrated circuit chips before they are constructed.

In all of these examples, and in many others, the ability to mathematically represent the system or the structure and then the capability for efficient computation, are becoming an economic way to do the work of experimentation. We will see a great deal more use of this new kind of engineering and scientific tool in the future.

Mathematics is on the verge of its greatest involvement in technology.

B. Mathematics in and as Science

1. The Nonlinear World

Mathematics has always had a close relationship with the physical sciences. Continuum mechanics and mathematical analysis developed together. In the new physics of this century, mathematics has been available in advance of physical concepts (e.g., matrix and group theory for quantum mechanics or differential geometry for general relativity) and has developed with them.[11] In chemistry and biology, mathematics has begun to move forward swiftly in recent years. For example, reaction-diffusion mechanism study in both fields has involved the nonlinear generation of wave patterns, pulses, and shock fronts which are phenomenologically new and require new modes of analysis. In geophysical sciences, analytical approximation to atmospheric, oceanic, and elastic wave motions has produced new interpretations with which to forecast weather and predict earthquakes.

In all these fields, considerable interest focuses on the new, nonlinear phenomena associated with strong force and energy interactions, discrete-continuous interactions, or the more subtle low-energy nonlinearities of the biological world, phenomena which will dominate much of the mathematics of science from now on. We already see this in the fascination with solitons, chaos, and bifurcation and singularity theories.

In some ways, this is a testing time for mathematics because it requires developing far more complex concepts and structures than those of the 19th-century linear world. The work is well begun. Topological and analytical methods of ergodic theory and dynamical systems theory are helping unravel such challenging problems as turbulence.[12]

2. Gauge Field Theory

Mathematical research, driven by its inner dynamics, has developed concepts important for gauge field theory in physics. The physicist C. N. Yang wrote, "I found it amazing that gauge fields are exactly connections on fibre bundles, which the mathematicians developed without reference to the physical world." Algebraic geometry produced all self-dual solutions for the Yang-Mills equations. But the physical theory also had important consequences in topology.

[11] See Jaffe's paper, Appendix C.

[12] A brief appreciation of where we stand on this problem is given in Attachment 2.

Physicists introduced gauge theories in four dimensions (space-time) as a unifying principle in field theory. The study of Yang-Mills equations of motion led Donaldson to a remarkable description of certain four-dimensional spaces. A little earlier, Freedman, using purely topological methods, had produced a comprehensive theory of four-dimensional manifolds. In all other dimensions there is essentially one mode of doing calculus in a Euclidean space: Euclidean space of dimension n has a unique differential structure for $n \neq 4$; but an entirely different situation exists in dimension four—there are at least two different structures on four-dimensional Euclidean space. This qualitative difference between dimension four and other dimensions is a startling development for topology, and may also reflect deep physical principles.

3. Global Analysis

Global analysis currently employs not only differential geometry, topology, and Lie group theory, but also partial differential equations, functional analysis, quasi-conformal mapping theory, and ergodic theory. Some of its direct uses have already been commented upon. Its ideas have evolved over a considerable span of time.

Every scientist since Newton's time has resorted to calculus to determine the effects of physical laws. While ideal for analysis of gradual changes, calculus is often mute on large-scale nonlinear ones. Before 1945, global configurations study was still fragmented, its concepts difficult to communicate. To be sure, we must pay homage to the topological ideas of Poincaré, Cartan, and Lefschetz. But only after 1945 were grand syntheses erected from the fundamental structural elements developed since the 1930s (principally in France and the United States). These syntheses led to an almost complete understanding of not only the local geometry, but also the global character of the basic mathematical spaces. These are the homogeneous spaces Felix Klein singled out in his 1872 Erlangen program: geometries in which any point's situation is like any other's. They include spheres and flag manifolds on the one hand (on which compact groups operate transitively) and higher-dimensional generalizations of Riemann surfaces on the other. Homogeneous spaces form the basic building blocks with which to comprehend spaces arising in physics as well as mathematics.

4. Finite Groups

The mathematical concept of "group" was born in 1832 when Galois perceived the importance of systematically studying the general structure of permutations of the roots of polynomial equations. Widespread application of the theory of groups has developed in the ensuing century and a half—application to mathematics, physics, chemistry, and numerous other fields.

A complete classification of finite simple groups is now known. Even more remarkable than the solving of this 100-year-old problem is the nature of the solution itself. A famous 254-page paper by Feit and Thompson, showing that any simple group has even order, touched off a chain of developments which led to the final classification: any finite simple group is an alternating group, or is a finite version of a simple Lie group, or is one of 26 exceptional groups.

The exceptional groups have their own interesting stories. The Mathieu groups play a role in coding theory. The "monster," the last exceptional group whose existence lacked proof, was constructed by Griess in 1981. Its further study has led to a rich set of mathematical problems, involving the relations between the structure of the monster; the Griess algebra, of which the monster is the group of automorphisms; the Leech lattice, in terms of which Frenkel, Lepowsky, and Meurman have reconstructed the Griess algebra; infinite-dimensional Kač-Moody algebras; and classical automorphic functions.

5. The Mordell Conjecture

Mathematicians in algebraic geometry and number theory were astounded in the summer of 1983 to learn that a conjecture of 60 years' standing had fallen under the assaults of a German mathematician, Gerd Faltings. The Mordell Conjecture was first formulated in 1922. It deals with the number of rational points on algebraic curves of genus 2 or higher. It concerns the number of points having rational coordinates on curves defined as the solution set for a polynomial equation in two variables with rational coefficients. Mordell conjectured that the number of rational solutions was finite; Faltings proved it, using the enormous mathematical machinery constructed over decades to attack fundamental questions in number theory and algebraic geometry.

Faltings's proof brought with it progress on the conjecture known as Fermat's Last Theorem. One of the cases covered by the Mordell Conjecture was the equation $x^n + y^n = 1$. Its solution with rational numbers x and y corresponds to finding integer solutions of the equation $a^n + b^n = c^n$, about which Fermat had made his famous conjecture 300 years ago: there are no solutions in positive integers a, b, and c when n is greater than 2. Fermat wrote in his workbook that he had found a truly remarkable proof, which unfortunately the margin was too small to contain. The pursuit of a proof has intrigued mathematicians ever since. Falting's proof that $x^n + y^n = 1$ has only a finite number of rational solutions is a significant step.

We come full circle in our discussion of the mathematical sciences by noting that number theory, long thought to be the purest of the parts of mathematics, is today of increasing use in constructing algorithms of practical importance in fields such as cryptography. The same is true of various parts of algebra and algebraic geometry. This should not surprise us, if we remember that

one of the goals of algebra has always been to reduce problem solutions to algorithms.

C. Trends

1. Size and Strength

As the mathematical sciences grew in scope after World War II, the associated research community grew in size and strength. The 1966 *World Directory of Mathematicians* listed 2,900 U. S. mathematical scientists active in research. By 1970, the number had grown to 3,800; by 1982, it had reached 7,600. These totals do not include all of the research mathematical scientists, because the *World Directory* literature search misses several hundred applied mathematicians.

The strength of the research community is attested to not only by the sophistication and significant impact of applications such as the design practices we cited in the aircraft industry, but also by the fact that of the 27 Fields Medals, awarded quadrennially since 1936 at the International Congress of Mathematicians, eleven have gone to U. S. mathematicians, six to France, three to Great Britain, and two to the USSR.

The strength of direct contributions to other fields is reflected in the fact that three U. S. scientists were awarded Nobel Prizes for largely mathematical work in the two-year period 1982–1983: Chandrasekhar in astrophysics, Debreu in economics, and Wilson in physics. Not long before, Cormack had been similarly recognized in medicine for his work on tomography.

2. Intellectual Trends

Some intellectual trends which have developed over recent decades prefigure future research.

(a) *The concern with nonlinearity.* We have already discussed a wide variety of nonlinear problems in science, including associated developments in mathematical analysis, topology, etc., so we will only repeat our conviction that the attempt to understand the nonlinear world will dominate large parts of mathematics in science in the years ahead.

(b) *The increased role of discrete mathematics.* For centuries people have been fascinated by puzzles and the algorithms describing the steps for their solutions. Many difficult mathematical problems have such a character. In recent decades this area has become formalized as combinatorics: the study of finite structures in which there are relations between the elements but (usually) no operations of an algebraic sort.

Such problems as network node location, routing of messages, and distribution of information have discrete combinatorial formulations and are of great practical interest. Along with the recognition of problem types and the development of algorithms has come the need to compute. The notion of complexity (degree of difficulty) has developed because many innocent-looking looking questions result in exponentially fast growth of computation as the number of nodes increases. The result has been a powerful and intriguing notion of completeness: can a calculation be done in polynomial time, that is, in a time related to the number of elements of the problem (nodes of a network), or in exponential time—something raised to a power equal to the number of nodes? This abstraction tells us when problems can be computed practically and when they cannot.

(c) *The increased role of probabilistic analysis.* Statistics, placed on solid mathematical footing through the work of Cramer, Fisher, Neyman, Pearson, and Wald, grew as a separate intellectual discipline during the postwar era, solidifying its academic base markedly through the 1970s. Advances moved from decision theory to sequential analysis, theories of robustness, and bootstrap/jackknife methods of data analysis and estimation.

Mathematical statistics is gathering momentum for another move forward. Reliability theory has both military and industrial applications. New statistical theories, taking advantage of modern computing power, are just emerging. Greatly enhanced capacity for handling data has helped develop powerful methods, free of Gaussian assumptions and linear mathematics, to challenge theorists and practitioners alike.

In physics, new classes of probability measures on function spaces have been constructed that describe phase transitions in statistical mechanics and establish existence of quantum fields. The solution of quantum physics problems by probability theory methods has become important to physicists and opened new research in probability theory as well.

Randomness in calculation dates back to the Monte Carlo method from the 1940s. Recently, randomizing algorithms—algorithms that are correct almost all of the time—have produced enormous savings in computer time (numbers of steps) with minimal risk of error. One such algorithm, vastly improving computer security, will soon be hard-wired into silicon chips. Such methods will be essential in the future and are all the more mathematically interesting since they depend on the structural properties of rings of polynomials, number fields, and permutation groups.

(d) *The development of large-scale scientific computation.*[13] Computers already affect all of science, and much of human endeavor. In the future some scientific fields will be completely dependent on the computer's highly accurate, reasonably cheap ability to solve approximately huge systems of equations. This has already happened in meteorology and climatology. New physical concepts, such as renormalization, will require vast

[13]See Appendix A for a discussion of the relationship of scientific computing to the mathematical sciences and to computer science.

calculations for their application. Large computations of this type have always moved with the leading edge of computational technology.

A host of three-dimensional problems exists in geophysics (e.g., oil recovery), aerodynamics, and engineering, which require new computer hardware and operating systems, such as array and parallel processors. These, in turn, demand new numerical analysis and algorithms. There is also challenge in doing the sort of mathematics which anticipates new computing mechanisms and guides in their construction. Mathematics of many kinds must be done as this new scientific computation generation gets under way.

D. Looking Ahead

As always, looks ahead either extrapolate from the recent past or make guesses. Speculations about the future are especially risky in the mathematical sciences because the field is very broad and its history is filled with unanticipated applications of great practical importance. The breadth of the field requires us to be highly selective in looking ahead, citing only a few of the promising areas, only a few of the opportunities. We shall speculate about some broad new areas of opportunity. Beyond what we describe, remember the diverse and sizeable research activity which continues to generate important concepts and tools for science and technology.

We have described an expanded use of mathematics in fields of science and technology that were already mathematically based, the rapid entry of mathematics into other fields, and the mathematical foundation of the newly formed sciences. This expansion, this mathematization, will continue and accelerate, for several reasons.

1. Proliferation of the Uses of Mathematics

(a) *Data handling and analysis.* In biology, the social sciences, commerce, industry, management, and government, there has always been a large amount of data. Modern data handling now allows for the systematic acquisition, storage, and analysis of the data; the stage is set for the empirical recognition of behavior and phenomena that will lead to rule and principle. Mathematics will play a role in this formative process, then allow generalizations, prediction, and further understanding to develop through solutions of the mathematical problems.

In many fields, one must look for patterns of behavior, rather than a single phenomenon. This is so in experimental psychology, and will be even more so in clinical psychology, and in attempts to formulate the psychological underpinnings of economics and sociological behavior. If one is trying to capture or recreate pattern formation using data from diverse sources, there may be a need for parallel data processing. Parallel processors are now being designed experimentally, and the related mathematics is just getting under way. It may be a skillful extension of existing sequential mathematics or require new approaches and techniques. The mathematics of pattern formation, recognition, transformation, and stability have also been forming in recent years and will move more quickly with increased demand.

(b) *Mathematical education.* Another driving force expanding the use of mathematics will be the large number of people who havereceived higher level mathematical education in recent years, education which includes the capability of using the mathematics. Students—especially those in MBA programs—emerge from business courses with a knowledge of linear programming, other optimization techniques, and statistics. They are already using these skills in production, finance, management, and marketing. The same is true of students in economics and psychology. Physics, chemistry, and computer science students will need mathematics of ever-increasing sophistication. Experimental scientists will count elements of signal processing, such as the Fast Fourier Transform, among their tools.

This is not, of course, new mathematics; it is the penetration of mathematics into much of the work of the world. It will *engender* the need for new mathematics, as it is doing today.

2. Interaction with Basic Science

In the traditional fields of science and engineering, as we have already mentioned in an earlier section, both discrete and continuous mathematics will contend with nonlinearity. Perhaps general principles of the kind that guided linear mathematics in the past will not be found, but examination of the new mathematical phenomena (chaos, solitons, etc.) has already begun.

A traditional area of contact between mathematics and other sciences has been mathematical physics. The frontiers of research in pure mathematics and in physics drifted apart after the advent of quantum theory some fifty years ago. We are beginning a new era leading to the reunification of many general ideas in mathematics with those of quantum physics. New opportunities for development cross the boundaries between the mathematics of topology, geometry, probability theory, analysis, and differential equations on the one hand, and the physics of quantum field theory, of semiclassical approximations to quantum fields (especially for gauge theories), and statistical mechanics (including the theory of phase transitions) on the other.

Manifestations of this trend include a diverse set of recent results: deeper understanding of integration over function spaces has beenachieved as a byproduct of the construction of quantum fields; the development of "phase space localization" in quantum field theory as a tool to study eigenvalue spectra provides for reexamination of classical problems as well; the use of renormalization theory as the basis of a mathematical study of

phase transitions and of localization yields striking results; as we mentioned, Yang-Mills theory played a central role in constructing an exotic R^4 and in understanding related topological problems; the new geometric methods developed to understand the positive energy theorem in relativity extend the theory of harmonic maps; the new proof of the index theorem inspired by supersymmetric quantum theory raises the possibility that index theory can be generalized; "anomalies" of quantum physics (classical equations of motion which fail in quantum theory) intrigue mathematicians and physicists all across the country as they attempt to understand them as an aspect of K-theory.

3. Higher-Dimensional Manifolds

A major new possibility in the discipline of mathematics itself is that three-dimensional and four-dimensional manifolds may prove as rich in structure as the two-dimensional underpinnings of complex function theory, with as many applications. If Riemann surface theory and the associated analysis were a guiding concern for the century 1860–1960, so may the study of manifolds of dimensions three and four and related analysis be for the decades ahead. Thurston's work in dimension three and the role of self-duality in dimension four suggest this. The work leading to the nonuniqueness of differential structures on Euclidean space of dimension four is, we suspect, just the tip of an iceberg.

4. Computing

One of the largest stimulations and challenges for mathematics, and one of its greatest opportunities, will come from computation and computers.[14] The mathematics of computation now means the preparation and analysis of algorithms, the numerical treatment of those algorithms, and the optimal preparation and use of the numerical analysis on computing systems. It means even more.

Qualitative mathematical understanding is required to determine whether the ensuing numerical solutions are meaningful: Are theyunique? Are they stable? Is the dependence on conditions and parameters reasonable? We must study the complexity of the algorithms to know whether the calculations are economical. Mathematics will be increasingly required in designing almost all aspects of the computing system itself.

5. Changes in the Research Community

In the recent past, the range of applications of mathematics has been dramatically expanded, while the discipline of mathematics itself significantly enlarged its scope and deepened in complexity and abstraction. These developments have increased specialization, and the erection of barriers here and there, to separate "pure" from "applied" mathematics, or the two of them from statistics, operations research, or mathematics in engineering.

We believe that the face of the mathematical sciences is currently changing in two important ways:

- Unifying ideas, blurring the boundaries of the major disciplines, have regenerated a sense of wholeness, despite vast size and scope. Diverse mathematical scientists again see themselves participating in a common enterprise.
- Mathematics is increasingly looking outward, toward its interactions with science and technology.

There is a heightened awareness that sophisticated and abstract systems of mathematical thought, developed only because of man's drive to understand order, turn out with surprising regularity to find application in science. There is increased respect for the wealth of mathematical ideas generated by those who pursue mathematics precisely because of its direct contributions to science or engineering. There is increased appreciation of the continuity of methods and ideas across the spectrum of the mathematical sciences.

The changing face of mathematics suggests that we are entering a new era, that we have just begun to see the power of the mathematical machine created over the last several decades, and that what lies ahead could be even more impressive.

III. Inadequate Support: Legacy of the Past

The remarkable developments just described were nurtured by a sometimes unarticulated pact between the universities and the federal government, rooted in successful university-government research projects during and just after World War II, and in feverish post-Sputnik commitment to strengthening scientific and technical education in the United States. The resulting injection of federal funds for research into universities, combined with faculty growth accompanying greatly expanded enrollments, attracted numbers of the best young minds in the country to science and mathematics and propelled the United States into world leadership in the mathematical sciences.

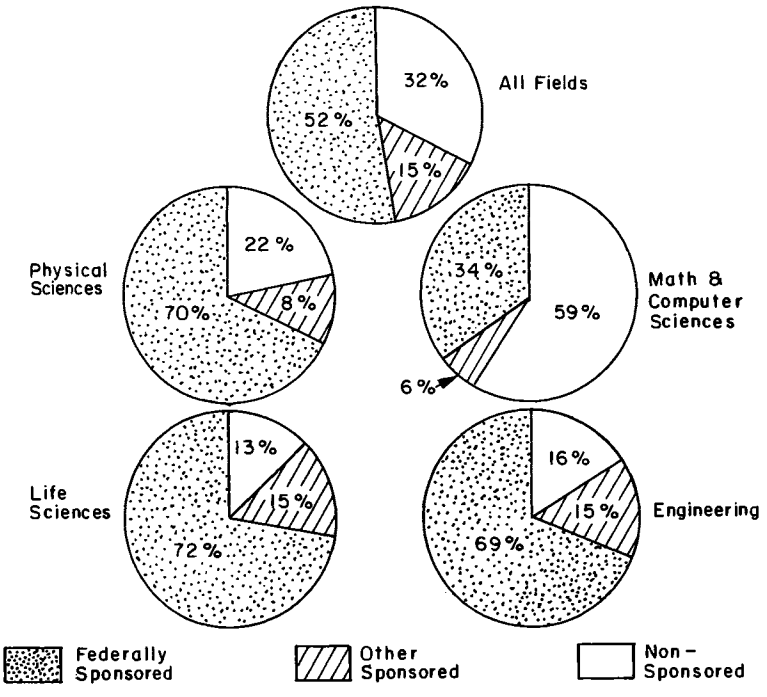
Although that leadership continues today, there are doubts about the years ahead. Extra-university support of mathematical sciences research[15] is inadequate to sustain the present quality and level of research effort, much less provide for renewing the field or capitalizing on future opportunities. We will identify marked inadequacies of extra-university support for the most basic needs of research scientists in mathematics, tracing the history of how the present

[14] Again, see Appendix A for the relation of the mathematical sciences to computer science.

[15] In discussions of federal support, it is especially important not to confuse the mathematical sciences with computer science. See Appendix A.

Figure 1

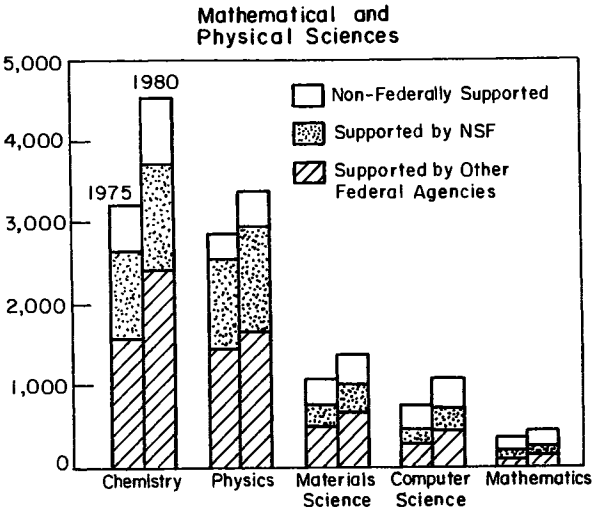
Research Time in Universities
November 1978 – October 1979



Source: National Science Foundation

Figure 2

Graduate Students with Research Assistantships Enrolled Full-Time in Doctorate Granting Institutions



Source: National Science Foundation
Status of Science Reviews, 1983

funding situation evolved and describing the impact of weak federal support. Finally, we will extract from this history some basic conclusions which bear on the future.

A. The Research Community and its Needs

The mathematical sciences research community in the United States has more than 10,000 members. About 9,000 of them are on faculties of the nation's universities and colleges. Additional groups are located at the "nearly academic" research centers: the Institute for Advanced Study at Princeton, the Mathematics Research Center at Madison, and two new institutes developing under NSF sponsorship, the Mathematical Sciences Research Institute at Berkeley, and the Institute for Mathematics and its Applications at Minneapolis. There are also several research groups in industry, the most prominent at Bell Laboratories and IBM, with others in the petroleum, aerospace, and defense industries. In government, basic work is being conducted at Argonne, Los Alamos, Oak Ridge, Sandia, and Lawrence Livermore National Laboratories, and at the Institute for Defense Analyses in Princeton, the National Bureau of Standards, the National Security Agency, and other agencies. The output of all these groups is extremely important, but we would point out that collectively they house less than 10% of the mathematical sciences research community.

A mathematical research scientist needs: (a) time to think and an appropriate place in which to do it; (b) interactions with developing young investigators (graduate students and postdoctoral fellows); (c) interactions with research associates, e.g., visiting faculty; (d) a certain amount of equipment (usually computational); and (e) support staff (primarily secretarial). Mechanisms for exchanging results, such as publications and conferences, are also important. In these respects, mathematical scientists are much the same as other scientists.[16]

B. Inadequacies

Figure 1 shows how research time in universities is paid for in the sciences and in engineering. In contrast to other fields, most mathematical sciences research is carried by the universities; a markedly smaller fraction is borne by the government.[17]

[16]Typically, equipment needs are less for mathematical scientists. Computation is changing this pattern, however.

[17]Separate data were not available for the mathematical sciences and computer science. Were computer science removed from the "math and computer sciences" piechart in Figure 1, the federally-sponsored percent would decrease. The effect would be relatively small, however, because the academic research community in the mathematical sciences is much larger than that in computer science.

Figure 2 and Table 1 show federal support for graduate research assistants and postdoctorals.[18] In interpreting them, one should be aware of some approximate sizes. Academic research communities number: chemistry, 10,000; computer science, 2,000; mathematics (mathematical sciences), 9,000; physics, 9,000.[19] The approximate annual Ph.D. productions are: chemistry, 1,500; computer science, 200; mathematics, 800; physics, 800. Thus the explanation for the cross-disciplinary disparities within Figure 2 and Table 1 is not that "mathematics is a small field." The notion that the field is small is prevalent and probably results from the fact that total dollar outlays for mathematics, in terms of industrial and federal budgets, or space and technical staff needs, will always be smaller than those in other sciences because of the great difference in equipment requirements. The mathematical sciences have enormous intellectual diversity and output; nearly all the practitioners are in colleges and universities. As a result, the faculty research group in the field is larger than that in either physics or chemistry. The total academic research communities are roughly comparable in size, as we have noted.

Table 1
Postdoctorals in Graduate Institutions, 1981

	Total	Federally Supported	Non-Federally Supported
Chemistry	2,870	2,465	405
Physics	1,450	1,217	233
Mathematical Sciences[20]	99	56	43

SOURCE: National Science Foundation.[20]

Figures 1 and 2, together with Table 1, show that mathematical research funding from the federal sector had become very thin by 1980 because, in the mathematical sciences, research time, graduate students, and postdoctorals together account for a very large fraction of the needed support. Since little money flows into these three categories collectively, little money flows in at all.

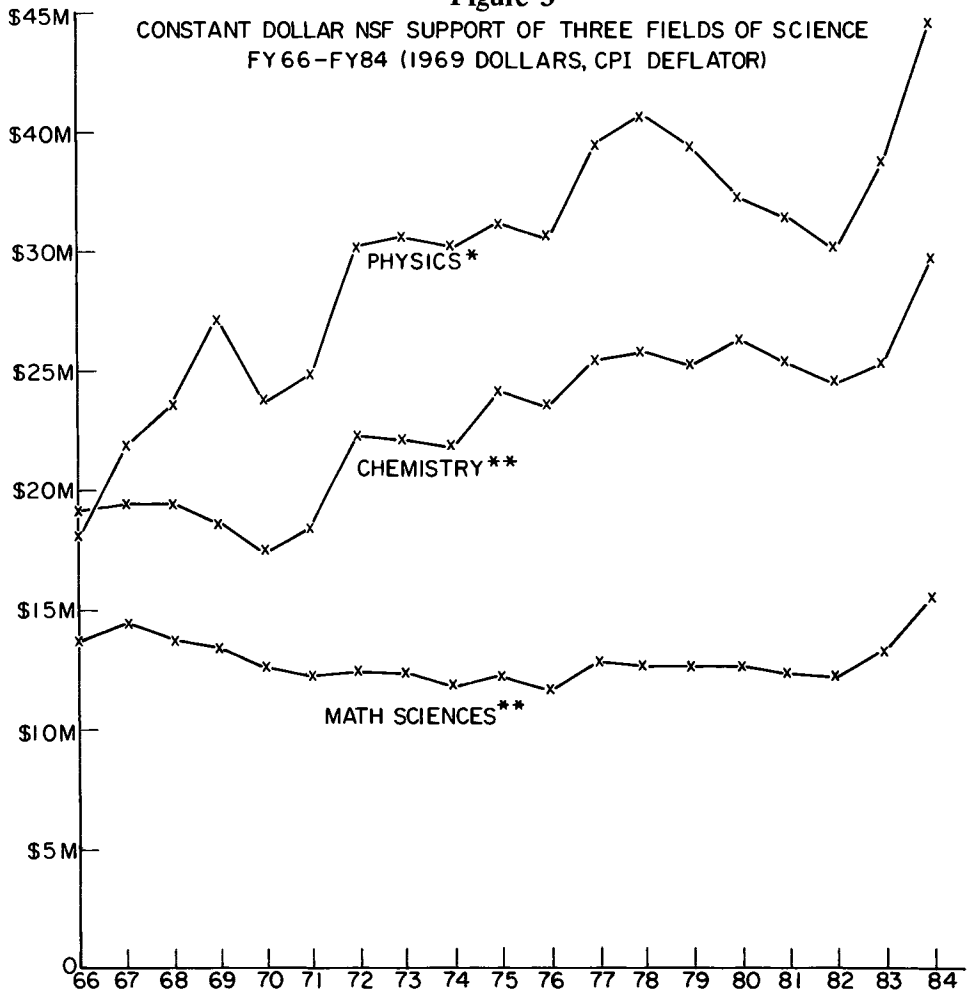
As in other fields of science, the university-government cooperation which built up our

[18]The data in Figure 2 are only approximate, of course. The federally-supported portions of the columns labelled "mathematics" would be half again as high for the broader field of the mathematical sciences. The qualitative impact of the data would not be affected by this change. Predoctoral fellowships/traineeships could be added to the columns to obtain total graduate students federally supported, adding about 60 to the "mathematics" column and larger numbers to chemistry, physics, and computer science, but producing little qualitative change.

[19]For the 50 major research universities, the mathematical sciences faculty is much larger than those in chemistry and physics. Postdoctorals and research staff make the total academic research groups comparable in size.

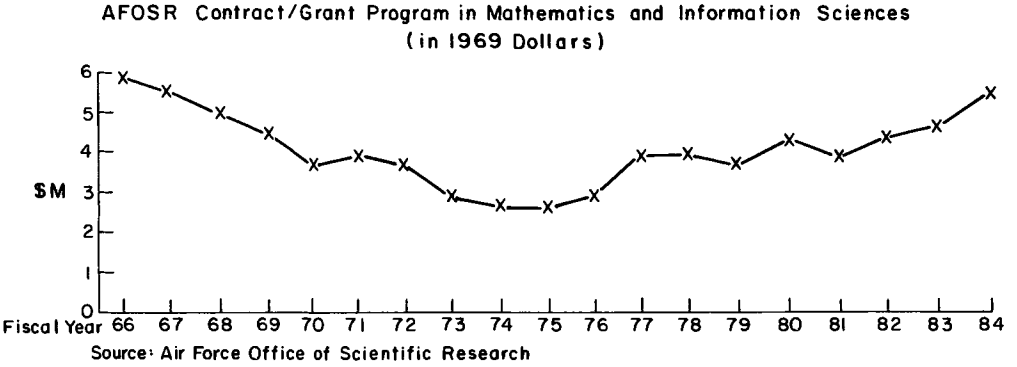
[20]This number excludes about 75 university supported "research instructors" in mathematics.

Figure 3



SOURCE: NATIONAL SCIENCE FOUNDATION BUDGET
*SOLID STATE AND LOW TEMPERATURE PHYSICS NOT INCLUDED.
**COMPUTER SCIENCE NOT INCLUDED.

Figure 4



Source: Air Force Office of Scientific Research

powerful mathematical sciences research machine required the injection of federal grant funds sufficient to support adequate portions of the mathematicians' research and the work of affiliated graduate students, postdoctorals, etc. In fundamental areas of pure and applied mathematics plus statistics, the government's contribution to the cooperative effort is considerably less today than it was in 1970. We shall describe how this came about and what the effect has been.

C. A Brief History

Weakening of federal support for the mathematical sciences began as long as 15 years ago. Government agencies which had supported research in the field began to focus on short-term results and to be impatient with the long periods of time required to bring the fruits of some mathematical research to bear on mission-oriented problems. The 1969 Mansfield Amendment limited investment in basic research by the Department of Defense. Presidential and Congressional actions dramatically reduced numbers of federal fellowships shortly therafter. The National Science Foundation was left to support both the researchers dropped by other agencies and the graduate students in research, but the resources with which to do this were never added to the budget of its Mathematical Sciences Section. Over one-third of the total federal support for the mathematical sciences was lost in just five years (1968–1973).

The following decade, 1973–1983, showed flat funding levels in constant dollars, while the field doubled in size. Other fields of science grew just as rapidly as did the mathematical sciences during this period. They, too, had to adapt to federal policy changes in the early 1970s and then survive a decade of relatively slow growth of support. But the situation of the mathematical sciences was extreme: (i) lacking industrial support, they turned to NSF when cutbacks occurred; (ii) very few of their people were supported by other agencies, except DOD, where programs had to be reconstructed in response to policy changes; (iii) their budget at NSF grew at a very slow pace.

Figure 3 shows in constant dollars the budgets for the mathematical sciences, chemistry, and physics at NSF, from FY1966 through FY1984. Note that (i) although chemistry and physics dipped at the end of the 1960s, recovery was rapid; (ii) mathematical sciences funding declined until 1973, then stayed extraordinarily flat in constant dollars through FY1982; (iii) not until FY1984 did mathematical funding at NSF regain its FY1968 level.

To fully appreciate the significance of this, one must see what was happening at DOD, and be aware that it was the only other major federal supporter of the mathematical sciences. Figure 4 shows in constant dollars the evolution of Air Force support of academic research in the mathematical and information sciences from FY1966 through FY1984. It decreased about 42% from 1968 to 1973. In fact, the decline began in the mid-1960s, and continued steadily until 1975, dropping 52% from 1966 to 1975. Some recovery has occurred since the mid-1970s, primarily in the information sciences (computer science and electronics).[21]

We can summarize our quantitative conclusions about the history of support as follows. The mathematical sciences provide a most dramatic example of weakening of support through the sequence of post-1968 phenomena described at the beginning of this section. Our findings indicate that

- federal support for the mathematical sciences research enterprise stood in 1982 at less than two-thirds its 1968 level (in constant dollars);[22]
- the principal reduction occurred during the period 1968–1973;
- it was followed by nearly a decade of zero real growth in support;
- these budgetary events occurred during the peak in growth of the field—growth in the range and depth of uses of mathematics, with a concomitant doubling of the number of mathematical scientists productively engaged in research.

D. Reasons for Decreased Federal Support

Let us examine more closely why and how these unusual budgetary events occurred.

1. General Reasons

Four reasons why "mathematics" seems to have been the field hardest hit by the general post-1968 trends lie fairly close to the surface:

- Research in the mathematical sciences is concentrated almost entirely in universities and colleges; hence it is very strongly affected by any general weakening of the support of academic research.
- Much (but not all) mathematical research has long-term payoffs; thus the field will be strongly affected by federal policy shifts which emphasize mission relevance or immediate applicability to technologies.
- The long periods of time involved in developing many important mathematical tools make it unlikely that the commercial sector will support large fractions of the research; therefore, relatively little help will be found from

[21] The mathematical sciences portion of the program stood in FY1982 at about 75% of its FY1968 level. Detailed programmatic data are not available for the intervening years. See Appendix B for a discussion of difficulties involved in gathering and interpreting support data.

[22] Detailed analyses to support this conclusion are found in Appendix B, § B VIII.

industry when there is a weakening of federal support for fundamental research in the field.

- Mathematical scientists (as mentioned earlier) require relatively little in the way of facilities, equipment, or technical staff to conduct their research; hence, their needs are less visible and often seem postponable.

Other reasons will emerge as we probe more deeply.

2. Priorities

The biggest blow to mathematical sciences funding occurred in the early 1970s. Although Congress earmarked some resources for transfer to the National Science Foundation in compensation for reductions in DOD support of mathematics, these resources never found their way into the budget of the Mathematical Sciences Section of the Foundation. In addition, one can see from Figure 3 that there was no budgetary growth in mathematics to compensate for the staggering losses which the field suffered when cutbacks in federal fellowships for graduate students and postdoctorals occurred.[23]

These events were directly related to the way the mathematical community then set its priorities in cooperation with the NSF staff. The community did not press hard for federal graduate student and postdoctoral support, because (a) mathematicians were extremely worried about an oversupply of Ph.D.'s in their field, and (b) at that time, the universities needed more teaching assistants and young faculty, and had the resources to hire them. A hole was left in the NSF budget where support for graduate students and postdoctorals was supposed to go.

In subsequent years, this priority pattern set by the mathematical community and NSF for allocation of resources at the Foundation had another effect: it left support of research activities in the field up to the universities to a far greater extent than they could really bear, after they began to experience financial hardships. This explains why the financial squeeze which is now plaguing the universities has hit the mathematical sciences especially hard; it also explains why the full extent of the funding problems in the mathematical sciences has become clear only in the last few years. University budget reductions and flattenings, although they had different patterns in various institutions, collectively cut back the support for a range of things which in earlier times the federal grants would have carried and which are essential to the research effort: postdoctoral positions, visiting faculty positions, secretarial help, travel, etc.

3. Masking and Inaction

If the finger-in-the-dike role of the universities for a number of years prevented the mathematical research community from grasping the deep seriousness of its federal support problems, why was it not apparent to federal budget and policy makers that something was wrong? A 33% constant dollar drop in support of a major field should have been readily discernible. There were two reasons.

First, during the 15-year period we have been discussing, computer science grew very rapidly. This important intellectual development also affected funding patterns. Until seven years ago, computer science was lumped with the mathematical sciences in the federal budget under the banner "mathematics and computer science." The line item was, of course, growing nicely—because computer science, although much smaller than mathematics as a field, was expanding and involved more costly research. It was all too easy not to notice that funding for the "mathematics" part was not growing at all.[24]

We have already mentioned the second reason that the decrease in support was not noticed, namely, that around 1971 federal policy changes regarding the support of young people shifted resources in many fields from the fellowship to the research grant side of the ledger. What we mean, of course, is that there was significant real growth in the budgets for these fields at NSF and other agencies and that part of the added funds were (asked for and used) to increase research assistant and/or postdoctoral support. Since this real growth did not occur in mathematics, the money for graduate students and postdoctorals simply went away, at least at NSF.[25]

We may still ask why, in light of the drop in grant support during 1968–1973, there was not an immediate outcry from the mathematicians. We can speculate that they were unaware of what was happening, that the mathematical community lacked the mechanisms through which to act, or even that attitudes about government support, especially from DOD, were affected by the turmoil over the Vietnam War. We can be certain, however, that an important part of the answer lies in the fact that the academic institutions initially carried just enough of the additional burden to obscure the problems. The major universities compensated for some of the lost research funding by maintaining reasonable teaching loads, supporting research during the academic year, providing some visiting faculty positions, picking up some graduate student support, and so forth, because they recognized the significance of mathematics and did not want the

[23] NSF Predoctoral Fellowships and Traineeships in mathematics dropped in number from 1,179 in FY1969 to 116 in FY1974. Several hundred NDEA fellowships were also lost.

[24] An example of this is seen in Figure 4, where post-1975 growth of the AFOSR Math and Information Sciences program disguises the relative flatness of the "mathematics" portion.

[25] During the years 1968–1973, the budget of NSF's Mathematical Sciences Section grew at less than 2% per year. In the critical years 1970–1972, there was a 9.5% growth compared with growths of more than 40% in fields such as physics and chemistry. See Appendix B.

working circumstances of mathematical scientists to get too far out of line with those of other scientists. The universities continued to increase their faculties and to use entry-level faculty positions as a partial substitute for postdoctorals. They were able to do this because they were still growing and in a reasonable state of financial health.

E. Consequences of Inadequate Support

1. Impact on the University Centers

By the mid-1970s, the financial squeeze on the universities had begun and the academic job market had tightened in numbers of fields, including the mathematical sciences.[26] Graduate programs in departments perennially strong in research began to shrink; national Ph.D. production dropped from 986 in 1972–1973 to 744 in 1982–1983, and the percentage of doctorates to U.S. citizens dropped from 78% to 61% during that period. Instructorships and junior faculty positions were reduced. At many mathematics departments, undergraduate enrollments mushroomed, driven by the needs of students in engineering, computer science, and the social sciences. The universities were unable to respond with comparable increases in teaching staff (there was usually no increase, in fact); hence class sizes and teaching loads went up, cutting into faculty research time and placing much greater responsibilities on teaching assistants.

Meanwhile, federal funding for research deteriorated steadily, because funding levels had taken no account of the growth of mathematical sciences. By 1982, federal support per active researcher was a third of what it had been in 1968. Most NSF research grants had been stripped down to support only summer research; hence, there was very little support and no flexibility. There were no funds in the grants to compensate for university cuts. There was little postdoctoral money, virtually no research assistant money to give the overloaded teaching assistants time to concentrate on research during thesis writing, little secretarial or travel money, or even money for duplication of essential documents.

The situation worsened. Even at historically high-ranked departments, the number of established mathematical scientists receiving outside support decreased noticeably over the last several years.

The chairman of a prestigious mathematics department wrote in a letter to the Research Briefing Panel on Mathematics[27] in the fall of 1982:

> Mathematical research has been flourishing in the past decade but the institutional structure of mathematical research is in trouble. Recruitment of young talent for the future looks to be in even more serious trouble. The level of research support has been very low in terms of the percentage of active research people supported, and recent cuts in support have produced signs of a serious deterioration of morale, especially among younger mathematicians.

Another chairman wrote:

> We are some one hundred in number. We are invariably ranked among the top twelve departments in the country, we continue to recruit good graduate students, and I claim with confidence that of the one hundred at least ninety are seriously engaged in research and scholarship. Yet, after two severe years, we are down from one-half to about one-third of the faculty on NSF grants. Moreover, we have sustained these severe losses without any sense of the prevalent quality of work having declined at all; on the contrary, several colleagues have lost grants in the very year when they have done their best work. Here, for example, loss of NSF grants has reduced departmental income from overhead just when the university, which in any case had always counted on strong departments like ours to earn much of its research support outside, is quite unable to raise the level of state support.

We are seriously concerned. Morale at many of the major mathematical science departments is low, and promising young persons considering mathematical careers are put off.

In most fields of science in the United States, the major university departments are at the center of research activity. In mathematics, there is little elsewhere: there are no national laboratories devoted expressly to the mathematical sciences and no special large facilities providing unique research capabilities. There is less concentration of research than in fields where cost prevents replication of expensive equipment at more than a few institutions. **The network of university centers embodies mathematical sciences research. It is in trouble.**

2. Delayed Impacts

The trouble we see could not be described as a crisis; the field is not faced with the imminent collapse of the major university research centers. What we do see is that several basic problems related to inadequate support have built up slowly over the years to near boiling point.[28] This is what comes through vividly in the letters from department chairmen. What also comes through is their clear sense, which we share, that unless something is done to alleviate the funding

[26] Not in the subfields of statistics or operations research.

[27] Panel of the National Academy of Sciences Committee on Science, Engineering, and Public Policy. Its report was published in the *Notices*, April 1983, pages 271–279.

[28] The development of these problems in mathematics was described clearly eight years ago in the Smith-Karlesky study *The State of Academic Science* (Change Magazine Press, 1976).

problem, we cannot expect the field to continue to perform at its customary high level.

The inevitable question is: If increased funding is necessary for the future health of the field, how have the mathematical sciences done so well over the last 10 to 15 years? Part of the answer, as we have noted, lies in the universities' supportive role, which delayed the impact of federal funding reductions. That role, although still strong, has diminished and needs augmentation. We believe the more important point is that we are talking about an almost entirely theoretical branch of science with a relatively secure base in the universities. In such a field, sharp reduction in federal support does not leave large numbers of scientists totally unable to do their research, as might be the case in an experimental science. What happens is more akin to malnutrition; the general enterprise begins to slow down. There is a considerable lag time even for the slowing down, when it comes to research output. The established researchers and the young people who were in the pipeline when reduction began carry the effort forward for 15 or 20 years, adjusting to increased teaching loads, to decreased income or extra summer work, and to simply doing with fewer of most things. If the number of first-rate minds in the field is large at the onset of the funding squeeze, an effort of very high quality can be sustained in this way for quite some time.

This is what has been happening in the mathematical sciences in the United States for over a decade. The field has been living primarily off the investments of human and dollar resources made in the late 1960s.[29] But tangible signs of erosion have surfaced: Ph.D. production has slowed; there are problems in the university centers, as we discussed; the field is not renewing itself.

One may also ask whether the quality and level of the research effort are being maintained now: Can we already see that research output has fallen off? The tangible warning signals and common sense tell us that it must have slowed down somewhat and surely will over the next decade, unless investments of human and dollar resources are increased. In any field of science it is difficult to discern on the time scale of 5 to 10 years whether the rate of generation of basic knowledge has changed. How does one see that an idea which might have been there is not? Presumably, the more creative the potential idea, the less noticeable will be its absence. This seems an especially important point in relation to the mathematical sciences, which develops tools for so many other fields. Without new tools, applications cannot be generated, but this effect may go unnoticed since people tend to abandon problems for which the required techniques are not available.

[29]The most recent U. S. Fields Medalists were people who received their Ph.D.'s around 1972.

A physicist walked into the office of one of our Committee members recently, somewhat excited because he had found in the (Japanese) *Encyclopedic Dictionary of Mathematics* a rather complete listing of the homotopy groups of spheres and classical Lie groups. He remarked that this would be "quite useful to us." Understandably he was unaware of the fact that many decades of mathematical creativity, involving large parts of the careers of some of the world's outstanding mathematicians had gone into making that "list." What he would have done had he gone to the *Encyclopedic Dictionary* and found only a few scattered items of knowledge about homotopy groups we do not know, but we doubt that he would have paused to wonder about the level of society's investment in mathematical research over the preceding 50 years.

3. Imbalance in the Scale of Support

Reviewing the field as a whole, with the advantage of historical perspective, we easily perceive that the tools which the physicist, engineer, or biologist will need some 5, 10, or 50 years hence may not be there, given society's present inadequate investment in the mathematical sciences. But what level of support or investment is adequate?

The first answer, we believe, comes from comparing support for the field to support for the rest of science and technology. Some broad-brush comparisons were made in Figures 1 and 2, plus Table 1. Rather telling data were also gathered by the Office of Mathematical Sciences of the National Research Council and presented to the (then) Assembly of Mathematical and Physical Sciences in 1981, supporting the request that led to the formation of this Committee. These data, from the science departments of 10 of the country's major research universities, gave the federal support per faculty member for research needs which all scientists share: research time, graduate students (academic year and summer), postdoctorals, visiting faculty and research associates, secretarial help. The support per faculty member in mathematics was less than one-third that of other sciences, and this was true in every category except research time in the summer. Something was badly out of balance.

Did such imbalances in "major" universities reflect less concentrated use of resources in the mathematical sciences, in the sense that too large a percentage of researchers was supported? No, the opposite is true. Of the academic mathematical scientists in the country with research as their primary or secondary activity, about 20% have some federal support. In chemistry the analogous number is 50%. In physics it is 70%.

The comparison of support for the mathematical sciences with support in other fields is not an issue of fairness. Mathematical research is a vital part of the scientific research effort. Looking at developments in the other sciences offers a

scale by which to measure mathematics funding. The imbalances which now exist will lead to deterioration relative to the rest of science, and an inability of the field to continue to generate the concepts and tools needed for future science and technology. This could be particularly serious as society (and, in particular, science) becomes increasingly mathematicized.

For academic mathematicians and their institutions, funding inequities across the sciences create real problems. At every major university, the mathematicians teach more, as do their graduate students, while for virtually anything important to their work, they have less help and less money than their colleagues in other fields of science and engineering.

If mathematicians teach more and have less help, less research is done; if there is practically no postdoctoral support, little postdoctoral education takes place; if virtually all graduate students are supported by teaching assistantships, intense concentration on research for dissertations is less possible; if the direct operating expenses connected with research are transferred to universities, there is less money for teaching staff and burdens increase; and, perhaps most importantly, if a range of such conditions obtains, the field will be less attractive to gifted young people. Should such conditions continue over time, the development of mathematics will be slowed and the scientific/technological effort of the country impaired.

The level of support for mathematical sciences research in the United States has come to be markedly out of balance with the level of support for the country's general scientific and technological effort. Because of the central role of the mathematical sciences in that effort, corrective action to bring the support back into balance must form the base in planning for future funding for the field.

IV. Future Support

Our discussions of the potential of the mathematical sciences and the history of consequences of its inadequate support provide us with some guidelines for future funding. We will develop these and analyze needed dollar support.

The analysis must do more than consider budget increments. Not only is the general level of support of mathematical research out of balance with that for other sciences and technology, it is weak across the entire spectrum of the mathematical sciences, for every major type of research support need: graduate students, postdoctorals, young investigators, senior investigators, support staff, etc. Our analysis will suggest how to reset levels of support for major research needs and project total dollar amounts necessary to put federal support of the mathematical sciences back on track and capitalize on future opportunities.

A. Importance of Mathematics

Our society is becoming increasingly mathematicized. Mathematical education at all levels must be strengthened. Mathematical research to generate the new tools which science and technology will require must be supported.

B. General Guidelines for Future Support

- Mathematical sciences research is intertwined with mathematical education, in itself of extreme importance to the country; hence the principal channel for support of research in the field should be through continuing university-government cooperation.
- We should support mathematical sciences research on a broad intellectual front, recognizing that mathematics provides tools and personnel for science and technology in many ways. Predictions as to what mathematics will or will not be of practical importance years from now are too often wrong.
- There is a further set of budgetary problems which the mathematical sciences face, problems of how available resources are utilized. These must be dealt with in planning for future support.
- The lack of industrial support for research in the mathematical sciences has weakened overall support to a degree much greater than any potential dollar amounts from that sector might indicate. Relations between the mathematical sciences and industry must be further developed.

1. University-Government Cooperation

The federal government must support the core of the research activity, as it does in other fields of science, and patterns of support must take account of what is required to keep the research operations of the major university departments productive. These departments have enormous undergraduate teaching obligations in addition to their responsibilities in graduate and postdoctoral education—education which affects many fields, not just mathematics. It is very easy to forget that each major department is simultaneously a teaching center and a research institute of international stature—an institute with a large faculty plus a sizeable annual influx of distinguished mathematicians from this country and abroad. The number of these major centers is large since mathematical science is concentrated almost entirely in universities. Teaching overloads and insufficient resources to sustain vital research in these centers of excellence are not exclusively university problems. This should be kept firmly in mind when thinking about federal support for the mathematical sciences.

An abundance of research scientists is required to generate the mathematical concepts and tools

which permeate science and technology. Their numbers and support should not be determined by teaching demands—important as they are—but by our best estimate of how many researchers we need to guarantee the intellectual productivity from which these tools develop.

We have referred several times to the significance of the network of university departments and to their current problems. Many important mathematical scientists do not work in departments of mathematics, applied mathematics, mathematical sciences, or statistics. Often they work in operations research groups, or in science or engineering departments (for example, mathematical researchers in mechanics, control theory, or communications theory). Although the problems seem to be most severe in mathematics departments, we want to stress that the entire field is being adversely affected by funding deficiencies.

2. Breadth of Support

We base our conclusion that mathematics needs to be supported on a broad front upon these observations:

- Probably no field regularly provides as many surprises about relevance and applicability as does mathematics.
- Frequently decades of research are necessary to create the conceptual framework which allows even the possibility of a particular mathematical tool to be seen.
- Further years of research may be required to develop a tool usable by other scientists and engineers.
- For much of the long period of research, it may not appear to the outside observer that the pure and applied mathematicians are at work on anything "useful."

The utility of the mathematical sciences is best assessed by considering the contributions of the field as a whole.

Mathematical scientists ply their trade for a variety of reasons. Some want to make tools which impact directly on technology. Others want to understand the physical world and develop methods and models with which to do that. Others pursue mathematics as a discipline in its own right, choosing their areas of inquiry in terms of their potential for applicability. Still others pursue the discipline solely for its own sake, making sets of tools to apply to mathematics itself, developing concepts with which to understand what methods, models, and techniques are possible.

The best work of each type must be supported. The record since World War II shows that we can have confidence in the internal navigational system of the mathematical sciences, which comes from agreement on major problems and directions, and continuously modifies support accordingly. Andrew Gleason described the reliability of the navigational system relative to the rest of science this way:[30]

> Mathematics is the science of order—its object is to find, describe and understand the order that underlies apparently complex situations. The principal tools of mathematics are concepts which enable us to describe this order. Precisely because mathematicians have been searching for centuries for the most efficient concepts for describing obscure instances of order, their tools are applicable to the outside world; for the real world is the very epitome of a complex situation in which there is a great deal of order.

3. Structural Budgetary Problems

The severe problems in the magnitude of extra-university support for research in the mathematical sciences have developed hand-in-hand with several problems concerning the ways in which available resources either are or are not allowed to be utilized, in keeping with federal policy and the priorities of the mathematical sciences community. Recommendations for dealing with these problems provide further general guidelines for future support:

(a) Long-term federal support for the mathematical sciences, particularly support by the National Science Foundation, must restore a balance between support of summer research time and support for research assistants, postdoctorals, research associates (visiting scholars), staff support, computer time, travel, and related year-round expenses.

(b) The number of established investigators who currently have any support at all is too small relative to the strength, excellence, and size of the field.

(c) Federal support for fundamental pure and applied research is too heavily concentrated at NSF. This presents two risks: (i) that mathematics will lose the stimulation provided by technological challenges facing mission-oriented agencies and that the agencies will experience diminished creative work on their problems; (ii) that inadvertently the Foundation will come to control policies which should be made by or with the research community.

(d) Support from the second major source, the Department of Defense, is vital to applied mathematics and statistics. A change in DOD policy 15-odd years ago contributed to the extreme concentration of pure mathematics support in NSF. Current DOD policies, if continued, will further shift the emphasis toward immediate applicability, so that more of fundamental applied mathematics and statistics is "transferred" to NSF, exacerbating the first three problems.

(e) Support from the third major source, the Department of Energy, is of increasing importance at the interface between mathematics

[30] Quoted in Arthur Jaffe's paper, Appendix C.

and scientific computation. Resources going to the mathematical side of the interface should be increased.

Conclusion (a) was implicit in our earlier discussion of how support inadequacies developed. Here we amplify our remarks about it to take into account what has been happening in the last few years. It must be read together with conclusion (b). Under severe restrictions on the level of funding, support for almost everything except summer research time disappeared from NSF grants, *and* the number of established investigators who had grants was severely constricted. Thus, although the structural imbalance in conclusion (a) is a problem, its solution can be accomplished without serious harm to the research effort only if total resources are significantly increased at the same time. Both parts of conclusion (c) can be made more specific. We feel that the spectrum of applied mathematics currently supported by NSF through its Mathematical Sciences Division is too narrow, in that it misses much of the interface of mathematics with technology. At the same time, if "purer" mathematicians do not interact with technical problems in mission-oriented agencies, then both mathematics and the agencies lose an important stimulus. Dominance of mathematical funding by NSF can also leave the field highly vulnerable because (i) most fields of science have other significant funding sources, and (ii) the natural tendency within a funding organization is to maintain equity among the fields it supports. This vulnerability concerns us over the long run. It should not be interpreted as a criticism of current events at the National Science Foundation. Indeed, great care is currently being exercised in its Mathematical Sciences Division to get meaningful advice from the research community, and a substantial Administration/research community effort is under way to correct some of the NSF budgetary problems we have described—problems of magnitude as well as of structure.[31] This effort must continue for several more years, so that improvements will not be short-lived.

In conclusion (d) concerning DOD support, our immediate message is clear: if DOD research concentrates even more on immediate applicability or direct mission relevance, fundamental mathematical sciences research will have trouble getting support. DOD will also have problems over the long run: policy decisions which narrow the scope of what DOD supports damage the health of the mathematical sciences and weaken their ability to contribute to the nation's defense effort. A major difference between what is happening now and the events of the late 1960s is that the shift in emphasis and the flatness of overall funding are occurring inadvertently, rather than as a result of deliberate policy decisions related to the mathematical sciences:

- The growth of funding for computer science masked the fact that support for the mathematical sciences was weakening at DOD.
- A new program of "initiatives" or "thrusts" has taken resources away from the "core" programs, those which support fundamental mathematical sciences research.

The mathematical research community has been vigorously debating all of these structural issues for the last few years. Discussions between members of the community and officials of federal agencies go on regularly at the NSF Advisory Committee for the Mathematical Sciences. Others have grown out of the activities of the National Research Council's Mathematics Briefing Panel, its report presented to the Office of Science and Technology Policy, and the addendum prepared for the Department of Defense.[32] A constructive dialogue with representatives of the Department of Defense has begun under the auspices of the DOD-University Forum, to discuss a range of issues about DOD support of mathematical research. It is an encouraging step.

Several of these structural issues, including the increasing role of the Department of Energy, are discussed in greater detail in Appendix B.

4. Industrial Support

Industry does not support academic research in the mathematical sciences. This is not likely to change significantly in the near future. Yet we feel it is important for the mathematical sciences research community and the universities to increase efforts to promote industrial interaction and perhaps attract some support, at least enough to fund the interaction.

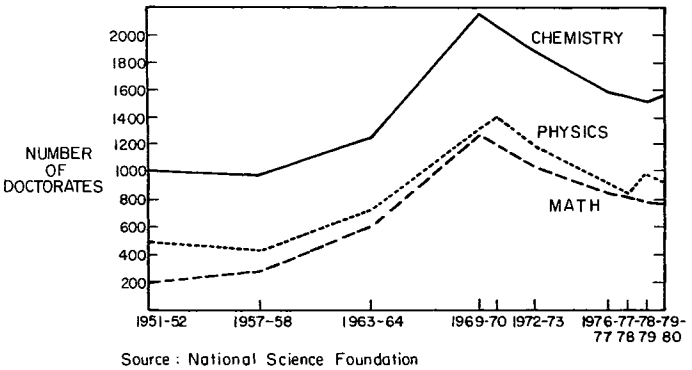
Industry awareness of the significance of mathematics for technology seems to be increasing. About one-fourth of the Ph.D.'s in the mathematical sciences currently move into industrial careers. The broadly-trained mathematician, even at the pre-Ph.D. level, is highly employable. Some mathematical research groups in industry are proliferating, and the attachment of mathematicians to other groups is growing. As mathematics penetrates into production control and manufacturing through automation, demand for mathematicians will increase; this will place new responsibilities on those who train mathematicians.

The broader academic community in mathematics has done too little historically to promote contact with the users of mathematics. This is changing, as mathematics looks outward. The new NSF-sponsored research institutes at Berkeley and Minneapolis show a substantial interest in

[31] See detailed discussions of NSF support in Appendix B.

[32] The Briefing Panel was established by the NAS's Committee on Science, Engineering, and Public Policy. Its report and the DOD addendum are Attachments 1 and 2 to this report.

Figure 5
EARNED DOCTORATES IN PHYSICS, CHEMISTRY AND THE MATHEMATICAL SCIENCES, 1951-52 THROUGH 1979-80



Source : National Science Foundation

promoting mathematics and science interactions. A unique institute is being started at the University of Chicago to promote such interaction. This effort is all the more notable because it will seek base support from outside the government.

Certain universities—those with strong engineering roles—mustreach out through mathematics to engineering and industry. Small,department-affiliated research institutes could bridge the mathematics-industry gap through seminars for department faculty and mathematical engineers or through leaves, to bring industrial mathematicians into the department. The institutes would benefit both education and research. Since industry would profit from both avenues, it might lend them financial support.

C. Guidelines for Renewal

Talented young people are essential for renewing mathematical research. Every effort must be made to maintain the flow of outstanding young people into the field and to see that they receive strong support and excellent training.

There are quantitative and qualitative questions:

- Are enough highly-talented young people being attracted into Ph.D. programs?
- Are the mathematical sciences turning out enough high-quality Ph.D.'s to replace the most productive present researchers?
- How can the best possible predoctoral and postdoctoral education be provided?
- What level of support is needed for graduate and postdoctoral students, and young investigators?

1. Ph.D. Production

About 200 mathematical scientists annually completed Ph.D.'s in 1950. That figure grew steadily through the fifties to peak at just under 1,300 in 1969-1970, thereafter falling off to approximately 800 by the late seventies. Figure 5 documents pattern similarities for mathematics, physics, and chemistry.

Table 2 shows numbers of mathematical sciences doctorates from U. S. universities since the peak production year of 1969-1970. For the last decade, percentages of Ph.D.'s granted to U. S. citizens are included. The annual number of Ph.D.'s has leveled off at about 800. The percentage who are U. S. citizens has dropped from 78% to 61% in the last decade. *Over the historical period* 1968–1982, *examined at some length in this report, the annual number of U. S. citizens obtaining doctorates in the mathematical sciences from U. S. institutions has been cut in half, from over* 1,000 *to fewer than* 500.

Table 2
Doctorates in the Mathematical Sciences
U. S. Universities, 1971–1983

	Total Ph.D.'s	Percent U. S. Citizens
1970-1971	1,217	—
1971-1972	1,192	—
1972-1973	1,042	78%
1973-1974	972	72%
1974-1975	992	74%
1975-1976	874	75%
1976-1977	827	76%
1977-1978	809	73%
1978-1979	751	74%
1979-1980	765	73%
1980-1981	799	68%
1981-1982	779	65%
1982-1983	796	61%

SOURCE: Committee on Employment and Educational Policy, American Mathematical Society (AMS/CEEP). Until a few years ago, some computer science Ph.D.'s were included in the AMS data. These have been excluded in Table 2.

2. Employment Prospects

In the late 1960s and early 1970s, Ph.D.'s glutted the field. Most of the young people who entered doctoral programs in the late 1960s were aiming at positions in colleges and universities. These institutions have traditionally employed most new Ph.D.'s in the mathematical sciences and virtually all of those interested in careers in basic research. The academic marketplace in mathematics became oversaturated and stayed that way for a number of years.

The effects on many young mathematicians were serious. Fewer industrial opportunities meant new careers had to be forged, careers which often made little use of doctoral training. The Ph.D.'s who did find academic employment frequently located in departments considerably farther down the list of national rankings than they had anticipated.

Today the employment situation in the mathematical sciences is brighter. Virtually all of the Ph.D.'s in 1982–1983 are working in areas related to their training. About 22% work in other countries. Of those employed in the United States, 48% teach or do research in doctorate-granting departments; 28% are in masters/bachelors-granting departments, and 24% in industry or government.

Additional retirements in the early 1990s should create greater demand for science faculty. The analyses in the 1979 NRC report *Research Excellence Through the Year 2000* projected gradually increasing death/retirement rates for total mathematics faculty between 1979 and 1984 (and a significant increase in the 1990s), but predicted little increased demand for mathematics faculty. The predictions have been wrong thus far and will probably continue to miss the mark in the years ahead. The principal reasons are stated in the report, in its description of the assumptions behind the major studies the report relied on:

> They assume that enrollments in four-year colleges and universities depend mainly on the number of people in the college ages, that science and engineering enrollments will move approximately as total enrollments do, and that enrollment levels are the main determinant of faculty size. They do not take account of changes in R&D funding as a possible source of variation in faculty size.

The report went on to say:

> They conclude that the enrollment squeeze coupled with the low retirement rates of the 1980s will cause the annual academic demand for new science and engineering Ph.D.'s at all colleges and universities to drop by nearly 50% between 1978 and 1985, with a further drop in the 1990s.

Table 3 shows the rapid growth of mathematics and statistics enrollments in four-year institutions over the last eight years. We can attribute only part of the growth to elementary computer science courses taught by mathematics faculties. Enrollment in such courses was about 300,000 in 1983.

Table 3
Enrollment
in Mathematics and Statistics Courses
in Universities and Four-Year Colleges,
Fall Semester

1960	744,000
1965	1,068,000
1970	1,386,000
1975	1,497,000
1979	1,999,000
1983	2,390,000

SOURCE: Conference Board of the Mathematical Sciences; AMS/CEEP.

Table 4 profiles the collegiate-level mathematics teaching community.

Table 4
Mathematical Sciences Faculty
at Universities and Four-Year Colleges,
Fall 1983

With doctorate	14,100
Without doctorate	4,400
Total	18,500

SOURCE: AMS/CEEP.

Overall demand for Ph.D.'s exceeds supply. The Committee on Employment and Educational Policy of the American Mathematical Society (AMS/CEEP) annually surveys the nation's four-year colleges and universities to determine faculty hiring in mathematical sciences departments. Where nondoctorates are hired, institutions are asked to indicate whether they would have preferred a person with a doctorate. Table 5 shows the results for the last three years.

Table 5
Hiring of Non-doctorate-holding Faculty
in the Mathematical Sciences
U. S. Universities and Four-year Colleges

	1980-1981	1981-1982	1982-1983
Full-time faculty positions filled by non-doctorates	700	880	724
Number of such positions where doctorates preferred	350	536	401

SOURCE: AMS/CEEP.

Most of the hires in Table 5 occur at nondoctorate-granting mathematical science departments. There is a shortage of doctorates to fill positions at such institutions.

At the doctorate-granting departments, faculty totals and hiring rates stabilized a decade ago at the levels indicated in Table 6.

Both academic and nonacademic employment for Ph.D.'s may be affected by rapid growth in the mathematics of computation. In Section IV-E we propose an initiative in this area, principally to attract and support young people, and we

note that demand for new Ph.D.'s in the subfield could reach the level of 100 per year in the near future. Let us summarize. There is an excess of demand for Ph.D.'s over supply, created by increasing undergraduate enrollments; Ph.D. production and hiring rates at doctorate-granting departments have been stable for several years; the percentage of U. S. citizens among new Ph.D.'s is decreasing; increased retirement rates in the 1990s will create somewhat greater demand for faculty at doctorate-granting departments; overall demand for Ph.D.'s could increase sharply because of growth in the mathematics of computation.[33]

We conclude that the current Ph.D. production level of 800 per year is unlikely to be adequate to meet demand over the next decade.

Table 6
Faculty Hiring in Doctorate-Granting Mathematical Science Departments
Fall 1983

Total Faculty	Positions Filled	Percent Filled With New Ph.D.'s
5,600	375	40%

SOURCE: AMS/CEEP.

3. Prospects for Renewal

Renewal presents problems. Out of 9,000 mathematical scientists in academia identifying research as their primary or secondary activity, 5,500 publish regularly, 4,000 frequently. In the next section, we estimate that 2,600 established mathematical scientists are highly productive.[34]

What is required to renew this last group on an ongoing basis? If the average span of highly productive years is 20–25, renewal requires that 105–130 mathematicians of high research ability be produced annually. Annual Ph.D. production is 800, of whom 22% accept foreign employment. One-fourth of the remainder go into government or industry, with a somewhat lower probability of ending up in basic research. Even discounting that, only 625 remain in the pool from which 105–130 strong mathematical scientists must emerge. Thus one out of every five Ph.D.'s must develop these strengths, a high success ratio (17–21%) for mathematics, computed on a national basis. Regeneration will be difficult.

We can see from this brief discussion that efforts must be stepped up to attract outstanding young people into the mathematical sciences and to nurture them as they move into the field.

Since no significant increase in numbers of talented doctoral students is likely to occur in the immediate future, one of the most pressing needs of the mathematical research community is to increase its support of young people. Those who are working in the mathematical sciences will need to be nurtured in three important ways:

- There must be much wider availability of graduate student support other than teaching assistantships, so that a period of intense concentration on research for dissertations is possible.
- There must be much wider availability of postdoctoral positions at major centers, so that recent Ph.D.'s of high promise deepen their commitment to research and develop the perspective and skills necessary for doing research at a high level.
- There must be an adequate number of research grants for young investigators (Ph.D. age three to five years) after the postdoctoral period (usually a period of two years).

A sizable increase in federal support is required to achieve these objectives. The research community must understand the problem of renewal and the importance of addressing it.

Efforts to attract brilliant young people into the mathematical sciences must move ahead simultaneously. There are several considerations.

Funding for the field can redirect interests over time to attract promising undergraduate and graduate students. If there are insufficient resources to support the field—and we have in mind both university and extra-university resources—the attractiveness of the field to young people is diminished.

The mathematical sciences share problems with many other sciences. One is general salary levels. Pressure from the industrial sector is great; large starting salaries for college graduates in areas such as computing help lead people away from graduate schools and science and into industry. But there are special problems within mathematical science itself.

The imbalance between extra-university funds for mathematical and other sciences suggests that the field is somehow less attractive to gifted young scientists. About the time they enter graduate school, our best and brightest future scientists choose from several specialties. This is the stage at which a young person "interested in mathematics" might easily shift away into another theoretical science, perhaps influenced by his/her perception of the circumstances of graduate students/faculty in various fields.

It will take more than money to attract additional creative young people into mathematics. The universities (the academic mathematicians) must convince students not only of the excitement and relevance of mathematics, but also of the career opportunities which exist. And mathematicians must reflect on their curricula to see if they strike good balances between student interests and the needs of mathematical sciences research. More importantly, professional organizations in the mathematical sciences should

[33] See §IV-E.

[34] This is the size of the group of established mathematical scientists whom we feel should be federally-supported.

buttress universities' efforts through national information campaigns. To take but one example: How well do high school guidance counselors or the public understand that the coming of the computer has greatly increased the demands for mathematical training and research, not lessened them?

4. A Plan for Renewal

We are recommending rapid development and implementation of a National Graduate and Postdoctoral Education Plan in the mathematical sciences, in response to the pressing need for renewal. It would have these features:

- Each of the approximately 1,000 graduate students per year who reaches the level of active research for a Ph.D. thesis would be provided with 15 months of uninterrupted research time, preceded by two summers of unfettered research time.
- Two hundred of the 800 Ph.D.'s per year would be provided with postdoctoral positions averaging two years in duration at suitable research centers.
- There would be at least 400 research grants for young investigators (Ph.D. age three to five years).
- At least 2,600 of the established mathematical scientists who, with young investigators, provide the training for the more than 5,000 total Ph.D. students and the 400 total postdoctorals, would have sufficient supported research time not only to conduct their own research, but also to provide the requisite training for these young people.[35]
- These levels of total support for graduate students, postdoctorals, and young and established investigators would be attained by ramping-up federal funds for mathematical research over five years, at the rate of 18% per year.[36]

We believe this plan to be consistent with the priorities set by the mathematical sciences research community through several self-studies in the last few years.[37] It is based on the guidelines for renewal which we presented and an approximate annual flow into the system as follows:

1,000 thesis students
↓
800 Ph.D.'s
↓
200 postdoctorals
↓
133 young investigators
↓
100 senior investigators

Implementation does not require major modifications of the way funds are dispersed. Most would go through research grants to "senior" investigators. Where appropriate, bloc grants (departmental grants) for graduate student or postdoctoral support could be made.

But implementation does call for modifying expectations and utilization. Universities which currently support virtually all mathematical Ph.D. students through teaching assistantships would need other staff to assume the teaching responsibilities of students who moved into pure research activities for a year. There is a simple way to do some of this at major centers: associate small amounts of teaching with some postdoctoral positions, a long tradition in mathematics. Further coverage of the teaching could come from visiting faculty, for which more support should also be provided. Funding agencies, mathematical science faculties, and university administrations—understanding the overall plan—can adjust. The additional resources should be injected over several years to allow for structural transition.

Another important adaptation for the universities and the mathematical scientists would be to strongly encourage new Ph.D.'s to move into postdoctoral positions as they become available, rather than accepting tenure-track positions immediately after the Ph.D. This may be difficult, simply because it is a change in the recent style of movement through the ranks of the profession,[38] but it can be done if the research community understands the need for it and pushes the idea with the universities and the young mathematical scientists.

This major effort can succeed only if everyone involved thinks nationally instead of locally.

D. Guidelines for Sustaining Research Output

Underinvestment in mathematical sciences research over the last decade has severely restricted the number of productive investigators who are supported. Figure 6 shows graphically that the number of established mathematical scientists with federal support is out of balance with the numbers for other sciences. In § III-E, we discussed the negative impact this is having on university centers and will have on research output if it continues. Research grants in the field have dropped from 2,100 to 1,800 in the last few years and are still declining.

1. A Basic Estimate

The number of federally-supported (principal) investigators must be reset at a level adequate to sustain research and provide appropriate graduate and postdoctoral education. We estimate 2,600 as

[35]The number 2,600 is obtained from an analysis in the following section on sustaining research output.

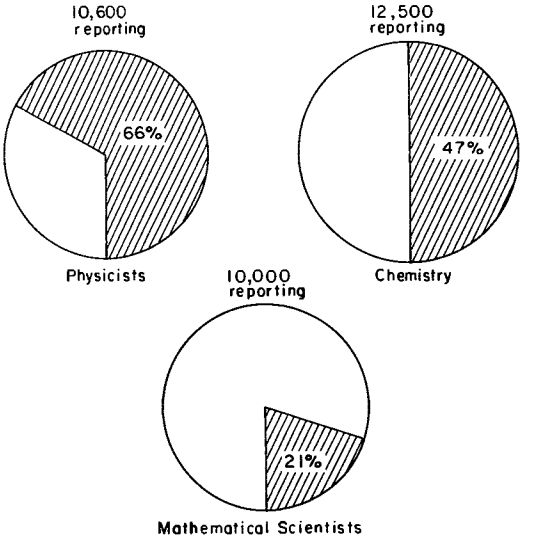
[36]See detailed estimates in § IV-F.

[37]See, for example, Attachments 1 and 2 to this report.

[38]Also because the residual effects of the previously tight academic market tend to push young people into tenure-track positions early.

Figure 6

Support Status of Doctoral Scientists in Educational Institutions, by Field – 1981



Numbers reporting as fractions of totals in educational institutions: Chemistry 85%; Physics 82%; Math Sciences 81%

Source: Characteristics of Doctoral Scientists and Engineers in the United States, 1981 – National Science Foundation 82-332

the threshold level for the number of established investigators to be federally supported, as follows.

Three review systems operate to monitor research productivity and quality on a national basis:

- professional journals
- peer or panel review of grant proposals
- hiring and promotion practices of universities.

Journals (publication rates) can be used as measures of research activity on a broad-brush basis, but do not have consistent standards within fields, let alone between them. The review processes of federal agencies monitor quality well, but will not help us here. Mathematical sciences research has a demonstrably low level of funding; hence, numbers of people currently supported provide only a lower bound for the estimate we need. Proposal pressure is not a good indicator; after a long period of underfunding, the proposal review process stabilizes; only those with good prospects of being funded continue to apply.

The standards of universities are not uniform either; however, in most there is intra-university consistency of standards across related fields. Table 7 shows 1980 faculty sizes and the percentages of those with federal suport at 156 doctorate-granting universities in engineering plus the physical, mathematical, and computer sciences. The "mathematics" faculty numbers would need to be scaled up by a factor of 1.3 to get approximate counts for the broader field of the mathematical sciences, i.e., to include mathematical scientists not in mathematics departments.[39] Note particularly the general consistency of the percentages for most fields other than mathematics, and the much lower percentage for mathematics. One reason for the larger size of mathematics faculty, as noted earlier, is that research in the field is concentrated almost entirely in universities.

Research quality and performance are monitored closely by universities, especially in tenure reviews. The performance level of faculty in the mathematical sciences is assumed to be comparable to that in related fields. It is implausible, then, that the significant discrepancy in percentages of faculty with federal support reflects assessments of quality of research. Nor is it plausible that this discrepancy is based on a lower level of research activity by mathematicians.

[39] At the 50 universities with the highest ranked departments of chemistry, mathematics, and statistics, mathematics accounts for about two-thirds of the mathematical sciences faculty. It constitutes three-quarters of mathematical sciences for the broader set of institutions in Table 7.

In fact, the number of mathematical scientists actively involved in research is large.[40]

Table 7
Full-time Faculty and Federal Support Status in Surveyed Departments at Doctorate-Granting Institutions Spring 1980

Field	Total Faculty	Percent With Federal Support
Engineering		
Chemical	1,039	69%
Civil	1,886	57%
Electrical	2,313	55%
Mechanical	1,998	54%
Physical Sciences		
Chemistry	3,380	63%
Geology	1,394	70%
Physics	3,580	67%
Mathematical and Computer Sciences		
Computer Science	840	57%
Mathematics	4,485	39%

SOURCE: *Young and senior science and engineering faculty, 1980,* NSF 81-319.

Apply to the mathematics faculty the lowest percentage for those with federal support in other fields, 54%. One obtains 2,400 as a base figure for the number of mathematicians to support. The mathematical sciences faculty is 1.3 times the size of that in mathematics, suggesting that $1.3 \times 2,400 = 3,100$ is about right for the number of mathematical science faculty members on grants. From this, subtract 400 young investigators (Ph.D. age three to five years), to obtain 2,700 as an appropriate number of established investigators.

There is one other "system" which operates to monitor research productivity and quality in a field: the judgment of the research community itself. We knew concern to be widespread and deep in the mathematical research community because cut-off levels for research grants had moved so far up into the "excellent" category that the best mathematicians could not discern the difference in quality between those who did and those who did not receive support.[41] Professor Guido Weiss of our Committee surveyed chairmen of mathematical science departments nationally, asking them to examine their faculties and judge how many researchers without support were doing research of the quality done by those with support. Extrapolation from the responses led to the estimate 2,600–2,900 for the total of "supported" plus "equally qualified."[42]

The range 2,600–2,900 brackets the 2,700 estimate. We adopt 2,600 as the threshold level for the number of established investigators to support.

2. A Crosscheck on Balance

Tables 8 and 9 give comparative academic research support data in chemistry, physics, and the mathematical sciences.

Table 8
Doctoral Scientists Employed in Eductaional Institutions by Field and Support Status—1979

	Chemistry	Physics/ Astronomy	Mathematical Sciences
Total Doctoral Scientists	14,900	12,100	15,000
Those with Primary or Secondary Work in R&D	9,800	9,200	9,100
Faculty with Federal Support	3,300	3,300	2,300
Non-faculty with Federal Support	1,800	3,100	Insuff. cases
Percentage in R&D With Federal Support	50%	70%	25%

SOURCE: Survey of Doctoral Recipients, National Research Council.

Table 9
Faculty in R&D by Field and Support Status—1979

	Chemistry	Physics/ Astronomy	Mathematical Sciences
Senior Faculty in R&D (Full & Assoc. Profs.)	6,000	4,900	5,800
Senior Faculty with Federal Support	2,800	2,700	1,500
Junior Faculty in R&D (Asst. Profs. & Insts.)	1,600	1,100	2,600
Junior Faculty with Federal Support	500	600	800
Total Faculty with Federal Support	3,300	3,300	2,300

SOURCE: Survey of Doctoral Recipients, National Research Council.

[40]The literature search used by the American Mathematical Society to prepare the list of U.S. entries for the *World Directory of Mathematicians* shows that 4,000 mathematical scientists publish at least three papers per five years. Numbers of papers per year are much smaller in mathematics than in most sciences. Mathematical scientists of high quality will, with rare exceptions, publish at least three papers every five years.

[41]This sense was conveyed in the letters from department chairmen in § III-E-1.

[42]Although this was an informal survey and had a subjective element to it, examination of the raw data from departments with which our mathematician members were familiar showed those chairmen had been conservative and had used high standards.

It is not the precise numbers in these tables which interest us. It is the evident imbalance of scale. The markedly lower percentage of mathematical sciences faculty supported is seen in Table 8. The general absence of postdoctorals in the mathematical sciences is reflected in Table 9 by the larger size of the junior faculty group—most academic researchers of postdoctoral age in the field were in beginning assistant professorships or research instructorships in FY1979. We have recommended that 400 postdoctoral positions (200 two-year positions each year) and 400 young investigators (Ph.D. age three to five years) be supported. If we raise the number of established researchers supported to the level 2,600, the total number of researchers supported will be 3,400, or 38% of doctoral mathematical scientists in R&D. This compares with the Table 8 figures of 50% in chemistry and 70% in physics/astronomy.

3. Related Comments

The sort of estimation given here would be difficult in any field. Start from scratch and determine how many biologists, chemists, physicists, or whomever the federal grants system "ought" to support. For the mathematical sciences, we tried a number of estimation methods: careful scrutiny of the groups of mathematicians with different publication rates; comparison of faculty sizes in "distinguished or strong" departments in the Roose-Anderson survey, etc. Our colleagues in different fields raised questions about each. Frequently, their queries were not directed at the method used but at the conclusion, or at the underlying question itself. We speak to three of these queries which came up often:

Why do mathematical scientists really need (federal) research support? Answer: For the same reasons that any theoretical scientist does. The needs are described specifically in the next section, IV-D-4.

How have the mathematical sciences been doing so well for the last 15 years with so little support? Answer: If the number of first-rate minds in a theoretical field is large at the onset of a funding squeeze, a research effort of high quality can be sustained for a decade or more by accommodation and doing without. It cannot be sustained for a much longer time, however. This is discussed in some detail in § III-E-2.

How many research mathematicians does the country need? Answer: Enough to generate the mathematical ideas which will be needed one, five, ten, and fifty years from now. The best way to estimate that number is to balance support for the field with that for related fields.

4. Specific Guidelines

The mathematical sciences do not have enough resources to sustain their research. We have estimated that there are at least 2,600 established investigators whom it is essential to support. These are the mathematicians who will be most heavily involved with the graduate and postdoctoral training necessary for renewal, so it is doubly important that their research be supported. They will need, first of all, research time, especially in the summer. Without the support of summer research they have to seek other employment in order to keep incomes up, and are not available at their institutions to work with graduate students and postdoctorals. Each investigator also needs support staff (say, $\frac{1}{4}$ secretary) and a sum (say, $6,000) to cover travel, publication costs, duplication, etc. Computer time/equipment is important for many investigators—crucial in various applied mathematical areas, and in statistics. This need is increasing rapidly. Mathematical scientists also need research associates, visiting scholars from around the world who come to centers to spend substantial time in direct research involvement. This need is not uniform, nor constant, but it is very important in mathematics. We take it to be about one person per year for every 20 investigators. Then there are "communication" needs: publication, travel, summer schools, conferences, mini-institutes, and the larger research institute costs beyond what we have described. Support for faculty leaves is important, and there is a need for resources to allow mathematicians from "outlying" institutions to spend time at major centers.[43]

E. Guidelines for an Initiative in the Mathematics of Computation

Large-scale advanced computers create unusual opportunities in many disciplines. These opportunities are essentially mathematical, although the applications are to other fields of science, such as the atmospheric sciences, physics, computational chemistry, VLSI and circuit design, fluid and solid mechanics, material sciences, astrophysics, the social sciences, and biophysics. In these fields, sophisticated mathematical models are used to simulate complex phenomena. Computational science activity is most important at the interface between mathematical and theoretical science, on the one hand, and experimental science on the other.

Large-scale computers will require new mathematical methods and algorithms for their appropriate exploitation. Moreover, a large cadre of sophisticated mathematical and computational scientists is needed for the proper utilization of these powerful tools. The more sophisticated the computational equipment, the larger the requirements for mathematical and algorithmic methods.

Several studies conducted during the past year have documented the needs and opportunities in the area of scientific computing. Notable among these are the December 1982 *Report of the Panel on Large-scale Computing in Science*

[43]When we come to dollar estimates, we include these under "research associates" and "travel to major centers."

and Engineering (Lax Panel), sponsored by the National Science Foundation and the Department of Defense in cooperation with the Department of Energy and the National Aeronautics and Space Administration, and the August 1983 *Report of the FCCSET Supercomputer Panel.* These reports detail needs for computing resources of all types: local computational facilities, Class VI computers, and networks. Both reports point out that there is a severe shortage of appropriately trained personnel for academic, industrial, and defense needs, and that the base of academic research in this area (computational mathematics, algorithms, software science, and architecture) is insufficient to take advantage of the scientific possibilities made available by the existence of modern Class V and Class VI computers.

In its survey of resources available for research in the mathematical sciences, the Committee has been impressed with the Department of Energy's Applied Mathematics program, as it relates to scientific computing. However, unless this program is significantly expanded, and similar programs properly funded at NSF and DOD, an important research opportunity with vital consequences for science, technology, and defense will not have been capitalized upon. Particularly worrisome are the scarcity of senior personnel in this area and the extremely small number of young researchers and graduate students. The Committee endorses those recommendations of the Lax Panel report which bear directly on the mathematical sciences (which are, with the computer sciences, the central basic research community involved).

A major effort in this area is needed to attract, educate, and support graduate students, postdoctorals, and young researchers, and to provide the computational equipment essential for the proper conduct of this research.

We estimate that an annual investment of approximately $15 million for computational equipment, for its maintenance and support, and for appropriate access to similar equipment, is required for mathematical scientists in scientific computing. Other support of basic research in the mathematics of computation, with particular emphasis on the support of graduate students and young researchers, will be included in our general estimates for the field.

Significant additional resources for the mathematics of computation may be needed in the years ahead. Expectations are that a few hundred supercomputers for academic, industrial, or governmental use will be put in place over the next decade. Each machine will require approximately ten scientists with sophisticated knowledge of applied mathematics related to computation. Demand for such new scientists may run 500–800 per year. Even though numbers of these scientists will come from computer science, the physical sciences, or engineering, the demand for new Ph.D. mathematical scientists in computing could easily reach 100 per day in the near future. Federal support of a subfield of this size could not be absorbed within the resources we have recommended.

The initiative we have proposed is just that, a first step. The resource needs for the mathematics of computation must be reviewed very carefully each year, in light of the subfield's development in relation to the mathematical sciences as a whole.

Table 10
Estimated Extra-University Support Needs of the Mathematical Sciences
(Where applicable, benefits and indirect costs are included)

I. Grants for established investigators (excluding graduate students, postdoctorals, research associates).	
Two months research time	$20,000
Support staff ($\frac{1}{4}$ secretary)	4,000
Travel, computer time, publication costs, duplication costs, etc.	7,500
	$31,000
$31,000 × 2,600 = $81.9 million	
II. Grants for young investigators (Ph.D. age 3 to 5 years).	
$25,000 × 400 = 10.0 million	
III. Postdoctorals.	
24 months	$90,000
$90,000 × 200 = 18.0 million	
IV. Graduate students.	
18 months—stipend plus tuition	$30,000
$30,000 × 1,000 = 30.0 million	
V. Research associates (visiting scholars, senior).	
$90,000 × 130 = 11.7 million	
VI. Summer schools, conferences, mini-institutes, travel to major centers, plus research institute costs, excluding posdoctorals.	
11.0 million	
VII. Mathematics of computation initiative.	
15.0 million	
VIII. Other computer equipment.	
2.5 million	
Total	**$180.1 million**

F. Estimates of Future Support Needs

Since the early phases of our Committee's work, we have recognized that the funding situation in the mathematical sciences is so badly out of order that incremental budget thinking could not properly address the question of needs. The support level must be reset at a magnitude appropriate to the size, style, quality, and potential of the field, one commensurate with support for the general scientific-technological

effort of the country. The guidelines we have developed tell us how to get a good estimate of the appropriate levels. Table 10 contains the numbers, which total $180 million per year.[44]

Since FY1984 federal funding for the mathematical sciences totals about $78 million per year, the recommended level seems high. It is not. It is a conservative estimate of what is required to put support back in balance and provide for the future.

For the wealth of tools the mathematical scientists provide, an investment of $180 million per year seems modest.

V. Recommendations

We end with our recommendations to various groups about what they should do to provide for the future of mathematical research.

A. To the Administration and Congress

The level of extra-university support for the mathematical sciences is dramatically low. The field is not renewing itself. With its present resources it cannot sustain its output, much less capitalize on the significant opportunities which exist.

The mathematical sciences play a major role in technology, and therefore in defense and the economy. Prospects for industrial support are slim, because much of the research has long-term payoffs. Therefore, the federal role is crucial.

We estimate that it will take an additional $100 million per year in resources to set things back on course and provide adequately for the future. If phased in over a period of five years, it will allow time for needed utilization adjustments in universities and the research community.

The groundwork for a joint government/university/research community effort has been laid by the successful self-studies which mathematical scientists have done over the last few years to evaluate and describe the significance and potential of their field, articulate needs, and set basic priorities.[45]

We have recommended a National Plan for Graduate and Postdoctoral Education as the framework for renewal in the field and for sustaining the research effort. Close cooperation will be especially important in implementing this plan. The research community, at considerable cost to the support of established investigators, has increased support for young mathematicians, even within existing resource limitations. Added resources and university-government cooperation will be essential if the effort is to be continued.

Federal support for basic research in the mathematical sciences is concentrated (62%) in the National Science Foundation and the three service agencies, (31%) in the Department of Defense (AFOSR, ARO, ONR). The support at NSF covers the spectrum of the mathematical sciences and includes 97% of the support of "pure" mathematics. That at DOD is concentrated in applied mathematics and statistics and constitutes nearly two-thirds of the federal support for those subfields. Prospects for increasing support significantly at other mission agencies are slim, except at the interface of mathematics and computation, where the role of the Department of Energy is of increasing importance. Thus, increase support significantly must be primarily a two-pronged effort by NSF and DOD.

Strong action has begun at NSF to increase support for the field, especially for young mathematical scientists. This effort must be continued, with large increases in the year-to-year budgeting. A similar effort must be initiated at AFOSR, ARO, and ONR. The mathematical sciences should become a target program in these agencies. What is required is an average 18% real growth per year, for each of the next five years.

Congressional support for the NSF initiative and DOD funding of basic research will be quite important.

B. To Universities

As the dominant supporters of mathematical sciences research and the nurturers of mathematical education, universities have a special interest in the state of federal research funding in the field. They also have responsibility for improving the current situation. The low level of research funding in the mathematical sciences, as contrasted with that of other fields of science and engineering, causes a number of serious intra-university problems.

Less direct outside support of research time is brought in by mathematical scientists, especially those in so-called "pure" mathematics. Less outside support is provided for secretarial help, for graduate student support, for travel, for supplies, for almost anything connected with research. This throws cost burdens back on the university. Tensions are created, as most deans can testify, because other scientists pointedly note that the

[44] FY1984 level.

[45] Report of the Research Briefing Panel on Mathematics (COSEPUP/NAS); the DOD Addendum to its Report; Report by the Committee on the Applications of Mathematics (NRC); Report of the Panel on Large-Scale Computing in Science and Engineering (NSF/DOD); regular reports of the Advisory Committee to the Division of Mathematical Sciences at NSF; Report on Computers and the Future of Statistics, Committee on Applied and Theoretical Statistics (NRC); Statistics: Change and Resources in a Growing Science, report to NSF Mathematical Sciences Advisory Committee by David S. Moore and Ingram Olkin; Operations Sciences at NSF; Status and Opportunities, Proceedings of Workshop on Research Directions in Operations Science, by George Nemhauser and George Dantzig.

institution is paying for a number of items in "mathematics" which investigators in other fields are expected to pay for from their own grants. Deans also feel pressure from mathematicians, who have to teach more, cannot give their graduate students time to think, have inadequate support staff, and no operating expense money. Images are created which suggest that the mathematical scientists may rank lower in their fields than their counterparts in other science departments because the percentage of mathematicians with outside grants is significantly lower.

Why have the universities remained silent in general discussions of federal mathematics funding? Here are some of the reasons:

- Mathematical research is cerebral. Its needs seem intangible when compared with those of other sciences.
- Mathematical science department budgets are justified to trustees or regents solely on the basis of teaching demands, as is graduate student support.
- The mathematical sciences community has not described its federal support problems well enough to make clear that they are nationwide.

The universities can help remedy the funding situation by:

(a) Calling to the attention of federal agencies and policymakers the fact that something has gone seriously wrong with mathematical sciences research support. It is evident in the internal dynamics of almost every major American university. This situation must be pointed out.

(b) Reviewing the substantial problems in the working circumstances of their mathematical science faculties and morale in the associated departments. University administration and faculty must identify these strains and work together to alleviate them. Such problems negatively affect both mathematical sciences research and mathematical education. University/federal agency discussions and understanding are essential. Increased injection of federal funding into mathematical sciences research will do scant good if followed by university cuts in other areas of support.

(c) Using their mathematical faculties to attract industrial support for academic research in the mathematical sciences and to promote interaction between mathematics and its users.

C. To the Mathematical Sciences Research Community

This group knows it bears primary responsibility for the future health of mathematical research. Both the self studies of the last few years and recent unified efforts towards improving federal funding demonstrate the community's commitment to present and future research and education.

We want to recommend some agenda items for that future. Each has a time scale of 10 or more years. They are not new, but they are pressing.

- The community, in part through its professional organizations, must promote understanding in universities of the range of problems besetting mathematical scientists and their departments and of their relationship to the lack of research support. The research needs of the mathematicians are not well understood, nor is the fact that attempting to meet them on an adequate national scale requires university-government cooperation.
- Renewal of mathematical sciences research means increased efforts to attract brilliant young people into the field. Larger numbers of Ph.D. students need unfettered research time for theses. Greater numbers of doctorates need postdoctoral experience at major centers before moving into industrial or faculty positions.
- Many Americans do not understand how mathematics works in our culture, science, or technology. Long-term, coordinated effort by the mathematical sciences research community could help nonmathematicians achieve this basic understanding and revise their attitudes towards supporting mathematical research.
- Mathematicians and nonmathematicians principally interactthrough education. This provides the major interface for clarifying the role of mathematics. The research community must continually expand its involvement in precollege mathematics and science education.
- The mathematical sciences community has always seemed fragmented to the rest of the world. It has not been effective in making its needs known. Factions in all fields are a sign of vigor. But mathematical scientists must seek the common ground unique to mathematical pursuits. Mathematicians are moving that way. They should continue to revamp the consortia through which their professional societies act together for mutual benefit.

As for the role of the research community in remedying the deplorable funding situation we have described, we asked Dr. Brockway McMillan—recently retired from Bell Laboratories, a member of our Committee, and an old hand in the worlds of mathematics, government, and industry—what advice he would give to the mathematical sciences community. After recalling the general appearance of disarray mathematicians presented in national affairs some years ago, he proffered this advice:

> Get your act together. Determine what it is that you believe mathematics is all about in our society. Define the needs and means for doing it. Then present your case in its proper context and to your whole constituency. It is in fact a good case, but it must be presented with breadth and clarity and maturity of judgment.

We believe the community is doing that now.

On the Status of the Mathematics Profession

by Murray Gerstenhaber

The following was written for the joint AMS-MAA-SIAM Committee on the Status of the Profession, but the views are purely personal. Publication of the David report has documented a 20-year decline in Federal support of mathematics, producing severe strains in the profession and potential harm to the nation. I am writing because I believe that the hazards are even greater than the David report represents.

A. Present Problems

The current status of the mathematical profession in this country is critical, putting the nation's technological superiority at risk. Many of the problems are present in all of American science, but some, including the following, are particular to the discipline of mathematics today:

1. While the value of mathematics to the nation is inestimable, no one will pay its cost mainly because these costs can not be recouped in the market; the government has ceased to fill this breach.

2. Since no one will pay, the mathematical community is demoralized to the point where the supply of new talent is choking off.

3. The problem is exacerbated by public misperception of what mathematics is and does.

1. Patent law is the true mother of invention since it grants the inventor a means of recouping from the market his cost of development and whatever else he can; no one will pay to produce something in which they can not acquire an economic interest. The trouble with mathematics is that anyone can use a theorem gratis, once they know of it. Since there is no mechanism to recoup development costs, that leaves only the Federal government, whose support has failed. The mathematical community is now expected to produce what will enrich the nation generally but is denied the means to make it possible.

How does this compare with other sciences, such as chemistry, physics and biology? As giant industries, each can establish an economic interest in intellectual property by preemptive investments. Moreover, with their wealth they can effectively lobby the government, forcing it to subsidize them by supporting both training and research from which they will ultimately profit. The process feeds on itself. Even physics, which did not exist as an "industry" before World War II has become a billion dollar business with the atomic bomb. Having reached a critical dollar mass, it can press the government for further massive projects which serve national prestige as much as defense. These investments permit it to lobby for further investment in training and research, on which new projects, in turn, will capitalize. In mathematics, by contrast, the burgeoning parts of economic value tend to split away from the basic core, e.g., Statistics and Computer Science. The latter is now seriously draining the pool of mathematical talent because of its economic position.

2. The development of a research mathematician requires training more rigorous and frustrating than in any other science because the obstacles are internal. The attrition rate is great and those who succeed are usually capable of doing many things well. It is a common perception in mathematics that those who withdraw often go to Computer Science or other marketable disciplines, where they may become star students. It is not lost on their former mathematics teachers that these transferred students with fresh graduate degrees often earn more in their first jobs than their erstwhile teachers with many years' experience.

With such a disparity between the ratio of effort and reward in mathematics and that in other fields, compounded by the collapse of Federal support for the individual research on which mathematics thrives, the supply of graduate students has shrunk alarmingly. Fundamental graduate courses are not offered for want of enrollment to justify them, and many mathematics departments must hire graduate students in other disciplines to service basic undergraduate studies which mathematics students carried before. Moreover, many of today's graduate mathematics students are foreign born and can read and understand English but not lecture in it; they now generally return to their native countries, further diminishing the pool of available talent. The "brain drain" has reversed.

3. The perception of mathematics by the public, and often by other scientists, is that it is static; the teacher of mathematics, they believe, is a curator rather than a creator. At best, the history of mathematical creation ends, for most, with the 18th century because, for most, mathematical education ends there. Mathematics of the 20th century, which has witnessed a greater explosion of discovery than all previous ones combined, is accessible only to those who have the

necessary background. The general public has not witnessed it and therefore has ignored it. Lately it is being ignored to death, even by makers of national policy, on the principle that while costly apparatus is necessary for progress in other fields, the mathematician, to the extent that he does anything at all, does it with pencil and paper, and like the starving artist will do it anyhow.

Mathematicians are not concerted in protest or as publicists, generally waiting for the community to reach out to them. In the cultural climate of Japan, by contrast, where a revered soldier or statesman must also have been a scholar, artist or poet, the nation will indeed reach into its scholarly community and honor some, including mathematicians, as "national treasures;" their names become household words. Here the scholar must generally blow his own horn. Since mathematicians are usually inaudible, there is little to disturb the mistaken public perception, or to move it toward more support if it remains unaware of the looming dangers.

B. How Bad Is the Present Situation?

The health of the profession can be measured by 1) its research productivity, 2) its ability to renew itself, and 3) its ability to educate "end users" and to transmit to them vital new discoveries. The outlook in all three is presently so bleak that even immediate infusion of significant new funding would not arrest the presently accelerating decline for several years.

1. No graduate programs existed in this country before 1890. Even to the end of World War II, American born and bred research mathematicians of any note were extreme rarities. This country's sudden post-WWII preeminence in mathematical research stemmed from the influx of refugee scholars and the large post-Sputnik expenditures in support of research. An effective system of peer review of small mathematical grants developed, through which, for many years, most worthwhile projects were supported. In turn, those individuals supported gave generously of their released time to evaluate proposals received by funding agencies. As a result, Federal monies sponsoring mathematical research were generally efficiently spent. The system is crashing. The catastrophic cuts in support have forced many established mathematicians to sell their time to supplement their incomes; they will no longer invest their energies to maintain a system that has ceased to support them. This has come at a time when the demographics of the profession's post-WWII expansion sees many of the cut mathematicians maturing into their best work. The resulting cynicism has sapped the vitality of the peer review system, which is no longer viewed as reliable. The damping effect on research is palpable.

2. The disillusionment resulting from the failure of national policy in the mathematical sciences has resulted in severe recruitment problems. Even a massive distribution of postdoctoral fellowships will not keep the best and brightest in the profession if they perceive their teachers as suffering from a national breach of faith; there is no assurance that the same will not happen to them in, say, the year 2000. The largesse, if offered, will be taken, but those who take it will keep their options open. A permanent commitment of new talent to the profession will, in the light of recent history, be possible only if there is a permanent commitment to some level of Federal support, and that, in turn, can only alleviate the problem some years in the future.

3. Years of neglect have so reduced the cadre of competent mathematics teachers relative to the incessantly growing demand that the load now imperils the system. Even at prestigious universities a professor may face several hundred students in a single calculus section, not one of whom is there for the excitement of the subject; all must fulfill major requirements. In such an ambience teaching threatens to decline to rote drill. The student who is not challenged to be original will not be so when he is called upon to use his mathematical skills later. At grade school, high school, and college levels alike, statements about the need for students to take more mathematics are viewed with alarm by those who see that they must do the additional teaching with no additional help for years, since the lead time to train that help is so great.

There is, however, a much greater national cause for alarm. The spectre is not that of an enormous influx of students into the classroom but a sudden emptying of those classrooms of their teachers by industries who discover that mathematical talent is valuable, in short supply, and is being paid poorly in the schools. A small initial displacement can rapidly generate a massive run that would be a national catastrophe, taking a generation to repair. This frightening threat, the end result of many prime researchers losing 22% to 33% of their base salaries through cuts in Federal support, is now squarely upon us. It is disingenuous to say that it has not been perceived because the universities eased the pain of the steady decline in support when they still had the money to do so. There is no place where scholars losing grant support have regularly been made whole by schools; more commonly they have been fired, since getting a grant has in many places been used as a criterion for tenure. It is precisely at this point where national science policy, which for years has been to steal from mathematics, has put the nation most at risk, and those who directed it can not escape culpability.

C. What Is to Be Done?

1. The prospects, while frightening, are not desparate if steps are taken immediately to forestall a possible industrial run on the nation's mathematical resources. A drain of teachers from classrooms can only be prevented by economic

means, but it would be politically impossible simply to appropriate enough money to build economic barriers at the exits. Much of the money must, therefore, come one way or another from the industrial end users. One possibility would be to offer substantial tax incentives for them to send their employees back into the mathematics classrooms provided the receiving university agreed that industrial payments in money or kind would benefit primarily the university's mathematical faculties. This would require a carefully crafted law, since vested interests always develop in the state of the law as it is when money is involved; subsequent change is difficult. However, the development of such interests is essential, since in view of the history of the past twenty years, the mathematical community would put much greater reliance on them than on any governmental "guarantees." Such interests would partially offset the lack of a "mathematics industry."

2. The next step to reestablishing community confidence that it is indeed national policy to maintain its mathematics research potential must be the reconstruction of the system of small grants and efficient peer review. It will take a continued supply of money to permit researchers the time to stay at the frontiers; research in mathematics today can not be done "on the side" while one sells all available time to meet financial obligations. However, a single rain on parched land does not restore fertility, and new entrants into the field will look for evidence that a policy of separate and invidious treatment of mathematics amongst the nation's scientific resources can not reemerge, say, in 2000. This may require a restructuring of the Federal scientific organization to include a monitoring board, independent of granting agencies, that regularly takes the pulse of the research community much as money supply and growing crops are monitored. What is so extraordinary in the pattern of the last twenty years is that the risk, plain to the community, seems to have been a "mystery" to those charged with husbanding the nation's scientific resources.

3. Finally, mathematicians must somehow find a voice. The community is small, with little political clout or savvy, and generally ignored by the media because of formidable barriers to communication. Everyone "understands" plastics, A-bombs, and synthetic bugs that must be squashed before they reproduce, not in the sense of what makes them, but of their consequences. Mathematicians have been more inept at explaining the consequences of mathematics than artists at explaining the consequences of art, and it is artists far more than other scientists that mathematicians most resemble. But mathematics' consequences are enormous because the deepest mysteries of the universe can be captured only through mathematics. What makes this so may be itself mysterious, but that it is so must be put forcefully to politicians and the public, or the cycle of recent history will repeat.

Letters to the Editor

Open Letter on NSF Reviews

Dear Colleagues:

As you are aware, during the past two years there have been some changes in the manner that reviews are handled at the National Science Foundation. The foremost of these is that reviews are now automatically sent to the Principal Investigator when action is taken on a proposal. This change was instituted by the National Science Board, after four years of experimentation, as part of an attempt to improve the peer review system and to increase the possible benefits for research activities of the time, effort, and expertise of the peer review community.

In the past, reviews were intended primarily for the program officer within the Foundation, to inform him or her of the value of the proposed research and of the ability of the pricipal investigator to carry it out. This is still the primary purpose of the reviews: They are the fundamental guide for the allocation of very scarce financial resources for the proper and appropriate support of research activities. However, it is important that it be remembered that these reviews are read and analyzed by other people, beside the program director. They are seen by members of the staff of the Foundation, and not only within the Division of Mathematical Sciences; and these reviews, their content and tone, contribute to the image of the mathematical sciences within the Foundation. The reviews are now also received by the Principal Investigator for information and advice.

At the urging of the staff of the Division and in an effort to determine how well the peer review system is meeting these several needs, I met with three other members of the NSF Advisory Subcommittee for the Mathematical Sciences and members of the staff of the Division to sample the review of several proposals, both funded and unfunded, from FY 1983. Our conclusion was that the system is working well. There is, however, a small, but not insignificant, percentage of the reviews that is not as responsive to the needs as all of us in the research community might desire. Since the vast majority of the reviews are very conscientious, some of these less thoughtful reviews can be overlooked. However, they remain in the proposal documentation and can color the opinions of outsiders on the adequacy of the reviewing process. They can also unnecessarily damage the morale of the investigator in some situations, and can be unintended discouragement to the conduct of research.

Rather than providing a list of do's and don't's which would make this letter longer than you or I would like, let me provide a sample of the kind of review that seems to us less than useful and that can cause problems. Put yourself in the shoes of a program director attempting to evaluate a proposal, someone within NSF trying to determine why a recommendation for or against funding should be made or agreed to, or the principal investigator trying to decide why a certain action was taken on his or her proposal. What could be done with reviews such as the following ones?

1. (No comments) - rating checked.

2. *X* has a strong reputation for doing very good work in the field.

3. This is pretty good stuff, but you can probably do better with your money.

4. *X* is a young Ph.D. While it is difficult to tell where he will go, I recommend funding her on the grounds that all young people should be funded. On that basis I rate the proposal Very Good.

5. *X* is one of the "grand old men" of the field. His results of 20 years ago provided a real stimulus and have proven their importance. I would certainly continue to support his research, independent of what he proposes to do.

6. This area of mathematics has produced little but garbage over the last twenty years. The investigator shows little sign of ability to produce mathematical research and no evidence of competence. What more need I say?

All of the above comments (of course, a sample of the most deplorable reviews) leave something to be desired in the way of providing the information and thoughtful analysis helpful to decision making. Many leave the impression that the reviewer may not even have seriously read the proposal. They certainly are not helpful and

Policy on Letters to the Editor

Letters submitted for publication in the *Notices* are reviewed by the Editorial Committee, whose task is to determine which ones are suitable for publication. The publication schedule requires from two to four months between receipt of the letter in Providence and publication of the earliest issue of the *Notices* in which it could appear.

Publication decisions are ultimately made by majority vote of the Editorial Committee, with ample provision for prior discussion by committee members, by mail or at meetings. Because of this discussion period, some letters may require as much as seven months before a final decision is made.

The committee reserves the right to edit letters.

The *Notices* does not ordinarily publish complaints about reviews of books or articles, although rebuttals and correspondence concerning reviews in the *Bulletin of the American Mathematical Society* will be considered for publication.

Letters should be mailed to the Editor of the *Notices*, American Mathematical Society, Post Office Box 6248, Providence, Rhode Island 02940, and will be acknowledged on receipt.

constructive to the proposer in developing research plans; the reviews are written by a researcher in part for and about his or her colleague, yet they do not display the consideration for the feeling of the proposing colleague which they should.

Since our consensus was that the majority of reviewers were doing a thoughtful, careful, and capable job at providing information in the desirable framework, it may seem unnecessary to single out the problems.

Nonetheless, we felt a responsibility, after careful consideration of this matter, to attempt to verbalize to the peer review community our continuing concern for the need of excellence in the operation of the peer review system. The allocation of scarce resources is dependent on it; it is also most influential as a vehicle for the transmittal of scientific information, and for the encouragement of research.

The Advisory Committee for the Mathematical Sciences of the National Science Foundation urges the research community to continue to involve itself thoughtfully in the peer review process.

William Browder,
Chairman
NSF Mathematical Sciences
Advisory Committee
Princeton University
(Received May 29, 1984)

Research Support for Mathematicians

In July 1983 we mailed a short questionnaire to 121 Departments of Mathematics, including all those granting the Ph.D. degree. Our purpose was to obtain an idea of how the mathematical community felt about the steady erosion in the number of individual mathematical scientists supported by government sources (the principal one being the National Science Foundation). Moreover, we hoped to obtain a meaningful estimate of the number of those mathematicians that should be supported by traditional summer grants. After explaining this intention we requested replies to the following four questions:

(1) We feel that, by and large, there is, in most departments, widespread agreement on who merits research support. Could you provide us with the number of such individuals in your department?

(2) Could you give us the number of full-time faculty members in your department that were supported by a federal grant in 1980-1981, 1981-1982, 1982-1983, 1983-1984 (N.B. the academic year 1980-1981 includes the summer of 1980 and not that of 1981, etc.)?

(3) Is there an obvious pattern in the changes that occurred during these four years? Is there a discernible shift (to the more junior, to the more senior, to specific fields, etc.)?

(4) Could you make a brief statement concerning your priorities for federal support for mathematical research? If there are (perhaps conflicting) other opinions in your department, we would appreciate hearing about them.

We think it is appropriate to share with the mathematical community the information we obtained.

Fifty-four departments responded to our questionnaire.

Response to Question 1: The departments responding provided the number 1,234 (mathematical scientists that "merit research support".) Since 45% of the institutions contacted replied, let us assume that this represents 45% of the *total* number of mathematical scientists meriting such support. Thus we may conclude that 2,700 is, approximately, the number of active mathematicians in the United States. We realize that this assumption is questionable but we would like to point out that this number is consistent with some arrived at by others. Edward E. David, Jr., who chaired the National Research Council's Ad Hoc Committee on Resources for the Mathematical Sciences spoke at the joint annual meeting of the AMS and MAA in Louisville, Kentucky, on January 25 about the findings and recommendations of the committee that he chaired. One of these recommendations is an "annual funding for grants and support of 2600 established mathematical scientists." A recent study indicated that about 2700 mathematicians at American institutions have published at least one research article in a refereed journal in each of the last five years.

Response to Question 2: We obtained the four numbers: 757, 750, 688, 657. This represents a continuing decrease from 1980 to 1983 of 13%. This information (which includes a very small number of grants not supported by the NSF) is completely consistent with the figures issued by the National Science Foundation. At present the number of Summer grants funded by the NSF is between 1200 and 1300.

Response to Question 3: The replies to Question 3 indicate that the respondents observed no trend beyond the decrease in the number of mathematicians supported and the accompanying loss of morale. Substantial minorities, however, mentioned two possible trends: a shift away from the support of senior people to the support of junior people and a shift away from the support of core mathematics to more applied and computational areas. A smaller group felt that senior people were being supported at the expense of beginners.

Response to Question 4: The responses revealed a near unanimity in urging an increase in the number of individual grants. About 40 replies specifically urged this and another 10 included this point as part of their reply. Several respondents expressed the belief that research support is concentrated in too few institutions, and that the mathematical sciences research institutes at

Berkeley and Minnesota have siphoned off too much support from other institutions. A smaller number of replies gave highest priority to the support of junior mathematicians.

We share the feelings expressed by the respondents and are concerned about this decrease in the number of individual grants. We quote two very famous mathematicians at two of the most prestigious institutions who say: "The cut-off line is both arbitrary and too high" and "the plight of our colleagues is perceived as very real even at the very top." Finally, we observe that the Advisory Subcommittee to the Mathematical Sciences Division recently passed a motion (unanimously) the main thrust of which was to recommend that this decrease be stopped and the number of grants actually be increased with future funding.

Salah Baouendi
Purdue University

Heini Halberstam
University of Illinois, Urbana

Alex Rosenberg
Cornell University

Guido Weiss
Washington University

Edward Wilson, DEAN
Washington University
(Received May 17, 1984)

Travel to Poland

I have read with interest the letter from Professor I. N. Herstein in your February issue. I do not approve of any government which treats Professor Herstein that way, and I would support him in bringing the facts to our attention and in any suitable protest.

All the same, I think his appeal to your readers could have been stronger. If he had sought a visa for the purpose of going to the International Congress of Mathematicians and had been refused one, then I think he would have had a claim on every mathematician who supports the International Mathematical Union. But since he mentions that he did not intend to go to the Congress, I presume his letter is aimed mainly at citizens of the U.S.A.

J. F. Adams
University of Cambridge
(Received May 14, 1984)

AMS Research Fellowships

The terms of the AMS Research Fellowship are again being changed. Last year, fellowships were open to individuals four to ten years past the Ph.D. degree (or equivalent), regardless of age, but below the academic rank of professor. This year, eligible candidates must be five to ten years past the Ph.D. degree. Moreover, the vita must include the equivalent of at least three full years (rather than two years) postdoctoral teaching or industrial experience, i.e. non-fellowship years.

The stipend has been set by the Trustees of the Society at $30,000 for nine months (rather than eleven) of full-time research or its equivalent. In addition, there will be an expense allowance of $1,000. Applicants must be citizens or permanent residents of a country in North America. Fellowships may be held at any institution the Fellow selects or at more than one in succession. There is flexibility in the choice of time interval(s) and manner in which the Fellow may draw funds. For instance, given the opportunity, a Fellow may elect to hold a half-time academic appointment with a teaching responsibility not exceeding one course per term while holding the fellowship at one-half stipend over a two-year period. The fellow should consult the Secretary of the Society to learn whether the arrangement proposed is acceptable to the Society.

The number of fellowships depends on the amount of money contributed to the program. The Trustees have arranged the matching program from general funds in such fashion that funds for at least one fellowship are guaranteed.

The deadline for receipt of applications is **December 3, 1984**. Awards will be announced late in January 1985.

For application forms, write to William J. LeVeque, Executive Director, American Mathematical Society, P.O. Box 6248, Providence, RI 02940.

Request for Photos

In conjunction with the Centennial of the American Mathematical Society which is to be celebrated in Providence in 1988, the AMS would like to set up an exhibit of group photos from meetings and similar items of interest.

If anyone has memorabilia of this kind which they would like to give or loan to the AMS, please write to William J. LeVeque, Executive Director, American Mathematical Society, P.O. Box 6248, Providence, Rhode Island 02940.

1984 Pierre Robillard Award

The winners of the 1984 competition for the Pierre Robillard Award of the Statistical Society of Canada (SSC) have been announced. The objective of this award is to recognize the best Ph.D. thesis defended at a Canadian university in a given year and written in a field covered by *The Canadian Journal of Statistics*. The winners, together with the titles of their theses, are: THOMAS J. DICICCIO, University of Waterloo, *Higher order comparisons of asymptotic methods for conditional and unconditional interval estimation* (Supervisor, Mary E. Thompson); and CHRISTIAN GENEST, University of British Columbia, *Towards a consensus of opinion* (Supervisor, James V. Zidek).

The coordinator of the 1985 competition for the Pierre Robillard Award is C. A. Field, Department of Mathematics, Statistics and Computer Science, Dalhousie University, Halifax, Nova Scotia B3H 4H8, Canada. (See News and Announcements, *Notices*, November 1983, page 763 for further information.)

Newly Elected Members of the American Academy of Arts and Sciences

The following mathematicians were elected to membership in the American Academy of Arts and Sciences in May 1984: WILLIAM BROWDER, Princeton University; CATHLEEN S. MORAWETZ, Courant Institute of Mathematical Sciences, New York University; JACOB T. SCHWARTZ, Courant Institute of Mathematical Sciences, New York University; and JAMES B. SERRIN, Minnesota Institute of Technology. STEPHEN W. HAWKING, Cambridge University, was elected a foreign honorary member.

Sloan Foundation Awards for Work in Applied Mathematics at Black Colleges

The Alfred P. Sloan Foundation has announced grants of $930,000 to sixteen predominantly black colleges and the Georgia Institute of Technology. The grants were made as part of the Foundation's New Liberal Arts Program. The purpose of this program is to encourage the study of quantitative modes of thought—applied mathematics and technology in particular—over a wide range of college courses and academic disciplines.

Four grants of $150,000 each were made to North Carolina A&T State University (Greensboro, North Carolina), Rust College (Holly Springs, Mississippi), Spelman College (Atlanta,

News from the Mathematical Sciences Research Institute

Berkeley

Institute programs through 1985-1986 have been announced in earlier issues of the *Notices*. Planning has now progressed to include subsequent years.

During 1986-1987 there will be one single large program at the Institute devoted to the topic Number Theory and Connections with Algebraic Geometry. This will be funded at almost twice the level of our usual programs and it will embrace a correspondingly wider area. The program committee consists of Benedict Gross (chairman), Barry Mazur, Nicholas Katz, John Tate and Ken Ribet. Additional information will appear in these reports in the *Notices* as planning for the program progresses.

The balance of the scientific budget for 1986-1987 will be devoted to providing support for scholars in all areas of the mathematical sciences without regard to programmatic focus. We expect that the extent of support outside of focused and structured programs will be greater in 1986-1987 than in previous years. Yearlong postdoctoral fellowships for new and recent doctorates as well as sabbatical supplements for more senior mathematicians will be available.

Preliminary planning has already begun for 1987-1988; we expect to have a program in classical analysis and a program in a second area yet to be determined. Details will be announced as they become available.

Construction of our permanent facility is on schedule; as of this writing (early June) the building is framed in, and the roof will be going on shortly. We expect to be in the building by December 1 of this year.

Georgia), and Tuskegee Institute (Tuskegee, Alabama). The Foundation announced at the same time grants of $15,000 to twelve additional black colleges and universities for small institutional projects in applied mathematics and technology. A grant of $150,000 was also made to the Georgia Institute of Technology to meet the costs of workshops and other activities conducted jointly by Georgia Tech and the same group of sixteen black colleges.

–Sloan Foundation News Release

Sloan Foundation Predoctoral Awards

The Alfred P. Sloan Foundation has announced grants of $525,000, representing the first awards under the Foundation's new Doctoral Dissertation Fellowship Program. These awards will provide support over one year of $8,000 plus tuition to forty promising Ph.D. candidates in mathematics and economics, allowing them to give full time to their doctoral dissertations.

"Completing the dissertation," said Albert Rees, president of the Sloan Foundation, "is a time-consuming scholarly task that is usually performed with great difficulty amidst the candidate's teaching duties and other obligations. These awards will give the fellows the freedom they need to get the job done and finish their degrees."

The sharp decline since the late 1960s in federal support of predoctoral students was the principal reason for Sloan's expansion of its fellowship programs. The new program of predoctoral fellowships complements the Foundation's well-known program of fellowships for junior faculty members. To launch the new program of predoctoral fellowships, the Sloan Foundation earlier this year invited leading graduate departments of economics and mathematics to submit nominations.

The mathematicians serving on the award committee are F. Thomas Farrell, Columbia University; Benedict Gross, Brown University; and Robert C. Gunning, Princeton University.

Those receiving awards in the mathematical sciences and their universities are Salman Abdulali (State University of New York, Stony Brook); Diego Benardete (City University of New York); Samuel R. Buss (Princeton University); Paulo Cordaro (Rutgers University); Steven Cutkosky (Brandeis University); Randall Lee Dougherty (University of California, Berkeley); Lin Fanghua (University of Minnesota, Twin Cities); Livio Flaminio (Stanford University); Robin Forman (Harvard University); Franc Forstneric (University of Washington); Peter Niels Heller (Princeton University); Gaven J. Martin (University of Michigan); Curtis Tracy McMullen (Harvard University); Richard W. Montgomery (University of California, Berkeley); Margaret M. Napolitano (Brown University); Frank S. Rimlinger (University of California, Berkeley); Jacob Rubinstein (Courant Institute of Mathematical Sciences, New York University); Mark F. Simpson (Cornell University); Christopher D. Sogge (Princeton University); Mark Spivakovsky (Harvard University); John Stembridge (Massachusetts Institute of Technology); Eric F. Van de Velde (Courant Institute of Mathematical Sciences, New York University); Howard N. Weiss (University of Maryland, College Park); David Witte (University of Chicago); and Da-Gang Yang (State University of New York, Stony Brook).

–Sloan Foundation News Release

C. B. Morrey, Jr., 1907 – 1984

Charles Bradfield Morrey, Jr., died April 29, 1984, at the age of 76. He was a member of the Society for 53 years. He was the Colloquium Lecturer at Amherst in August 1964 and served as President of the Society in 1967 and 1968 and as Trustee from 1963 to 1968.

Morrey was born in Columbus, Ohio, July 23, 1907. He earned a B.A. (1927) and an M.A. (1928) from Ohio State University and a Ph.D. (1931) from Harvard University. He was a National Research Council Fellow at Princeton University (1931-1932) and Rice University (1932-1933). He joined the department of mathematics at the University of California, Berkeley, as an instructor in 1933 and retired as professor emeritus in 1977.

He was a member of the *Transactions* editorial committee from 1945 to 1950. He was a member of many other AMS committees and represented the Society on the National Research Council, Division of Physical Sciences, 1958–1961.

He was elected to the Section of Mathematics of the National Academy of Sciences in 1962. His research interests included area of surfaces, calculus of variations, and elliptic partial differential equations. His work provided the decisive steps in the solutions of Hilbert's 19th and 20th problems.

At the suggestion of Mrs. Morrey, a Charles Morrey Memorial Fund is being established to honor his memory in a way which will reflect his deep interest in helping students who are devoting themselves to the study of mathematics. The precise form of the memorial will depend on the final size of the fund; inquiries and contributions can be directed to the chairman, Department of Mathematics, University of California, Berkeley, California 94720.

U.S. Mathematical Olympiad Winners

Eight U.S. students have earned Olympiad medals in a mathematics competition involving nearly 400,000 high school students. The final round in this competition was the Thirteenth USA Mathematical Olympiad (USAMO) in which ninety students competed in a challenging examination designed to test ingenuity as well as mathematical background. The finalists were the top performers in the American High School Mathematics Examination and the American Invitational Mathematics Examination which were held in high schools throughout the United States and Canada in February and March 1984.

The eight USAMO winners are David J. Grabiner, Claremont, California; Douglas R. Davidson, McLean, Virginia; David J. Moews, Willimantic, Connecticut; Michael Reid, Woodhaven, New York; Joseph G. Keane, Pittsburgh, Pennsylvania; Steven Newman, Ann Arbor, Michigan; William C. Jockusch, Urbana, Illinois; and Andrew Chin, Austin, Texas.

Following an awards ceremony, the eight winners and sixteen other students who did well in the USAMO participated in an intensive three-week seminar at the U.S. Naval Academy at Annapolis in preparation for the 1984 International Mathematical Olympiad held in Prague, Czechoslovakia in July.

The Mathematical Olympiad and the High School Mathematics Contests are sponsored by five major organizations in the mathematical sciences. Financial support is provided by IBM, the Army Research Office and the Office of Naval Research. –MAA News Release

News from the Institute for Mathematics and its Applications

Minneapolis

The 1984-1985 program on Continuum Physics and Partial Differential Equations will begin with an opening workshop entitled Equilibrium and Stability Questions in Continuum Physics and Partial Differential Equations. The Conference is being organized by Millard Beatty, Haim Brezis, Jerry Ericksen and David Kinderlehrer. This conference will lay the framework for the year's activities by providing perspectives about recent progress and future work in these areas. Contemporary Issues of Continuum Theory will be presented by engineers, scientists, and mathematicians in a manner designed to interest mathematicians and to produce a dialogue with the applied scientists.

A workshop on homogenization and effective moduli of materials and media, organized by Jerry Ericksen, J.-L. Lions, David Kinderlehrer and Robert Kohn will be held from October 22 to 26. This workshop will focus on recent advances in the theory of homogenization of equations and the determination of effective moduli of materials. These areas are closely linked to a wide variety of phenomena such as the elastic and thermal responses of composites and the interpretation of seismic measurements, as well as to questions in optimal design.

The periods following these workshops will be devoted to more detailed study of and research on related topics. All activities of the IMA are open, and visitors are welcome. Further workshops and related activities will occur during the winter, spring and summer of 1985.

The 1985-1986 program on Stochastic Differential Equations is now being planned in detail. It will be described in the October issue of the *Notices*.

The board of Governors of the Institute for Mathematics and its Applications has decided that the year 1986-1987 will be devoted to Scientific Computing. The organizing committee will consist of Bjorn Engquist (chairman), Roland Glowinski, Mitchell Luskin and Andrew Majda.

Committee on Applications of Mathematics

The Committee on Applications of Mathematics, a standing committee of the Commission on Physical Sciences, Mathematics, and Resources of the National Research Council, has recently

published a report of its findings. Entitled *Computational Modeling and Mathematics Applied to the Physical Sciences*, this report reflects the committee's conclusion that computational modeling, a high-leverage element of our nation's scientific and technological effort, requires increased emphasis and support. The committee recommends increased support for research in computational modeling and applied mathematics, computing facilities dedicated to this area, and education and manpower development in computational and applied mathematics.

Members of the Committee on Applications of Mathematics are James G. Glimm, New York University; James M. Hyman, Los Alamos National Laboratory; Robert J. Kee, Jr., Sandia National Laboratories; James A. Krumhansl, Cornell University; John E. Osborn, University of Maryland; Werner C. Rheinboldt, University of Pittsburgh (Chairman); Martin H. Schultz, Yale University; and Ivar Stakgold, University of Delaware.

Copies of this report are available from the Office of Mathematical Sciences, National Research Council, 2101 Constitution Avenue, N.W., Washington, DC 20418.

M. H. A. Newman, 1897 – 1984

Maxwell Herman Alexander Newman, since 1964 emeritus professor of mathematics, University of Manchester, died early in March. Newman was a Fellow of St. John's College (1923–1945) and University Lecturer in Mathematics (1927–1945), Cambridge University. He was a Fellow of the Royal Society and was recipient of the Sylvester Medal of the Royal Society (1959) and the De Morgan Medal of the London Mathematical Society (1962). He was President of the London Mathematical Society, 1949–1951, and President of the [British] Mathematical Association, 1959.

The following is excerpted from *The Times* of London, 5 May 1984:

"Newman was the first British mathematician to work in combinatorial topology. Here he contributed to fixed-point theory, and paved the way for the work of P. A. Smith; but his main achievement was to rework the foundations of combinatorial topology, in a series of papers from 1926 to 1932. Later he returned to topology, publishing from 1960 to 1966 work of a quality and topicality seldom attained by mathematicians in their sixties.

"Newman spent most of the period 1939–1945 at Bletchley Park. Much has been written about the 'Enigma' cipher. The work to which Newman contributed, though distinct from that on 'Enigma', has been described as being of comparable importance. He devised a way of carrying forward the work of Tiltman and Tutte by the use of specially-designed machines, and for this purpose was given charge of a section, commonly called the 'Newmanry'. ...

"In 1945 Newman followed Mordell as Fielden Professor of Mathematics in Manchester. He was a shrewd judge of mathematicians; he recruited for his department a star studded cast, including Alan Turing, Bernhard Neumann, J. W. S. Cassels and others. Having brought them there, he looked after them."

He was the author of *Elements of the topology of plane sets of points*, Cambridge, 1939, second edition, 1951, and of numerous research papers, many of which may be located by consulting *Zentralblatt für Mathematik* (since 1931) or *Mathematical Reviews* (since 1940).

University of Texas Endowed Positions

The University of Texas System Board of Regents has approved the appointment to endowed academic positions of six members of the faculty in the University of Texas, Austin, College of Natural Sciences. Of the six faculty members, three are in the mathematical or computer sciences. These three and the academic positions they will hold are: James C. Browne, the David Bruton, Jr., Centennial Professorship in Computer Sciences; K. Mani Chandy, the Second David Bruton, Jr., Centennial Professorship in Computer Sciences; and Cameron M. Gordon, the Joe B. and Louise Cook Professorship in Mathematics. –University of Texas News Release

Management Science Roundtable Offers $2,000 Commissions

The Management Science Roundtable, the institutional membership division of The Institute of Management Sciences (TIMS) is offering $2,000 commissions on two topics: (1) artificial intelligence and management; (2) spreadsheet modeling as a stepping-stone.

Each commission carries a normal honorarium of $2,000. Half will be paid in advance and half upon completion of the report. Proposals must be received by the TIMS Business Office no late than **September 15, 1984.** Awards will be made by October 30. Reports normally are due within four months of award notification. Proposals should be no more than three pages long. One or two pages should be devoted to a *substantive* outline of the main ideas to be developed in the report, and one page should state the submitter's pertinent background and qualifications.

Entries should be submitted to The Management Science Roundtable, c/o TIMS Business Office, 240 Westminster Street, Providence, Rhode Island 02903. Further information concerning the commissions and the Management Science Roundtable can be obtained at this address.

Erich Bloch to be Nominated as NSF Director

President Reagan has announced his intention to nominate Erich Bloch as Director of the National Science Foundation (NSF). Bloch, an engineer, is currently Vice President for Technical-Personnel Development at IBM Corporation. He will succeed Edward A. Knapp, who has announced plans to resign from the top NSF post later this year to return to research in the field of physics at the University of California's Los Alamos National Laboratory.

Bloch's name was recommended to the President by the National Science Board, policymaking body of NSF. Government and Congressional sources said Bloch had originally been selected by the White House to fill the post of deputy director of the foundation, a position that has been vacant for about a year and a half. Bloch was asked to take the directorship when Knapp submitted his resignation.

The Board's chairman, Roland W. Schmitt, expressed his regret over Knapp's impending departure, noting that "he has made numerous contributions to the Nation's scientific and engineering health during his two years with the Foundation."

"In recommending Erich Bloch for the NSF post, we feel confident that we have selected a worthy successor, who will continue the NSF's tradition of support to the Nation's scientific and technical goals."

White House officials said they thought Bloch was particularly qualified to head the foundation at a time when the Reagan Administration has proposed a twenty-two percent increase in funds for its engineering-research programs.

In his present IBM position, Bloch is charged with promoting the technical vitality of IBM's professional engineering, programming, technology, and scientific people throughout the world. His responsibilities include programs with universities, the firm's technical libraries, operation of IBM's corporate technical institutes, and publication of technical journals. He serves as a member of the Corporation's Education Relations Board, which is responsible for IBM contributions to academic institutions.

Bloch is a member of the National Academy of Engineering and serves on the National Research Council's Manufacturing Studies Board and Committee on Education and Utilization of the Engineer. He is a fellow of the Institute of Electrical and Electronics Engineers and a member of its Computer Society.

He will take over an agency in which several key posts have been vacant for more than a year. In addition to the deputy directorship, three of the seven assistant-director positions at the foundation remain unfilled.

Following is a list of directors of the science foundation, their academic specialties, their affiliations at the time they were appointed, and the years they served:

ALAN T. WATERMAN, physicist; Yale University and the Office of Naval Research; 1951–1963.

LELAND J. HAWORTH, physicist; Brookhaven National Laboratory; 1963–1969.

WILLIAM D. MCELROY, biochemist; Johns Hopkins University; 1969–1972.

H. GUYFORD STEVER, physicist (aeronautics and astronautics); Carnegie-Mellon University; 1972–1976.

RICHARD C. ATKINSON, psychologist; University of California, Los Angeles; 1977–1980.

JOHN B. SLAUGHTER, engineer; Washington State University; 1980–1982.

EDWARD A. KNAPP, physicist; Los Alamos National Laboratory; 1982 to present.

–NSF News Release & Chronicle of Higher Education

New Assistant Director for Science and Engineering Education

Edward A. Knapp, Director of the National Science Foundation (NSF), recently announced the appointment of Bassam Z. Shakhashiri, a University of Wisconsin, Madison, chemist, as Assistant Director for Science and Engineering Education.

Shakhashiri, who has received many citations for his contributions to science education, is professor of chemistry and director of the Institute for Chemical Education at the university.

He replaces Laura P. Bautz who has been acting Assistant Director for Science and Engineering Education since October 1, 1983. Bautz will return to her former position as director of NSF's Division of Astronomical Sciences.

–NSF News Release

Visiting Professorships for Women

The Visiting Professorships for Women program was instituted to encourage women to develop careers in research in the disciplines of science and engineering, and to provide greater visibility for women scientists and engineers in industry, government and academic research centers. In

providing support for the program, NSF is addressing the need to make full use of the scientific and technical resources of the nation.

Proposals will compete for awards on the basis of the scientific merit of the proposed research and a specific plan for teaching, mentoring, and counseling activities. The new deadline for applications is **November 15, 1984** with a scheduled announcement of awards May 15, 1985. For further information about the guidelines and eligibility requirements write to the Visiting Professorships for Women Program, National Science Foundation, 1800 G Street, N.W., Washington, DC 20550.

Grants for Experimental Computer Science Research

The National Science Foundation (NSF) has awarded grants totalling $15.9 million to four universities to provide long-term support for experimental computer science research in the United States. Institutions receiving the five-year grants were the University of Arizona, $3.6 million; New York University, $4 million; University of Rochester, $3.9 million; and the State University of New York at Stony Brook, $4.4 million.

The grants, made through the NSF's Division of Computer Research, are made to help alleviate a shortage of computer scientists in industry and academia and to stem the deterioration of U.S. facilities for experimental computer science research. Over the next five years, the grants will support university efforts to buy or upgrade computing equipment, provide professional and technical support staff, defray graduate student salaries and cover other costs involved in maintaining experimental computer research facilities.

Fourteen research facilities already have been established under NSF's Coordinated Experimental Research (CER) Program started in 1980. The NSF expects the awards to stimulate an increase in research in computer science and computer engineering and, in that way, to increase the incentives for students to pursue advanced degrees in those fields.

Researchers in the University of Arizona's Computer Science Department propose to enlarge their current research facility to allow them to expand their research in experimental programming languages and to pursue new lines of investigation. Planned activities include continued work on the Icon programming language, several new functional programming languages, high-level language tools, software testing, distributed systems, and editor-based programming environments.

At New York University's Courant Institute for Applied Mathematics, computer researchers have investigated several theoretical issues related to robotics and vision. They now propose to expand their new robotics laboratory to allow them to experiment with techniques for processing robot data and design and development of languages for robotics. (See *Mathematical Problems and Training in Robotics* by Jacob T. Schwartz and Micha Sharir, *Notices*, August 1983, pages 478–481.)

The University of Rochester proposes to purchase a large multicomputer to support investigations of complex models, computer image processing, knowledge representation, natural language understanding and computer architectures. This powerful machine will be integrated into the Rochester research network, providing an excellent testbed for artificial intelligence, system and architecture research. The knowledge gained with this multi-computer will provide real insight into the strengths and weaknesses of such systems.

The researchers at the State University of New York at Stony Brook have proposed to build a data-oriented computer system within a network environment. The proposed facility is planned to support research in graphics, very large-scale integration designs, office automation and natural language processing. –NSF News Release

NSF Grant Policy

Organizational Prior Approval Systems (OPAS) are intended to give prior approval and are not authorized to give retroactive approval. Grantees may request retroactive approval from NSF Grants Officers who, after consultation with Program Officers, may approve such requests in unusual circumstances.

It is not NSF practice to encourage such requests or to treat them in a routine manner. Each request is considered based on its importance to the project, the situation giving rise to the need for the retroactive approval, and the grantee's demonstrated ability and willingness to control matters requiring prior approval. For further information, contact Frank Naughten, Policy Office, Division of Grants and Contracts, 202-357-7880. –*NSF Bulletin*

Cooperative Research with Eastern Europe

NSF's Eastern Europe Cooperative Science programs seek to foster and support scientific and technological cooperation between the U.S. and Bulgaria, Hungary, and Romania.

The programs offer financial support for three types of activities: cooperative research projects, seminars and workshops, and scientific visits for planning purposes. Proposals must be submitted to NSF by American institutions, and to the appropriate foreign agency by foreign institutions. Proposals should be prepared according to standard NSF guidelines, but must also contain a section on "International Cooperation" which describes the cooperative aspects of the work plan and the mutual benefits to be obtained. Proposals

for joint research should be submitted at least nine months before the requested starting date; for seminars, twelve months, and for short-term visits, six months.

For further information, call Deborah Wince, Division of International Programs, 202-357-9516.
–NSF Bulletin

Cooperative Science Program with Austria

The U.S.-Austria Cooperative Science program has been established within the Division of International Programs as a result of the signing of a Memorandum of Understanding between NSF and the Austrian Science Research Fund. The program includes cooperative research projects, scientific visits, and joint seminars/workshops. Support is limited to travel and subsistence costs for U.S. scientists. Currently established deadlines for submission of proposals to NSF are September 15, 1984, March 1, 1985, and September 15, 1985. Allow nine months for proposal processing.

For further information including guidelines for preparation of proposals, call Warren Thompson, Division of International Programs, 202-357-9700.
–NSF Bulletin

Addendum to Presidential Young Investigators

In the article, *First Presidential Young Investigators, Notices*, April 1984, page 286, one mathematical scientist was omitted from the list of investigators. A Presidential Young Investigator award has been given to Jean-Marc Vanden-Broeck of the University of Wisconsin, Madison. His field of research is Numerical Fluid Mechanics.

Automation and Employment

A report entitled *The Impacts of Automation on Employment, 1963–2000* has just been published by New York University's Institute for Economic Analysis. The report, funded by the National Science Foundation's (NSF) Division of Policy Research and Analysis, is the result of three years of collaboration by ten researchers. The study was supervised by Wassily Leontief, director of the Institute, and Faye Duchin, associate director.

The study incorporates information from diverse sources into an input-output model of the U.S. economy to draw a picture of what can be expected to happen from the progressive introduction of computers and computer-based automation. It details the probable effects of these technological changes on outputs and inputs of all goods and services and on the demand for labor services.

A limited number of copies of the report are available without charge from the Division of Policy Research and Analysis, National Science Foundation, 1800 G Street, N.W., Washington, DC 20550. A limited number of copies are available for $15 each from the Institute for Economic Analysis, New York University, 269 Mercer Street, New York, NY 10003.

Positions Open in NSF

Applicants for the following positions should submit résumés including current salary to NSF, Personnel Administration Branch, Room 212, 1800 G Street, N.W., Washington, D.C. 20550; Attn: Catherine Handle, 202-357-7840. Hearing impaired individuals should call: TDD 202-357-7492. NSF is an equal opportunity employer.

These positions will be filled on a one- or two-year rotational basis under the provisions of NSF's Rotator Program and are excepted from the competitive civil service. Specific years of successful scientific research experience beyond the Ph.D. are required for the following positions in all fields: Program Director, six to eight years; Associate Program Director, four to six years; Assistant Program Director, three to four years. Salaries range from $30,000 to $45,000 for assistant program director; $35,000 to $55,000 for associate program director; and $40,000 to $65,000 for program director.

NSF's Division of Computer Research is seeking qualified applicants for the positions of assistant program director, associate program director and program director for Intelligent Systems and for Theoretical Computer Science. A broad, general knowledge of computer research and some administrative experience are required. For technical information about these positions, contact Kent Curtis, Acting Division Director, Division of Computer Research, 202-357-9747.

NSF's Division of Mathematical Sciences is seeking qualified applicants for positions which periodically become available. Applicants should have a Ph.D. and equivalent experience and training in an appropriate field. A broad, general knowledge of the field and some administrative experience are required.

NSF's Division of Information Science and Technology is seeking qualified applicants for the program director position in the Information Science program. The position will be filled no later than September 1984. The program supports basic and applied research under three related programs: Information Science, Information Technology, and Information Impact. Applicants should have a Ph.D. in information science or a cognate discipline. For further information, call Charles Brownstein, Division of Information Science and Technology, 202-357-9572. *–NSF Bulletin*

Queries

Edited by Hans Samelson

QUESTIONS ARE WELCOMED from AMS members regarding mathematical matters such as details of, or references to, vaguely remembered theorems, sources of exposition of folk theorems, or the state of current knowledge concerning published or unpublished conjectures. This is not intended as a problem corner, except for occasional lists of problems collected at mathematical meetings.

REPLIES from readers will, when appropriate, be edited into a composite answer and published in a subsequent column. All answers received will be forwarded to the questioner.

QUERIES and RESPONSES should be typewritten if at all possible and sent to Professor Hans Samelson, American Mathematical Society, P. O. Box 6248, Providence, Rhode Island 02940.

Queries

307. John M. Rassias (Department of Mathematics, The American College of Greece, Aghia Paraskevi, Attikis, Greece). Are there any techniques available to show that the system $19x-361y-30z+16=0$, $6x-8u+28v-7t=0$, $19y > x-19$, $4u > x-4$, $7v > x-7$ has no solutions in $\mathbf{N}=\{1,2,3,\ldots\}$?

308. Francis D. Lonergan (Department of Mathematics, Catholic University of America, Washington, D.C. 20064) and **John Hosack** (Department of Mathematics, Colby College, Waterville, ME 04901). There is good reason to conjecture that the following group presentations are those of finite groups:

generators: x, z;

relations: $(1)_m : z^3x^{m-4}z^3x^{-1}=1$,
$(2)_m : z^5x^{m-3}z^2x^{m-3}=1$

for the two cases $m=+1,+5$. These are fundamental group presentations of closed, orientable 3-dimensional manifolds. We have tried, unsuccessfully, to determine their orders by using the computerized Todd-Coxeter Coset Enumeration Algorithm or by adjoining relations of the form $x^r=1$, $z^t=1$ in an attempt to obtain an infinite homomorph. Are there other techniques available in the literature that we might try?

309. M. L. Glasser (Department of Mathematics and Computer Science, Clarkson University, Potsdam, NY 13676). The following conjecture has been verified in a number of cases for dimensions $n=1,2,3$. Short of finding a proof or counterexample, can anyone locate an antecedent result or perhaps relate it to the Jacobian conjecture? Let $\phi : \mathbf{R}^n \to \mathbf{R}^n$ be rational with singularities on hyperplanes that partition $\mathbf{R}^n$ into domains D_k, $k \in \Lambda \subset \mathbf{Z}$. Suppose $g_k \equiv \phi | D_k : D_k \to \mathbf{R}^n$ is a diffeomorphism for all $k \in \Lambda$. Then $\sum_{k\in\Lambda} J_k =$ constant, where J_k is the Jacobian determinant of g_k^{-1}.

310. Michael T. Dagg (294641 Wynne, Department of Corrections, Huntsville, TX 77349). Has it been proved by elementary means that Haar measure is completion regular?

Responses

The editor would like to thank all those who sent in replies.

288. (Vol. 30, p. 759, November 1983, Seymour Kass) The inequality $|a+b|^2 \le (1+c)\cdot|a|^2 + (1+1/c)\cdot|b|^2$ once more (cf. earlier responses: (1) Notices Amer. Math. Soc. **31** (1984), 164; (2) ibid. **31** (1984), 282). **Reply:** The inequality generalizes to: For $z_1,\ldots,z_k$ complex, $\lambda_1,\ldots,\lambda_k > 0$ with $\sum\lambda_i = 1$, $p \ge 1$, one has $|\sum z_i|^p \le \sum \lambda_i^{1-p}\cdot|z_i|^p$, with equality for $p>1$ iff $z_i = \lambda_i \cdot c$ (for $p=1$ iff $z_i = |z_i|\cdot c$). This is an interesting and potentially useful version of the Hölder inequality. The inequality in the title was used by H. Bohr without proof or comment (Acta Math. **45** (1924), 78). The case $p=2$, k arbitrary, appears as a problem in J. W. Archbold, *Algebra*, Pitman, London, 1958, p. 75. The general inequality was discovered independently (for $p=2$), generalized to $p \ge 1$ (including the conditions for equality), and shown equivalent to the Hölder inequality by P. S. Schnare in 1978 (see (1)). It follows immediately from convexity of $|z|^p$ (including the conditions for equality (see (2); this is also essentially Schnare's proof)); this, together with the simple transformation to the Hölder inequality (for $z_i = a_i\cdot b_i \ne 0$ put $\lambda_i = |b_i|^q/\sum|b_i|^q$, $1/p + 1/q = 1$), seems a sensible way to establish the latter.

290. (Vol. 30, p. 759, November 1983, Albert A. Mullin) Composite Fermat and Mersenne numbers. **Reply:** There are in fact infinitely many composite Mersenne numbers. If p is a prime such that $2p+1$ is prime and $p \equiv 11 \pmod{12}$, then $2p+1$ divides $M_p = 2^p - 1$. Example: $p = 10000079$. (Contributed by A. Boneh)

303. (Vol. 31, p. 282, April 1984, Pavel G. Todorov) Can $(n-1)X^{n-2}+(n-2)X^{n-3}+\ldots+2X+1=0$ be solved by radicals (for $n \ge 7$)? **Reply:** The Galois group for $n = 7, 9, 10$ is the symmetric group S_{n-2}; for $n=8$ it is S_6 or S_5. Details available from the Queries column. (Contributed by W. Parry)

301. (Vol. 31, p. 282, April 1984, Bertram Ross) References to publications on Fractional Calculus. **Reply:** (1) See A. C. McBride, *Fractional calculus and integral transforms of generalized functions*, Pitman, Belmont, Calif., 1979. (2) For questions of

this sort one could well use MATHFILE (computer data base version of *Mathematical Reviews*); at present this covers the period ≥ 1973. Fractional calculus has no specific classification number, but "fractional derivatives and integrals" appears in 26A33. A quick search in MATHFILE, catching all occurrences of the term (but not in other languages!) in the title or review of the paper "Fractional Calculus" produced 57 citations. A search under 26A33 produced 195 citations. For the procedure one should consult one's library, or contact Ms. Taissa Kusma, Database Specialist at the AMS office. An example of a search follows. (Contributed by M. Kryzytski, J. R. Tucker, T. Kusma)

MATHFILE Search on "Fractional Calculus"
Using the BRS/After Dark System

[*Note*: Characters enclosed in boxes are those typed by the user, the others are typed by the system. Explanatory comments are enclosed in brackets.]

```
TYPE IN SEARCH TERMS
S1 -->  [FRACTIONAL CALCULUS OR PC26A33]
                          [PC = Primary Classification]
A1    115 DOCUMENTS FOUND
ENTER COMMAND  [S]                          [Search]
TYPE IN SEARCH TERMS
S2 -->  [SC26A33]  [Secondary Classification 26A33]
A2    120 DOCUMENTS FOUND
ENTER COMMAND  [S]
TYPE IN SEARCH TERMS
S3 -->  [1 OR 2]          [Union of sets 1 and 2*]
A3    211 DOCUMENTS FOUND*
              [SC 26A33 gives 96 additional citations]
ENTER COMMAND  [P]                          [Print]
ENTER SEARCH QUESTION NUMBER.  [1]
   [Fractional Calculus or PC26A33 (from S1 above)]
ENTER S, M, OR RETURN  [S]
                  [Short form-citation without review]
ENTER DOCUMENT NUMBER OR RANGE.  [1--2]
                          [The two most recent entries]

1
MR 84F:26010.
AU RAKESH-S-L.
                                        [AU = Author]
TI ON FRACTIONAL INTEGRATION OPERATORS.
                                        [TI = Title]
SO MATH. ED. (SIWAN) 16 (1982), NO. 3, 45--47..
                                        [SO = Source]

2
MR 84C:26013.
AU AL-BASSAM-M-A.
TI ON FRACTIONAL CALCULUS AND ITS APPLICATIONS
     TO THE THEORY OF ORDINARY DIFFERENTIAL
     EQUATIONS OF GENERALIZED ORDER.
SO DEKKER, NEW YORK, 1982.
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*A set is the Search/Answer grouping: for example, S1/A1 is one set.

Factorizations of $b^n \pm 1$, b = 2, 3, 5, 6, 7, 10, 11, 12 up to High Powers

John Brillhart, D. H. Lehmer, J. L. Selfridge, Bryant Tuckerman, and S. S. Wagstaff, Jr.

Every person interested in factorization has been waiting eagerly to see this book. Now and then during the past twenty or so years word has reached us about the so-called Cunningham Project, being carried out by a group of dedicated persons. No conceivable effort has been spared to make these factor tables as complete and as accurate as possible, even though their planned range surpasses the limits of what can be achieved by today's factorization algorithms and computers.

The book begins with some handy short tables for the factorizations of $2^n \pm 1$ and $10^n \pm 1$. Then follows a most readable historic account on the development of factorization methods and tools over the past years, covering 40 pages of text. The rest of the book is taken up by the Main Tables, giving all to date known factorizations of the numbers within the range set out for each of the tables.

And–best of all–update sheets containing brand new information found by the authors or communicated to the authors by other researchers are offered the owners of the book. One formal update, covering the period from autumn 1982, when the manuscript was sent to the printer, and to July 20, 1983, when the book was issued, is included in a pocket on the back inside cover. It contains such interesting factorizations as $2^{212}+1$, $2^{253}-1$, and $10^{64}+1$. After this, several "informal" sheets with further factorizations have been sent out, giving among others, the factors of $2^{211}-1$, $2^{251}-1$, and $10^{67}-1$.

– Hans Riesel,
Royal Institute & Technology, Stockholm

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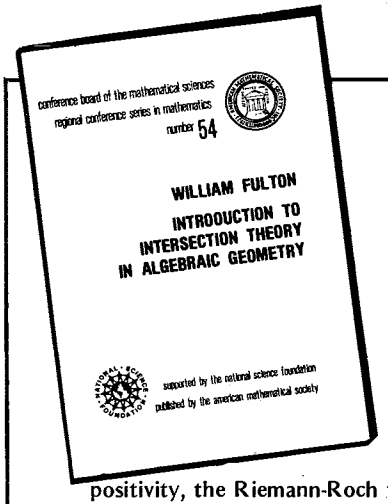

Introduction to Intersection Theory in Algebraic Geometry

William Fulton

Expository Lectures from the CBMS Regional Conference
George Mason University, June 27–July 1, 1983

"This book is a must! A broad survey of an old and important theory, it touches on many topics: numerous definitions of multiplicity, rational equivalence, Chern classes, degeneracy loci, excess and residual intersections, flag varieties and blowups, positivity, the Riemann-Roch theorems, and enumerative geometry. The book is basically pleasant and readable. It requires little technical background and whets the appetite. Most important of all, it introduces a revolutionary new approach, developed by the author in collaboration with R. MacPherson, which is technically simpler and cleaner, yet much more refined and general. The power is staggering; the promise, far-reaching!"

– Steven L. Kleiman, MIT

April 1984, vi + 82 pages (soft cover), List price $16, individuals $8, ordering code: CBMS/54N
Prepayment is required for all AMS publications. Order from AMS, P. O. Box 1571, Annex Station, Providence, RI 02901, or call toll free 800-556-7774 to charge with Visa or MasterCard.

Election Information

The ballots for election of members of the Council and Board of Trustees of the Society for 1985 will be mailed on or shortly after August 27, in order for members to receive their ballots well in advance of the November 10 deadline. Prior to casting their ballots members are urged to consult the following articles and sections of the Bylaws of the Society: article I, section 1; article II, sections 1, 2; article III, sections 1, 2, 3; article IV, sections 1, 2, 4; article VII, sections 1, 2, 5. The complete text of the Bylaws appears on pages 809–813 of the November 1983 issue of the *Notices*. A list of the members of the Council and Board of Trustees serving terms during 1984 appears in the **AMS Reports and Communications** section of this issue.

SUGGESTIONS FOR 1985 NOMINATIONS

Each year the members of the Society are given the opportunity to propose for nomination the names of those individuals they deem both qualified and responsive to their views and needs as part of the mathematical community. Candidates will be nominated by the Council to fill positions on the Council and Board of Trustees to replace those whose terms expire December 31, 1985. See the **AMS Reports and Communications** section of this issue for the list of current members of the Council and Board of Trustees. Members are requested to write their suggestions for such candidates in the appropriate spaces on the form in the next column.

REPLACEMENT BALLOTS

This year ballots for the AMS election will be mailed August 27, 1984 or within a day or two thereafter. The deadline for receipt of ballots in Providence is November 10, 1984.

There has been a small but recurring and distressing problem concerning members who state that they have not received ballots in the annual election. It occurs for several reasons, including failure of local delivery systems on university or corporate properties, failure of members to give timely notice of changes of address to the Providence office, failures of postal services, and other human errors.

To help alleviate this problem, the following replacement procedure has been devised: A member who has not received a ballot by October 10, 1984, or who has received a ballot but has accidentally spoiled it, may write after that date to the Secretary of the AMS, Post Office Box 6248, Providence, RI 02940, asking for a second ballot. The request should include the individual's member code and the address to which the replacement ballot should be sent. Immediately upon receipt of the request in the Providence office, a second ballot, which will be indistinguishable from the original, will be sent by first class mail. It must be returned in an inner envelope, which will be supplied, on the outside of which is the following statement to be signed by the member:

The ballot in this envelope is the only ballot that I am submitting in this election. I understand that if this statement is not correct then no ballot of mine will be counted.

_____
signature

Although a second ballot will be supplied on request and will be sent by first class mail, the deadline for receipt of ballots will not be extended to accommodate these special cases.

SUGGESTIONS FOR 1985 NOMINATIONS

Council and Board of Trustees

Vice Presidents (2)

_____

_____

Associate Secretaries (2)

_____

_____

Member of the *American Journal of Mathematics* Editorial Committee (1)

_____

Member of the *Bulletin* Editorial Committee (1)

_____

Member of the *Colloquium* Editorial Committee (1)

_____

Member of the *Mathematical Reviews* Editorial Committee (1)

_____

Member of the *Mathematical Surveys* Editorial Committee (1)

_____

Member of the *Mathematics of Computation* Editorial Committee (1)

_____

Members of the *Proceedings* Editorial Committee (2)

_____

_____

Members of the *Transactions* and *Memoirs* Editorial Committee (2)

_____

_____

Members of the Committee to Monitor Problems in Communication (2)

_____

_____

Members-at-large of the Council (5)

_____

_____

_____

_____

_____

Member of the Board of Trustees (1)

_____

The completed form should be addressed to AMS Nominating Committee, Post Office Box 6248, Providence, RI 02940, to arrive no later than **November 10, 1984**.

New Rules Concerning Abstracts
of Papers Submitted to the Society

Two changes have recently been ordered in the procedure for processing abstracts. These changes in procedure were made by the Executive Committee, the Council and the Board of Trustees.

A fifteen dollar fee for each abstract (except for abstracts of invited hour addresses) has been instituted to cover a portion of the expenses of preparing the abstract for publication in the journal *Abstracts of papers presented to the American Mathematical Society.* Abstracts should be accompanied by the payment of $15: send a check or money order, or use VISA or MASTERCARD, but do **not** send cash. If an abstract is received in Providence without payment, an invoice will be sent and the abstract will be set aside until payment is received. If payment is not received before the issue of the *Notices* containing the program of the meeting is typeset, the paper will not be listed in the program of the sessions.

Each person who is not a member of the Society but who wishes to present a paper at a meeting or by title, must henceforth be sponsored by a member, whose signature must appear on the abstract form. The only exceptions to this rule are invited hour speakers and invited speakers in Special Sessions; in the latter case such speakers will be considered to be sponsored by the organizer of the Special Session. Abstracts of papers, none of whose authors is a member of the Society, which are received in Providence without the signature of a sponsoring member will be returned to the submitter, who must bear the responsibility for locating a suitable sponsor.

New abstract forms have been prepared for use by mathematicians who present papers at AMS meetings or who submit abstracts for presentation "by title" in *Abstracts.* The new forms contain instructions covering these new procedures. They are being distributed to departments of mathematics in universities and colleges in the United States and Canada and are available on request from the Society's office in Providence. The new forms should be used as soon as possible, in order to avoid confusion and distress.

The new rules will be enforced beginning with by title abstracts to appear in the October 1984 issue and papers to be presented at the fall 1984 sectional meetings of the Society.

For copies of the new abstract forms, write to the Editorial Department, American Mathematical Society, Post Office Box 6248, Providence, Rhode Island 02940, U.S.A.

Eugene Meetings, August 14–19, 1984

Program

The August 1984 Joint Mathematics Meetings, including the 88th Summer Meeting of the AMS, the 64th Summer Meeting of the Mathematical Association of America, and the 1984 annual meeting of Pi Mu Epsilon, will be held August 16–19, 1984 (Thursday–Sunday), at the University of Oregon, Eugene. The meetings will be preceded by the AMS Short Course on August 14 and 15 (Tuesday and Wednesday), 1984. Sessions will take place on the campus of the University of Oregon, Eugene.

The members of the Local Arrangements Committee are Frank W. Anderson, Frank T. Birtel (ex-officio), Mary Fulton, William J. LeVeque (ex-officio), Henry Loeb, Jill McKenney, Theodore W. Palmer (publicity director), and Kenneth A. Ross (ex-officio, chairman).

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IMPORTANT DEADLINES	
AMS Abstracts,	
For consideration for special sessions	**Expired**
Of contributed papers	**Expired**
MAA Abstracts,	
Of contributed papers	**Expired**
Preregistration and Housing	**Expired**
Summer List of Applicants	**Expired**
Motions for AMS Business Meeting	**Expired**
Preregistration cancellations (50% refund)	**August 10**
Dues credit for nonmembers/students	**September 19**
Tours	**Expired**

88th Summer Meeting of the AMS August 16–19, 1984

Colloquium Lectures

There will be a series of four Colloquium Lectures presented by PAUL H. RABINOWITZ of the University of Wisconsin, Madison. The title of this lecture series is *Minimax methods in critical point theory and applications to differential equations.* The lectures will be given at 1:00 p.m. daily, Thursday through Sunday, August 16–19.

Steele Prizes

The 1984 Leroy P. Steele Prizes will be awarded at a session at 4:30 p.m. on Saturday, August 18.

Invited Addresses

By invitation of the Program Committee, there will be seven invited one-hour addresses. The list of speakers, their affiliations, the dates and times of their talks, and the titles follow:

RALPH L. COHEN, Stanford University, *Applications of homotopy theory to geometric problems*, 3:20 p.m. Friday; RALPH GREENBERG, University of Washington, Seattle, *Elliptic curves and L-functions*, 3:20 p.m. Sunday; YIANNIS N. MOSCHOVAKIS, University of California, Los Angeles, *Foundations of the theory of algorithms*, 2:05 p.m. Sunday; PAUL SEYMOUR, Bell Communications Research, Inc., *Generalizing Kuratowski's theorem*, 11:00 a.m. Thursday; CLIFFORD H. TAUBES, University of California, Berkeley, *Applications of gauge theories*, 3:20 p.m. Thursday; CHUU-LIAN TERNG, Northeastern University, *Higher codimension isoparametric submanifolds and their relation to the theory of Coxeter group*, 8:40 a.m. Saturday; DAVID A. VOGAN, JR., Massachusetts Institute of Technology, *Unitary representations of semisimple Lie groups*, 8:40 a.m. Thursday.

Paul H. Rabinowitz, Colloquium Lecturer

American Mathematical Society Short Course Series

Introductory Survey Lectures on

Environmental and Natural Resource Mathematics

Eugene, Oregon, August 14–15, 1984

The American Mathematical Society, in conjunction with its eighty-eighth summer meeting, will present a two day short course on *Environmental and Natural Resource Mathematics* on Tuesday and Wednesday, August 14 and 15, at the University of Oregon in Eugene. The program is being coordinated by Robert McKelvey of the University of Montana.

The field of environmental and resource management is a highly interdisciplinary one, where mathematical modeling analyses have proved to be extremely effective. From the beginnings of the subject, mathematical scientists have been able to play major, sometimes decisive, roles in its development. At the same time, the requirements of resource modeling applications have stimulated new initiatives in mathematical theory.

The purpose of the course is to provide participants with an overview of natural resource modeling and the kind of mathematical ideas which enter. In addition the course will provide an entré to the literature of the subject, for those who might wish to learn more, or even become actively involved in research.

Synopses of the talks and accompanying reading lists appeared in the April issue of the *Notices*. The course will consist of six 75 minute survey lectures, and a final discussion session with audience participation. Richard Plant, a mathematician from the University of California, Davis, will lead off, discussing the role of mathematical models in integrated management of insect pests. Maureen Cropper, an economist from the University of Maryland, will describe recent theoretical work on decentralized management of environmental systems. Geoffrey Heal, resource economist from Columbia University, will introduce some of the classical issues, of equity and economic efficiency, in the management of an exhaustible resource such as oil. Colin Clark of the Applied Mathematics Institute of the University of British Columbia, will examine models of renewable resources, especially marine fisheries, and will discuss the effect of fluctuating environments and incomplete information. Frank Clarke, of the Centre de Recherche de Mathématiques Appliquées, Université de Montréal, an authority on convex analysis and control theory, will explore some perspectives on optimal control theory that are particularly relevant to applications to natural resource modeling. Finally Graciela Chichilnisky, of Columbia University, will examine some macroeconomic aspects of trade in resources, a subject that relies heavily on game theory and topological methods. Dr. Chichilnisky holds doctorates in both mathematics and economics.

Environmental and natural resource modeling can draw on a wide variety of mathematical disciplines, such as optimization theory, differential equations (stability, qualitative theory, etc.), stochastic processes, variational calculus and control theory, game theory (including differential games), decision theory and risk analysis, etc., and can utilize some of the most sophisticated techniques that bear upon these disciplines (e.g. nonlinear functional analysis, topological degree theory, nonsmooth analysis, Ito calculus, etc.). Resource modeling also draws on much of modern economic theory, and on theoretical concepts from biology, physics and chemistry. It provides fascinating opportunities for the applied mathematician to expand his intellectual horizons.

The lectures in the short course should be accessible to advanced graduate students and professional mathematicians. No previous experience in resource modeling, nor familiarity with economic theory, will be assumed. It would be helpful to know a little about nonlinear optimization (e.g. the Kuhn-Tucker conditions), and to be familiar with the simplest ideas from optimal control theory (such as can be obtained quickly by reading about the maximum principle, e.g. in Colin Clark's book, *Mathematical Bioeconomics*). More detailed and specific references are listed by the lecturers in their synopses.

The short course is open to all who wish to participate upon payment of the registration fee. There are reduced fees for students and unemployed individuals. Please refer to the section titled **Registration at the Meetings** for details.

The short course was recommended by the Society's Committee on Employment and Educational Policy, whose members were Lida K. Barrett, Stefan A. Burr, Lisl Novak Gaal, Irwin Kra and Donald C. Rung (chairman). The short course series is under the direction of the CEEP Short Course Subcommittee, whose members were Stefan A. Burr (chairman), Lisl Novak Gaal, Cathleen S. Morawetz, Barbara L. Osofsky, and Philip D. Straffin, Jr.

Special Sessions

By invitation of the same committee, there will be six special sessions of selected twenty-minute papers. The topics of these special sessions, the names and affiliations of the mathematicians arranging them, a list of speakers, and dates and times are as follows:

Nonlinear Problems, FELIX E. BROWDER, University of Chicago, 8:00 a.m. and 2:10 p.m. Sunday. Henri Berestycki, Felix E. Browder, Frank H. Clarke, Michael Crandall, I. Ekeland and D. H. Sattinger.

Algebraic topology, RALPH COHEN, 8:00 a.m. and 1:00 p.m. Saturday. Paul Baum, Gunnar Carlsson, F. R. Cohen, Donald M. Davis, James F. Davis, Richard Lashof, M. Mahowald, R. James Milgram, Stephen Mitchell, F. P. Peterson, Stewart B. Priddy, Douglas C. Ravenel, and S. A. Wegmann.

Geometry of configurations, JACOB E. GOODMAN, CUNY, City College and RICHARD POLLACK, Courant Institute of the Mathematical Sciences, New York University, 8:00 a.m. and 1:00 p.m. Friday and 2:00 p.m. Saturday. N. Alon, David W. Barnette, Louis J. Billera, Peter Borwein, Andreas Dress, Paul H. Edelman, Herbert Edelsbrunner, Branko Grünbaum, Sten Hansen, David W. Henderson, László Lovász, W. O. J. Moser, George B. Purdy, Joseph O'Rourke, Joel Spencer, William Trotter, Jr., Neil L. White and Thomas Zaslavsky.

Computational complexity, LAŚZLÓ BABAI, Eótvós University, MARIA KLAWE, IBM Research, San Jose, and EUGENE M. LUKS, University of Oregon, Eugene, 8:30 a.m. and 1:00 p.m. Sunday. Lenore Blum, F. R. K. Chung, Michael L. Fredman, Katalin Friedl, Zvi Galil, Narendra K. Karmarkar, Richard M. Karp, Eugene L. Lawler, Silvio Micali, A. M. Odlyzko, John Reif, Michael Sipser, Andrew Yao, and Francis Yao.

Structures of graphs and matroids, PAUL SEYMOUR, 8:00 a.m. and 2:10 p.m. Thursday. Dan Archdeacon, Thomas Brylawski, K. Cameron, J. Edmonds, Curtis Greene, Jeff Kahn, Gil Kalai, Joseph P. S. Kung, Jim Lawrence, James G. Oxley, N. Roberston, Saul Stahl, and Klaus Truemper.

Applications of Gauge theories, CLIFFORD H. TAUBES, 10:00 a.m. and 2:10 p.m. Thursday and 9:40 a.m. Friday. Henri Berestycki, Ronald Fintushel, Frank J. Flaherty, Robert E. Gompf, Adam D. Helfer, James Isenberg, Shoshichi Kobayashi, Martin Lúbke, Richard Montgomery, Thomas H. Parker, and Ahmad Zandi.

May 15 was the deadline for submission of abstracts for consideration for inclusion in these special sessions.

Contributed Papers

There will be sessions for contributed papers on Thursday, Friday, Saturday and Sunday mornings and afternoons as needed. **The deadline for submission of abstracts of contributed papers was June 5. Late papers will not be accepted.**

Other AMS Sessions

Council Meeting

The Council of the Society will meet at 5:00 p.m. on Wednesday, August 15.

Business Meeting

The Business Meeting of the Society will take place immediately following the Steele Prize Session on Saturday, August 18. The secretary notes the following resolution of the Council: Each person who attends a Business Meeting of the Society shall be willing and able to identify himself as a member of the Society. In further explanation, it is noted that *each person who is to vote at a meeting is thereby identifying himself as and claiming to be a member of the American Mathematical Society.* For additional information on the Business Meeting, please refer to the box titled Committee on the Agenda for Business Meetings.

64th Summer Meeting of the MAA August 16–19, 1984

Hedrick Lectures

The 33rd Earle Raymond Hedrick Lectures will be given by NEIL J. A. SLOANE of AT&T Bell Laboratories. The title of this series of

Committee on the Agenda for Business Meetings

The Society has a Committee on the Agenda for Business Meetings. The purpose is to make Business Meetings orderly and effective. The committee does not have legal or administrative power. It is intended that the committee consider what may be called "quasi-political" motions. The committee has several possible courses of action on a proposed motion, including but not restricted to

(a) doing nothing;

(b) conferring with supporters and opponents to arrive at a mutually accepted amended version to be circulated in advance of the meeting;

(c) recommending and planning a format for debate to suggest to a Business Meeting;

(d) recommending referral to a committee;

(e) recommending debate followed by referral to a committee.

There is no mechanism that requires automatic submission of a motion to the committee. However, if a motion has not been submitted through the committee, it may be thought reasonable by a Business Meeting to refer it rather than to act on it without benefit of the advice of the committee.

The committee consists of Everett Pitcher (chairman), Marian B. Pour-El, David A. Sanchez, and Guido L. Weiss.

In order that a motion for the Business Meeting of August 18, 1984, receive the service offered by the committee in the most effective manner, it should have been in the hands of the secretary by July 18, 1984.

Everett Pitcher, Secretary

three lectures is *Lattices, sphere packings and applications.* These lectures will be given at 11:00 a.m. on Friday, Saturday, and Sunday, August 17–19.

Invited Addresses

There will be seven invited fifty-minute addresses. The list of speakers, their affiliations, dates and times of their talks, and the titles follow:

PETER J. HILTON, SUNY, Center at Binghamton, *How to fold polygons and do number theory, Part* II, 10:00 a.m. Sunday.

ROBERT I. JEWETT, Western Washington State University, *Applications of geometry to the social sciences,* 1:00 p.m. Sunday.

JEAN J. PEDERSEN, University of Santa Clara, *How to fold polygons and do number theory, Part* I, 9:00 a.m. Sunday.

CARL POMERANCE, University of Georgia, Athens, and Bell Communications Research, Inc., *How to factor an integer,* 1:00 p.m. Saturday.

CONSTANCE REID, San Francisco, *Mathematicians without mathematics,* 2:15 p.m. Friday.

DAVID P. ROSELLE, Virginia Polytechnic Institute and State University, *Combinatorial problems with surprising solutions,* 2:15 p.m. Thursday.

RONALD J. STERN, University of Utah, *Instantons and the topology of 4-manifolds,* 8:40 a.m. Friday.

Minicourses

Eight Minicourses are being offered by MAA. The names and affiliations of the organizers, the topics, the dates and times of their meetings, and the enrollment limitations of each are as follows:

Minicourse #1: *The intersection of mathematics and statistics* is being organized by THOMAS R. KNAPP, University of Rochester, and will be given from 8:00 a.m. to 10:50 a.m. on Friday and Saturday, August 17 and 18. Total enrollment for this Minicourse is limited to 30 persons. This course will focus on the incorporation of crucial statistical concepts into the mathematics curriculum, with particular emphasis on the last two years of secondary school and the first two years of college. There will be two three-hour sessions featuring small-group exercises and discussions of issues such as how much descriptive statistics to include, where you stop with probability, estimation vs. hypothesis testing, and the proper roles for computers and derivations.

Minicourse #2: *Applications of probability theory to the analysis and design of computer systems* is being organized by ROBERT GEIST, Clemson University, and KISHOR TRIVEDI, Duke University, and will be given from 8:40 a.m. to 10:40 a.m. on Saturday and Sunday, August 18 and 19. Total enrollment for this Minicourse is limited to 80 persons. The course is designed to provide the professional mathematician, who has a knowledge of elementary probability theory, with the fundamental tools necessary to independently investigate the configuration design of computer systems. Most examples will be suitable for use in the senior undergraduate curriculum, but extensions to current questions will also be explored. The material will be presented in four fifty-minute lecture sessions titled *Fundamental concepts, performance evaluation, reliability evaluation,* and *optimization.*

Minicourse #3: *Introductory computer science* is being organized by J. ARTHUR SEEBACH, St. Olaf College, and will be given from 2:15 p.m. to 4:15 p.m. on Friday and Saturday, August 17 and 18. Total enrollment for this Minicourse is limited to 30 persons. This Minicourse will present a number of the most central concepts of the conceptual core of the 1978 Association for Computing Machinery recommended courses in machine organization and data structures. The key structural or logical issues will be presented for mathematicians, starting with the use of binary arithmetic to represent the actual state of a computer. Next the course will introduce the representation and manipulation of data. The latter part of the Minicourse will discuss what is involved in more complex and higher-level organization of data and instructions. This will include several important data structures and the concepts of assemblers and operating systems. In addition, if time and the interest of the audience permit, the course might close with a brief foray into programming languages or input/output techniques. This is not a programming course nor is a programming background expected. Binary modular arithmetic, intuitive logic, and curiosity about what all the fuss and fancy jargon are about are the appropriate tools for this course.

Minicourse #4: (A COMET Minicourse) *Teacher in-service programs* is being organized by EUGENE A. MAIER, Mathematics Learning Center and Portland State University, and will be given from 8:00 a.m. to 10:50 a.m. and from 2:15 p.m. to 4:15 p.m. on Friday, August 17. Total enrollment for this Minicourse is limited to 80 persons. Mathematicians are becoming more aware of the responsibility of the mathematics community for developing programs to improve mathematics teaching at all levels in the schools. The CUPM Panel on Continuing Mathematical Education of Teachers (COMET) is sponsoring this minicourse for mathematicians who are interested in designing quality in-service programs. Mathematicians with no prior involvement in "math education" are especially welcome. The course will investigate strategies and procedures for offering continuing education that serves to increase teachers' competence and confidence in teaching mathematics. Topics discussed will include: types of programs, funding, judging needs and interests of teachers, program design and selection of content, instructional approaches, examples of exemplary programs, and reflections of a mathematician as a mathematics educator.

Minicourse #5: *Pascal for mathematicians* is being organized by HARLEY FLANDERS, Florida Atlantic University, and will be given from 5:00 p.m. to 7:00 p.m. on Thursday, August 16, and from 6:15 p.m. to 8:15 p.m. on Saturday, August 18. Total enrollment for this Minicourse is limited to 40 persons. This is a four-hour, self-contained introduction to computer programming in the programming language Pascal. No previous programming experience is expected. The language will be presented through a sequence of graded examples. As far as possible, the examples will solve the kinds of problems that interest scientists and mathematicians rather than data organizers. Some program listings and other material will be

handed out, and many programs will be run on a demonstration computer. However, the course will be hands-off rather than hands-on, since the main purpose is to teach Pascal, not how to communicate with a particular machine. (References: 1. K. Jensen & N. Wirth, *Pascal User Manual and Report*, Springer-Verlag, 1978; and 2. H. Flanders, *Scientific Pascal*, Reston Publishing Co., 1984.)

Minicourse #6: *Introduction to computer graphics* is being organized by JOAN WYZKOWSKI, Bradley University, and will be given from 8:40 a.m. to 10:40 a.m. and 2:15 p.m. to 4:15 p.m. on Sunday, August 19. Total enrollment for this Minicourse is limited to 30 persons. Graphs and illustrations of geometrical objects are useful tools in the teaching of mathematics. Computer graphics simplifies the production of these teaching aids. This Minicourse will present some of the mathematical techniques used to produce realistic pictures on graphics terminals. Emphasis will be on the use of these techniques to complement mathematics instruction. Some of the topics to be discussed are curve and surface sketching, 2D and 3D transformations, perspective drawing, and hidden line removal. Since personal computers will be available for demonstrations and in-class implementations, programming experience is necessary.

Minicourse #7: *Discrete algorithmic mathematics* is being organized by STEPHEN B. MAURER, Swarthmore College and Alfred P. Sloan Foundation, and will be given from 9:00 a.m. to 11:30 a.m. and from 7:30 p.m. to 9:30 p.m. on Thursday, August 16. Total enrollment for this Minicourse is limited to 80 persons. The organizer will present his ideas on how to give a freshman-sophomore mainstream discrete mathematics course which is neither "finite math" nor "discrete structures" and which highlights the algorithmic point of view. He will discuss how to glue the course together using induction/iteration/recursion; how to avoid the Scylla of dull play with definitions and the Charybdis of too many subtle proofs; how to make the course valuable to all students, not just computer science students; and how you don't have to be an expert in combinatorics or computer science to teach it, because it is based on ideas all mathematicians are familiar with in other contexts.

Minicourse #8: *Microcomputer software in mathematics instruction* is being organized by ROY E. MYERS, Pennsylvania State University, New Kensington, and will be given from 10:00 a.m. to noon and 2:15 p.m. to 4:15 p.m. on Thursday, August 16. If necessary, Minicourse #8 will also be given from 7:15 p.m. to 9:15 p.m. on Thursday, August 16 and from 8:30 p.m. to 10:30 p.m. on Saturday, August 18. Total enrollment for each Minicourse is limited to 30 persons. A wide variety of instructional software is becoming available for use with microcomputers. It varies in nature, including drill and practice, tutorial, and materials for use as lecture aids. Software is available for use in courses from introductory algebra through calculus, statistics, differential equations, and linear algebra. In this Minicourse, various types of software will be demonstrated, and issues relating to their uses will be discussed. It is planned that a large variety of software will be available and that Minicourse participants will have the opportunity to work with the software on microcomputers.

The Minicourses are open only to persons who have registered for the Joint Mathematics Meetings and paid the Joint Meetings registration fee.

The Minicourses have separate registration fees of $20 each. This fee entitles the registrant to attend all sessions of the Minicourse for which he/she has registered. Please note in the descriptions above the dates and times when these Minicourses meet. Participants are limited to two Minicourses each. It is advised that alternate choices be given in the event the first and/or second choice Minicourses are full. Payment of the fee(s) must be made to the Minicourse Cashier at the meeting registration desk in Eugene two working hours prior to the beginning of the Minicourse or the reservation will be relinquished to someone on the waiting list. When making payment, the participant should present the confirmation to the Minicourse Cashier. "Standby" reservation confirmations will be issued to participants whose preregistration was received after the Minicourse was filled. These individuals should check with the Minicourse Cashier one working hour prior to the Minicourse to see if any openings have occurred.

Contributed Papers

Papers are being accepted on four topics in collegiate mathematics for presentation in contributed paper sessions at the MAA Summer Meeting in Eugene. These sessions will be held on Thursday morning and afternoon and Friday morning. The topics are:

- Precollege, college, and remedial instruction–common concerns (Anneli Lax, Courant Institute of the Mathematical Sciences, New York University, Session Leader)
- Visual mathematics in the undergraduate curriculum (Martin E. Flashman, Humboldt State University, Session Leader)
- Motivating teaching ideas that do not compromise mathematics: Presentations, examples, or applications (Larry Runyan, Shoreline Community College, Session Leader)
- Use of computers in upper division mathematics courses (Ronald H. Wenger, University of Delaware, Session Leader)

Presentations are normally limited to ten minutes, although selected contributors may be given up to twenty minutes.

Individuals wishing to submit papers for any of these sessions in Eugene should have sent the following information to the MAA Washington office (1529 Eighteenth Street, NW, Washington, DC 20036) **before May 15, 1984**.

1. Title
2. Intended session
3. A one-paragraph abstract (for distribution at the meeting)
4. A one-page outline of the presentation
5. A list of special equipment required for the presentation (e.g., computer, film projector, videotape player).

Late papers will not be accepted.

This information will be sent to session leaders who will arrange for refereeing. Selection of papers will have been announced by July 1, 1984.

Other MAA Sessions

The Panel on Curriculum at Two-Year Colleges will hold a session from 2:10 p.m. to 4:20 p.m. on Saturday, August 18. The first hour will be devoted to a presentation of the panel's investigations and the second hour will be an open forum during which reactions and suggestions from the audience will be encouraged. The moderator is RONALD M. DAVIS, Northern Virginia Community College.

A one-hour presentation of *Challenge of the unknown*, an American Association for the Advancement of Science project to help middle school mathematics teachers present quantitative problem-solving in the context of interesting film episodes, will be held on Saturday, August 18 at 2:15 p.m.

The schedule for the MAA Film Program on Thursday evening, August 16, can be found in the timetable.

Business Meeting

The Business Meeting of the MAA will take place at 4:35 p.m. on Friday, August 17 at which the 1984 Carl B. Allendoerfer, Lester R. Ford, and George Pólya Awards for expository writing will be presented. Awards of Certificates for Meritorious Service will be announced. This meeting is open to all members of the Association.

Board of Governors

The MAA Board of Governors' will meet at 9:00 a.m. on Wednesday, August 15. This meeting is open to all members of the Association.

Section Officers

The Section Officers' Annual Meeting will take place at 3:30 p.m. on Thursday, August 16.

Banquet for 25-year Members

The MAA is planning its ninth annual banquet for individuals who have been members of the Association for twenty-five years or more. The banquet will take place at 6:15 p.m. on Saturday evening, August 18, in Gerlinger Lounge. Part of the program will be a special tribute to G. BALEY PRICE. Dinner will be served at 7:00 p.m.; the menu is as follows: soup, stuffed beef tenderloin, asparagus with Hollandaise sauce, herbed rice, marinated vegetable salad, Devonshire cream with raspberries, rolls and coffee. Dinner will be preceded by a reception.

Please note that all tickets for this banquet should have been purchased through preregistration.

Joint AMS-MAA Sessions

By invitation of the AMS-MAA Joint Program Committee (Jeanne L. Agnew, Melvin Hochster, Robion C. Kirby (chairman), Roy W. Ryden), the following speakers will address the joint meeting of the AMS and MAA on the history and development of mathematics. The names of the speakers, their affiliations, the dates and times of their talks, and the area of the subject they will address follow:

RAOUL H. BOTT, Harvard University, *Topology*, 9:45 a.m. Saturday; PHILIP J. DAVIS, Brown University, *Mathematics and rhetoric*, 9:45 a.m. Thursday; and JUDITH V. GRABINER, California State University, Dominguez Hills, *Controversies in artificial intelligence: A historian's perspective*, 9:45 a.m. Friday.

ACTIVITIES OF OTHER ORGANIZATIONS

Association for Women in Mathematics. The AWM Membership meeting will run from 10:00 a.m. to 10:30 a.m. on Friday, August 17. KAY GILLILAND of EQUALS at the University of California, Berkeley, will speak at 9:00 a.m. on Friday, August 17, on *Closing the gender gap in school mathematics*, a discussion will follow. The AWM Party will follow the Salmon Bake on Friday, August 17.

Pi Mu Epsilon (IIME) will hold its annual meeting on Friday and Saturday, August 17 and 18. The J. Sutherland Frame Lecture will be given by JOHN L. KELLEY, University of California, Berkeley, 8:30 p.m., on Saturday, August 18. The title of his lecture is *The concept of plane area.*

OTHER EVENTS OF INTEREST

Book Sales

Books published by the AMS and MAA will be sold for cash prices somewhat below the usual prices when these same books are sold by mail. **These discounts will be available only to registered participants wearing the official meeting badge.** VISA and MASTERCARD credit cards will be accepted for book sale purchases at the meeting. The book sales will be open the same days and hours as the exhibits.

Exhibits

The book and educational media exhibits will be open from 1:00 to 5:00 p.m. on Thursday, August 16 and from 8:30 a.m. to 4:30 p.m. on Friday and Saturday, August 17 and 18. All participants are encouraged to visit the exhibits during the meeting.

MATHFILE

The online MR database MATHFILE will be shown in the exhibit area during regular exhibit hours. Information published in *Mathematical Reviews* since 1973 can be located by the computer in seconds. A printout of results is ready in minutes.

MATHFILE can now be accessed on two inexpensive evening systems especially designed for users of personal computers. BRS/After Dark and now DIALOG's Knowledge Index are offering MATHFILE in addition to many other databases. Knowledge Index requires no monthly minimum and includes 2 hours of free introductory search time with the initial fee of $35. Both systems use simplified command languages, but differ in price and in the software used. BRS/After Dark is menu-driven, Knowledge Index is not.

Petition Table

At the request of the AMS Committee on Human Rights of Mathematicians, a table will be made available in the meeting registration area at which petitions on behalf of named individual mathematicians suffering from human rights violations may be displayed and signed by meeting participants acting in their individual capacities.

Signs of moderate size may be displayed at the table, but must not represent that the case of the individual in question is backed by the Committee on Human Rights unless it has, in fact, so voted. Volunteers may be present at the table to provide information on individual cases, but notice must be sent at least seven (7) days in advance of the meeting to the Meetings Department in Providence (telephone 401-272-9500). Since space is limited, it may also be necessary to limit the number of volunteers present at the table at any one time. The Committee on Human Rights may delegate a person to be present at the table at any or all times, taking precedence over other volunteers.

Any material which is not a petition (e.g., advertisements, résumés) will be removed by the staff. **When registration closes, any material on the table will be discarded, so individuals placing petitions on the table should be sure to remove them prior to the close of registration.**

Although the evening services are designed for personal users, an academic department can also subscribe at the same low prices. Both systems will be demonstrated during exhibit hours.

MATHFILE is searched in libraries on the main systems of DIALOG and BRS, and is also available from the European Space Agency–Information Retrieval Service (ESA–IRS).

The MATHFILE User's Guide will be available for inspection at the booth and can be purchased at the AMS book sale.

For those interested in obtaining more information on the vendors' services, the toll-free numbers are:

BRS: 800-833-4707; in New York 518-783-1161.

DIALOG: 800-227-1927; in California 800-982-3810.

Summer List of Applicants

At the direction of the AMS-MAA-SIAM Committee on Employment Opportunities, which is charged with operation of the Employment Register and with the publication of *Employment Information in the Mathematical Sciences*, the Society will publish a Summer List of mathematical scientists seeking employment for distribution at the Eugene meeting.

Copies of the 1984 summer list will be available at the Transparencies section of the registration desk for $3. Following the meeting, they may be purchased from the AMS office in Providence for $5. This list should prove useful to employers who have last-minute openings in the latter part of the summer or in the fall.

Instead of an Employment Register at the Summer Meeting in Eugene, there will be an opportunity for posting of both applicant résumé forms and employers' announcements of open positions in or near the main meeting registration area. There will be no special room set aside for interviews. No provisions will be made by the Society for interviews: arrangements will be the responsibility of each employer and applicant. Messages may be left in the message box located in the registration area.

Special applicant and employer forms will be available at the Transparencies section of the registration desk both for applicants to post résumés and for employers to post forms announcing positions.

Applicants who submit an applicant form, but do not plan to attend the meeting, will appear on the printed list only. There is no provision made for posting résumés for participants who do not attend the meeting.

ACCOMMODATIONS

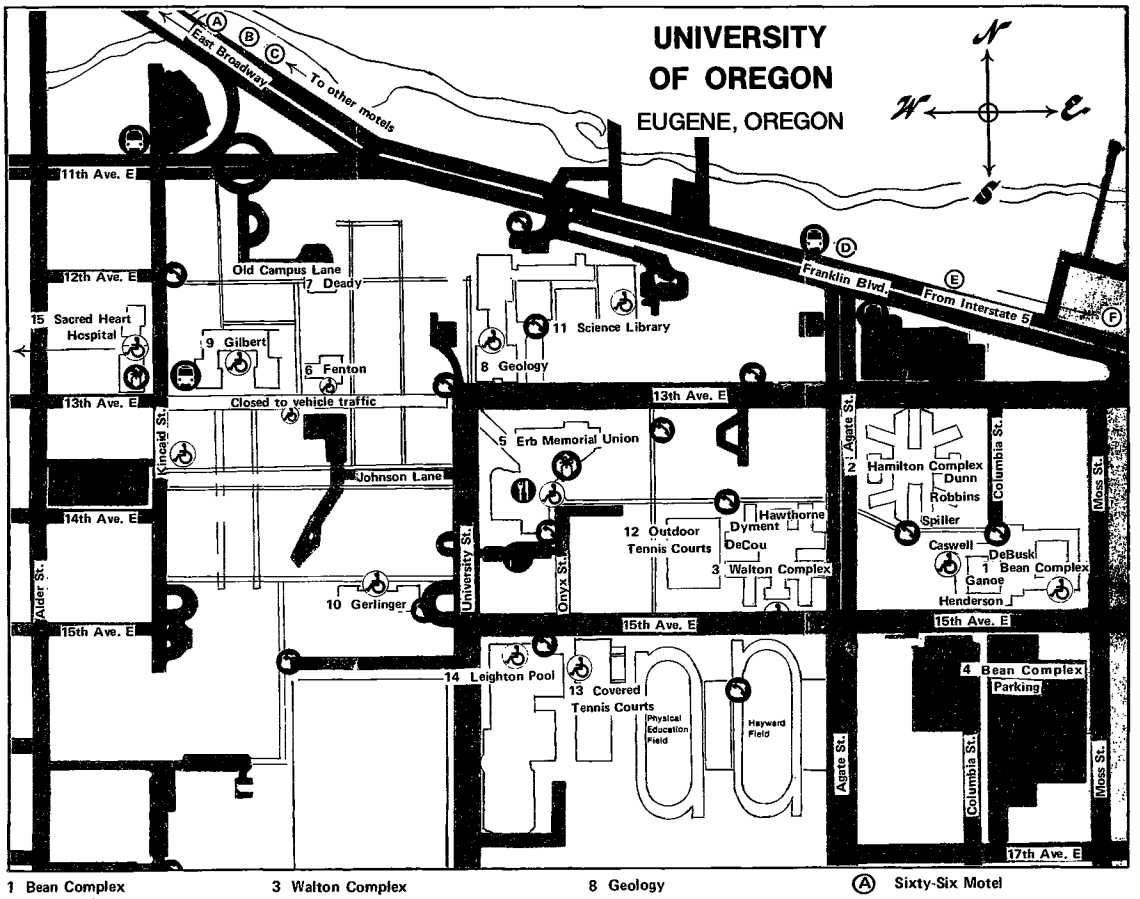
University Housing

Participants in the Joint Mathematics Meetings will occupy residence hall rooms at the University of Oregon during the period of August 13 through 19 only. A very limited number of rooms will be available for those who did not preregister.

Participants who requested housing on the University of Oregon campus during the meetings will be assigned to the Bean, Hamilton and Walton Complexes. (Please refer to the section below titled **Room and Board Rates**.)

Families with children under the age of two will not be allowed to stay in the dormitories. Children between the ages of two and four may stay in the dormitories but must occupy a bed at the adult rate. Meals for children in this category are free. Only two persons will be allowed in each room. The university neither provides cots nor allows sleeping bags. Because the university residence hall facilities are not suitable for children under the age of two, participants with very young children are advised to consider the various motels in the area. (See section on **Motel Accommodations** below.)

Dormitories at the University of Oregon are not air-conditioned and have no elevators. The buildings have either two or four floors; porters will be on hand to assist participants with their luggage during peak hours. Room assignments will be made on ground or lower floors for those who requested this in writing on the housing form. Each dormitory room contains two beds, desks with lamps and chairs, bookcases, and closets with approximately five hangers. Each bed will be prepared in advance with sheets, a blanket, pillow, and pillowcase for the duration of the conference, and one towel and washcloth will be supplied daily, as well as soap and drinking glasses. Bathrooms (one on each floor) will be appropriately identified by gender. For this reason, it may be necessary for one sex or the other to use the rest rooms on either the floor above or below the one



1 Bean Complex
- Caswell
- DeBusk
- Ganoe
- Henderson Hall (check-in)

2 Hamilton Complex (cafeteria)
- Dunn
- Robbins
- Spiller

3 Walton Complex
- DeCou
- Dyment
- Hawthorne

4 Bean Complex Parking

5 Erb Memorial Union

6 Fenton
- Mathematics Library

7 Deady

8 Geology

9 Gilbert

10 Gerlinger

11 Science Library

12 Outdoor Tennis Courts

13 Covered Tennis Courts

14 Leighton Pool

Ⓐ Sixty-Six Motel

Ⓑ City Center Lodge

Ⓒ Continental Motel

Ⓓ New Oregon Motel

Ⓔ Greentree Motel

Ⓕ Angus Inn

on which their rooms are located. There is limited privacy in the bathrooms since the shower stalls are separated only by shower curtains. The dressing rooms are in a recessed area; however, there are no doors. Participants may wish to bring dressing gowns to ensure privacy in going from the dressing area to the showers.

No pets are allowed in the residence halls. Alcoholic beverages are allowed provided the 21 year age limit is observed. There will be no telephone service in any of the university accommodations; however, there are pay telephones and campus phones in the public areas.

Check-In Location and Times

The check-in desk for all residence halls is located on the ground floor of **Henderson Hall in the Bean Complex on 15th Street between Agate and Moss Streets**. Those arriving via I-5 should exit onto Franklin Boulevard, follow signs to the university onto Agate Street (south), cross 13th Street, and continue to 15th Street where a left turn will take them to Henderson Hall. Participants may use the unloading area next to Henderson Hall on Agate Street while checking in and then move their vehicles to the campus parking lot at 15th and Moss Streets. There are no parking fees and no stickers are required for cars.

Participants should ensure that they arrive at the university during the hours the check-in desk is open. Anyone arriving after these hours may not be able to obtain keys to his or her room and may have to seek accommodations elsewhere for the night. The check-in desk will be in operation daily from 8:00 a.m. to 5:00 p.m. on August 14, 17, 18, and 19. On August 15 and 16 the desk will be in operation from 8:00 a.m. to 9:00 p.m.

At time of check-in, participants will receive two keys which will open doors to their rooms as well as the outside and basement doors. **Although there is no deposit required for keys, a $13 charge will be imposed for keys that are lost or not returned.**

Room and Board Rates

The following rates apply for residence hall accommodations at the University of Oregon. Please note there is no room or food tax applicable.

Adults (16 years of age and up) includes breakfast and lunch

Singles	$23.50
Doubles (per person)	$18.50

Children (5 years of age through 15) includes breakfast and lunch

Singles	$20.50
Doubles (per person)	$15.50

Children (over 2 years of age and under 5) bed only–meals free $11.50

Food Services

Breakfast and lunch for those participants staying in the residence halls will be served in Hamilton Cafeteria located in the block bordered by 13th, 15th, Agate, and Columbia Streets. Meal tickets will be issued to each preregistered individual (and family members, if applicable) at time of check-in. Dining hours are:

Breakfast	6:45 a.m. to 10:00 a.m.
Lunch	10:30 a.m. to 1:30 p.m.
Dinner	4:00 p.m. to 6:30 p.m.

Meals in the cafeteria are generous. A typical breakfast would be fruit juices, canned or fresh fruit, cold or hot cereals, scrambled or fried eggs, waffles, cottage cheese, assorted condiments, and assorted hot and cold beverages. Lunch would typically be soup, seafood casserole, grilled sandwiches and a meatless sandwich or plate, tossed green salad with assorted dressings, cookies or coffee cake and various hot and cold drinks. It will be possible for a limited number of those staying in the residence halls to purchase dinner in the Hamilton Cafeteria on a cash basis.

Fountain Court Cafe in Erb Memorial Union will be open from 7:00 a.m. to 4:00 p.m. daily. Food, offered cafeteria-style, may be purchased on a cash basis. Hours of operation are:

7:00 a.m. to 10:30 a.m.	Breakfast
10:30 a.m. to 2:00 p.m.	Soups, salads, hamburgers, etc.
2:00 p.m. to 4:00 p.m.	Soft drinks, snacks

For those participants who wish to eat off-campus, there is a variety of restaurants within walking distance of the university. Other restaurants in the area may be reached by using public or private transportation. A detailed restaurant list will be available at the meeting.

Motel Accommodations

Blocks of rooms have been set aside for use by participants at the motels listed below. All are located within walking distance, on East Broadway and Franklin Boulevard. East Broadway merges with Franklin Boulevard; this main area borders the campus on the north side. **These motels would be ideal accommodations for families, since there are no restrictions regarding children.**

The rates listed below are subject to a 6 percent tax. The following codes apply: AC = Air Conditioned; CL = Cocktail Lounge; FP = Free Parking; RT = Restaurant; SP = Swimming Pool; TV = Television. In all cases, "Single" refers to one person in one bed; "Double" refers to two persons in one bed; "Twin" refers to two persons in two beds. A rollaway cot for an extra person can be added to double or twin rooms only in some of the motels. The age limit for children below which there is no charge, providing a cot is not required and they are in the same room as a parent, is shown in parenthesis on the same line as the charge for an extra person in the room.

Participants should make their own reservations early, directly with the motels, and should identify themselves as participants in the Joint Mathematics Meetings. Participants making motel reservations should be prepared to remit a one night's deposit

to the motel in order to guarantee their room reservation.

Angus Inn Motel (F on campus map)
2121 Franklin Boulevard–4 blocks from campus
Telephone: 503-342-1243

Singles	$24
Doubles	$28
Twin Queens	$28 (2 persons) $32 (3 persons) $36 (4 persons)
Cots	$ 4
Cribs	Free
Suites	$38–$50 (accommodating 6-8)

No charge for children using cribs.

AC, FP, SP, TV, sauna, jacuzzi, limited kitchenettes are available (no utensils provided)

Deposit and balance due may be paid by personal check (Canadian checks must be marked "Payable in U.S. funds"), travelers' check, or American Express, Carte Blanche, Diners Club, MASTERCARD, or VISA.

City Center Lodge (B on campus map)
476 East Broadway–4 blocks from campus
Telephone: 503-344-5233

Singles	$22
Doubles or Queens	$24
Twin Doubles	$26
Triples	$30 (2 beds)
Quads	$34 (2 beds)
Cribs	$ 4 (complete)

Children must occupy a crib or bed.

Maximum number of beds in room: 2

AC, FP, TV, SP (heated)

Deposit may be paid by personal check (Canadian checks must be marked "Payable in U.S. Funds"), American Express, Diners Club, MASTERCARD, VISA. Balance due must be paid by credit card.

Continental Motel (C on campus map)
390 East Broadway–4 blocks from campus
Telephone: 503-343-3376

Singles	$20
Doubles	$26 (also queen and king-sized beds)
Triples	$30 (2 or 3 beds; 3 persons)
Quads	$34 (2 or 3 beds; 4 persons)
Cots	$ 6
Port-a-cribs	$ 3 (complete)

No charge for children under two years of age.

AC, FP, SP, TV

Deposit may be paid by personal check (Canadian checks must be marked "Payable in U.S. funds") or travelers' check or American Express, Diners Club, MASTERCARD, VISA. Personal checks will be accepted for payment of balance due with credit card identification.

Greentree Motel (E on campus map)
1759 Franklin Boulevard–4 blocks from campus
Telephone: 503-485-2727

Singles	$36.50
Doubles	$44.50 (1 queen)
Twin doubles	$46.50 (2 queens)
Triples	$50.50 (2 queens) $53.50 (2 queens + cot, 3 persons)
Quads	$54.50 (2 queens; 4 persons)
Cots (6)	$ 7.00
Cribs (2)	Free (no linen provided)

No charge for children using cribs.

Maximum number of beds in room: 3

AC, SP, FP, CL, TV, RT, coffee shop, kitchenettes (must provide own utensils)

Deposit may be paid by personal check (Canadian checks must be marked "Payable in U.S. funds"), or travelers' check, or American Express, Amoco, Carte Blanche, Diners Club, MASTERCARD or VISA. Balance due must be paid by credit card.

New Oregon Motel (D on campus map)
1655 Franklin Boulevard–4 blocks from campus
Telephone: 503 683-3669

Singles	$40.50
Doubles/Twin doubles	$44.50
Triples	$48.50 (2 beds, 3 persons) $51.50 (3 beds, 3 persons)
Quads	$52.50 (2 beds, 4 persons)
Cots (10)	$ 7.00
Cribs (limited)	Free (no linen provided)

No charge for children using cribs.

Maximum number of beds in room: 3

Family units: $65.50 (2 bedrooms each with 1 or 2 queen-sized beds and connecting bath); maximum occupancy 6 or 7. AC, FP, SP (indoor), TV, sauna, jacuzzi, raquetball court, handicapped facilities

Deposit may be paid by personal check (Canadian checks must be marked "Payable in U.S. funds"), travelers' check or American Express, Amoco, Carte Blanche, Diners Club, MASTERCARD or VISA. Balance due must be paid by credit card.

Sixty-Six Motel (A on campus map)
755 East Broadway–8 blocks from campus
Telephone: 503-342-5041

Singles	$17.95
Doubles	$19.95
Twin doubles	$21.95 (2 beds, 2 persons)
Triples	$23.95 (2 beds, 3 persons)
Quads	$24.95 (2 beds, 4 persons)

There are no cots or cribs. No charge for children using sleeping bags; towel charge only. NOTE: One sleeping bag allowed per room.

AC, FP, TV

Deposit may be paid by personal check (Canadian checks must be marked "Payable in U.S. funds") or travelers' check or American Express, MASTERCARD or VISA. Balance due must be paid by credit card only.

Registration at the Meetings

Meeting preregistration and registration fees only partially cover expenses of holding meetings. All mathematicians who wish to attend sessions are expected to register, and should be prepared to show

TIMETABLE

EMU = Erb Memorial Union (Pacific Daylight Saving Time)

The final version of the Timetable and Program, including room assignments, will be distributed at the meeting.

AMERICAN MATHEMATICAL SOCIETY SHORT COURSE SERIES

TUESDAY, August 14	ENVIRONMENTAL AND NATURAL RESOURCE MATHEMATICS
9:00 a.m. - 4:00 p.m.	REGISTRATION (Short Course Only) Outside Gilbert Hall 138
10:30 a.m. - 10:45 a.m.	Introduction
10:45 a.m. - noon	Applications of mathematics in insect pest management Richard Plant
2:00 p.m. - 3:15 p.m.	Economic incentives for pollution control Maureen Cropper
3:15 p.m. - 3:45 p.m.	Break
3:45 p.m. - 5:00 p.m.	Classical issues in the management of exhaustible resources Geoffrey Heal
WEDNESDAY, August 15	
8:00 a.m. - 2:00 p.m.	REGISTRATION (Short Course Only) Outside Gilbert Hall 138
9:00 a.m. - 10:15 a.m.	Renewable resource management Colin Clark
10:15 a.m. - 10:45 a.m.	Break
10:45 a.m. - noon	Applying abstract control theory to concrete models Frank Clarke
2:00 p.m. - 3:15 p.m.	General equilibrium theory and the international trade in extractive resources Graciela Chichilnisky
3:15 p.m. - 3:45 p.m.	Break
3:45 p.m. - 4:45 p.m.	Panel Discussion: Mathematicians and natural resource modeling Robert McKelvey

JOINT MATHEMATICS MEETINGS

WEDNESDAY, August 15	American Mathematical Society	Mathematical Association of America
9:00 a.m. - 4:00 p.m.		BOARD OF GOVERNORS' MEETING
4:00 p.m. - 8:00 p.m.	REGISTRATION EMU 108-111	
5:00 p.m. - 10:00 p.m.	COUNCIL MEETING	

THURSDAY, August 16	AMS	MAA
	SPECIAL SESSION	
8:00 a.m. - 10:50 a.m.	Structures of graphs and matroids I	
8:00 a.m. - 4:30 p.m.	REGISTRATION EMU 108-111	
8:15 a.m. - 8:30 a.m.	WELCOME ADDRESS Paul Olum, President University of Oregon, Eugene	
8:40 a.m. - 9:40 a.m.	INVITED ADDRESS Unitary representations of semisimple Lie groups David A. Vogan, Jr.	
8:40 a.m. - noon		CONTRIBUTED PAPER SESSION Visual mathematics in the undergraduate curriculum Martin E. Flashman
8:40 a.m. - noon		CONTRIBUTED PAPER SESSION Precollege, college, and remedial instruction—common concerns Anneli Lax

their meeting badge, if so requested. The fees for Joint Meetings registration at the meeting (listed below) are 30 percent more than the preregistration fees.

Joint Mathematics Meetings

Member of AMS, MAA, IIME	$61
Emeritus Member of AMS, MAA	$15
Nonmember	$93
Student/Unemployed	$15

AMS Short Course

Student/Unemployed	$10
All Other Participants	$30
One-day Fee (Second Day Only)	$15

MAA Minicourses #1 through #8

All Participants	$20 each

Registration fees may be paid at the meetings in cash, by personal or traveler's checks, or by VISA or MASTERCARD credit card. Canadian checks must be marked for payment in U.S. funds.

There is no extra charge for members of the families of registered participants, except that all professional mathematicians who wish to attend sessions must register independently.

All **full-time** students currently working toward a degree or diploma qualify for the student registration fees, regardless of income.

The unemployed status refers to any person currently unemployed, actively seeking employment, and who is not a student. It is not intended to include any person who has voluntarily resigned or retired from his or her latest position.

Persons who qualify for emeritus membership in either the Society or the Association may register at the emeritus member rate. The emeritus status refers to any person who has been a member of the AMS or MAA for twenty years or more, and is retired on account of age from his or her latest position.

Nonmembers who register at the meetings and pay the $93 nonmember registration fee are entitled to a discount of the difference between the member registration fee of $61 and the nonmember registration fee of $93 as a $32 credit against dues in either the AMS or MAA or both, provided they apply for membership before September 19, 1984.

Nonmember students who register at the meetings and pay the $15 registration fee are entitled to a discount of the difference between the student preregistration fee of $12 and the registration fee of $15 as a $3 credit against dues in either the AMS or MAA or both, provided they apply for membership before September 19, 1984.

Nonmembers and nonmember students who thus qualify may apply for membership at the meetings, or by mail afterward up to the deadline.

Registration Dates, Times, and Locations

AMS Short Course
Outside Room 138, Gilbert Hall

Tuesday, August 14	9:00 a.m. to 4:00 p.m.
Wednesday, August 15	8:00 a.m. to 2:00 p.m.

Joint Mathematics Meetings
[and MAA Minicourses (until filled)]
Rooms 108 through 111, Erb Memorial Union

Wednesday, August 15	4:00 p.m. to 8:00 p.m.
Thursday, August 16	8:00 a.m. to 4:30 p.m.
Friday, August 17, and Saturday, August 18	8:30 a.m. to 4:30 p.m.

Assistance and Information Desk
Outside Ballroom, Erb Memorial Union

Sunday, August 19	8:30 a.m. to 1:30 p.m.

Please note that the Joint Mathematics Meetings registration desk **will not be open on Sunday, August 19**, and that the telephone message center will not be in operation that day. Other services provided during the meeting at the registration desk will also no longer be available (see section below on **Registration Desk Services**). There will, however, be a small desk set up outside the Ballroom in Erb Memorial Union, where local information will be available and where a staff member will provide limited assistance to participants. No registration or cash transactions will be possible at this desk.

Registration Desk Services

AMS/MAA Information

Information on the publications and activities of both organizations may be obtained at this section of the registration desk.

Assistance, Comments and Complaints

A log for registering participants' comments or complaints about the meeting is kept at the Transparencies section of the registration desk. All participants are encouraged to use this method of helping to improve future meetings. Comments on all phases of the meeting are welcome. If a written reply is desired, participants should furnish their name and address.

Participants with problems of an immediate nature requiring action at the meeting should see the meetings director, who will try to assist them.

Audio-Visual Assistance

A member of the AMS/MAA staff will be available to advise or consult with speakers on their audio-visual requirements.

Rooms where special sessions and contributed paper sessions will be held will be equipped with an overhead projector, screen, and blackboard.

Presenters of ten- or twenty-minute papers are strongly urged to use the overhead projector rather than the blackboard for their presentation in order to obtain maximum visibility by all members of the audience of the material being presented.

Baggage and Coat Check

Provision will be made for participants checking out of the residence halls or motels early to leave baggage in the registration area until leaving the campus.

TIMETABLE

EMU = Erb Memorial Union

THURSDAY, August 16	American Mathematical Society	Mathematical Association of America
9:00 a.m. - 11:30 a.m.		MINICOURSE #7 (Part A) Discrete algorithmic mathematics Stephen B. Maurer
	SESSION FOR CONTRIBUTED PAPERS	
9:00 a.m. - 12:10 p.m.	Geometry and topology	
9:45 a.m. - 10:45 a.m.	AMS-MAA INVITED ADDRESS Mathematics and rhetoric Philip J. Davis	
	SPECIAL SESSION	
10:00 a.m. - 11:50 a.m.	Applications of gauge theories I	
10:00 a.m. - noon		MINICOURSE #8 (Part A) Microcomputer software in mathematics instruction Roy E. Myers
11:00 a.m. - noon	INVITED ADDRESS Generalizing Kuratowski's theorem Paul Seymour	
1:00 p.m. - 2:00 p.m.	COLLOQUIUM LECTURE I Minimax methods in critical point theory and applications to differential equations Paul H. Rabinowitz	
1:00 p.m. - 5:00 p.m.	AMS BOOK SALE	MAA BOOK SALE
1:00 p.m. - 5:00 p.m.	EXHIBITS	
	SESSION FOR CONTRIBUTED PAPERS	
2:10 p.m. - 3:35 p.m.	Algebraic topology and manifolds	
	SPECIAL SESSIONS	
2:10 p.m. - 5:20 p.m.	Applications of gauge theories II	
2:10 p.m. - 5:30 p.m.	Structures of graphs and matroids II	
2:10 p.m. - 5:10 p.m.		CONTRIBUTED PAPER SESSION Motivating teaching ideas that do not compromise mathematics: Presentations, examples, or applications Larry Runyan
2:15 p.m. - 3:05 p.m.		INVITED ADDRESS Combinatorial problems with surprising solutions David P. Roselle
2:15 p.m. - 4:15 p.m.		MINICOURSE #8 (Part B) Microcomputer software in mathematics instruction Roy E. Myers
	SESSION FOR CONTRIBUTED PAPERS	
3:00 p.m. - 4:55 p.m.	Analysis I	
3:20 p.m. - 4:20 p.m.	INVITED ADDRESS Applications of gauge theories Clifford H. Taubes	
3:30 p.m. - 5:30 p.m.		SECTION OFFICERS' MEETING EMU Dad's Room
5:00 p.m. - 7:00 p.m.		MINICOURSE #5 (Part A) Pascal for mathematicians Harley Flanders

Check Cashing

The meeting cashier will cash personal or travelers' checks up to $50, upon presentation of the official meeting registration badge, provided there is enough cash on hand. Due to the increased use of credit cards, cash availability may be lower than at other meetings. It is strongly advised that participants bring travelers' checks which are honored by banks and most restaurants. Canadian checks must be marked for payment in U.S. funds.

Local Information

This section of the desk will be staffed by members of the Local Arrangements Committee and other volunteers from the Eugene mathematical community.

Lost and Found

See the meeting cashier during the meeting. After the meeting, all lost articles not claimed will be turned over to the Department of Mathematics.

Mail

All mail and telegrams for persons attending the meetings should be addressed to the participant, c/o Joint Mathematics Meetings, Department of Mathematics, University of Oregon, Eugene, Oregon 97403. Mail and telegrams so addressed may be picked up at the mailbox in the registration area during the hours the registration desk is open. U.S. mail not picked up will be forwarded after the meeting to the mailing address given on the participant's registration record.

Personal Messages

Participants wishing to exchange messages during the meeting should use the mailbox mentioned above. Message pads and pencils are provided. It is regretted that such messages left in the box cannot be forwarded to participants after the meeting is over.

Telephone Messages

A telephone message center will be located in the registration area to receive incoming calls for participants. The center will be open from August 15 through 18 only, during the hours that the Joint Mathematics Meetings registration desk is open. Messages will be taken and the name of any individual for whom a message has been received will be posted until the message has been picked up at the message center. The telephone number of the message center is 503-686-5599.

Transparencies

Speakers wishing to prepare transparencies in advance of their talk will find the necessary materials and copying machines at this section of the registration desk. A member of the staff will assist and advise speakers on the best procedures and methods for preparation of their material. There is a modest charge for these materials. **Please note that this service will be not be available on Sunday, August 19.**

Visual Index

An alphabetical list of registered participants, including local addresses, arrival and departure dates, is maintained in the registration area.

MISCELLANEOUS INFORMATION

Athletic Facilities

Participants may use the swimming pool on campus for a daily fee of $1. The pool is available from 7:00 a.m. to 8:00 a.m. and from noon to 1:30 p.m., Monday through Friday; from 6:00 p.m. to 7:30 p.m., Monday through Thursday; and from 2:00 p.m. to 4:00 p.m. on Saturday and Sunday. The Esslinger gym, which includes indoor handball, tennis, and racquetball courts, and weight room is open from 7:00 a.m. to 9:00 p.m., Monday through Friday. There is a nominal charge for the use of these facilities. Reservations are required for use of the indoor tennis courts. There is no charge for the use of the outdoor tennis courts; however, reservations for these courts cannot be made.

Book Store

The University Book Store is located at 13th and Kincaid at the west edge of campus. It will be open 8:30 a.m. to 5:30 p.m., Monday through Friday.

Camping and RV Facilities

Chalet Village, 7 miles west of Eugene. RV hook up. Blacktop with trees, Laundromat. $8/night. 503-747-8311. 205 South 54th, Springfield, Oregon 97478.

Diamond Hill RV Park, 15 miles north. Pool, store. $9 full hook up. 503-995-8050. 32917 Diamond Hill Drive, Harrisburg, Oregon 97446.

Eugene KOA. 7 miles north on I-5. Tents, full hook ups. $7–$12. 503-343-4832. 200 S. Stuart Way, Coburg, Oregon 97401.

Fern Ridge Shores Campground & Marina, 12 miles west of Eugene on Fern Ridge Lake. 300 unimproved tent sites. 20 hook ups with lights and water. Swim, water ski, sail, fish. Restrooms, food concession. 503-935-2030. 29652 Jeans Road, Veneta, Oregon 97487.

Sherwood Forest KOA, 8 miles south of Eugene. Shade trees, pool, jacuzzi. Tents, full hook ups. $8 and up. 503-895-4110. 298 East Oregon Avenue, Creswell, Oregon 97426.

Child Care

The EMU Child Care Center may be able to accommodate the needs of a few participants, provided they are contacted well in advance of the meeting. For more information, write to the University of Oregon Child Care and Development Center, 1511 Moss Street, Eugene, Oregon 97403, or call 503-686-4384. In addition, there will be a list of babysitters at the Local Information section of the registration desk.

Crib Rental

Cribs and rollaway beds can usually be arranged directly with one's hotel or motel. (Cribs and

TIMETABLE

EMU = Erb Memorial Union

THURSDAY, August 16	American Mathematical Society	MAA and Other Organizations
7:00 p.m. - 9:14 p.m.		MAA - FILM PROGRAM
7:00 p.m.		M. C. Escher: Geometries and impossible worlds
7:28 p.m.		Accidental nuclear war
7:38 p.m.		Regular homotopies in the plane, Part I
7:54 p.m.		Trio for three angles
8:04 p.m.		Area under a curve
8:20 p.m.		Flatland
8:34 p.m.		Curves of constant width
8:52 p.m.		Newton's equal areas
9:02 p.m.		An animated approach to fractions
7:00 p.m. - 10:00 p.m.		Pi Mu Epsilon - RECEPTION
7:30 p.m. - 9:30 p.m.		MAA - MINICOURSE #7 (Part B) Discrete algorithmic mathematics Stephen B. Maurer
8:00 p.m. - 10:00 p.m.	WINE TASTING	

FRIDAY, August 17	AMS	MAA and Other Organizations
	SPECIAL SESSION	
8:00 a.m. - 10:50 a.m.	Geometry of configurations I	
8:00 a.m. - 10:50 a.m.		MAA - MINICOURSE #1 (Part A) The intersection of mathematics and statistics Thomas R. Knapp
8:00 a.m. - 10:50 a.m.		MAA - MINICOURSE #4 (Part A) (A COMET Minicourse) Teacher in-service programs Eugene A. Maier
8:30 a.m. - 10:50 a.m.		MAA - CONTRIBUTED PAPER SESSION Use of computers in upper division mathematics courses Ronald H. Wenger
8:30 a.m. - 4:30 p.m.	REGISTRATION EMU 108-111	
8:30 a.m. - 4:30 p.m.	AMS BOOK SALE	MAA BOOK SALE
8:30 a.m. - 4:30 p.m.	EXHIBITS	
8:40 a.m. - 9:30 a.m.		MAA - INVITED ADDRESS Instantons and the topology of 4-manifolds Ronald J. Stern
9:00 a.m. - 9:50 a.m.		Association for Women in Mathematics ADDRESS AND DISCUSSION Closing the gender gap in school mathematics Kay Gilliland
	SESSION FOR CONTRIBUTED PAPERS	
9:00 a.m. - 10:25 a.m.	Differential equations	
	SPECIAL SESSION	
9:40 a.m. - 10:50 a.m.	Applications of gauge theories III	
9:45 a.m. - 10:45 a.m.	AMS-MAA INVITED ADDRESS Controversies in artificial intelligence: A historian's perspective Judith V. Grabiner	
10:00 a.m. - 10:30 a.m.		AWM - MEMBERSHIP MEETING

cots are not allowed in the university residence halls.) A limited number of cribs are available for rent at Franklin Boulevard Rent All, 4340 Franklin Boulevard (503-726-6517).

Handicapped

Some, but not all, of the residence halls and other facilities are accessible for the handicapped. Those handicapped persons with special requirements for on campus housing should have made this clear in writing when submitting the preregistration/housing form. Persons with special needs with regard to the scheduling of the sessions should write Kenneth A. Ross at the University of Oregon or telephone 503-686-4721 as soon as possible.

Libraries

Library facilites are excellent. In addition to the main library which houses most mathematics education journals and a computer search service, branch libraries of interest include the following:

Mathematics library, 210 Fenton, 686-3023

Science library, Science Library Building, 686-3075

Documents Room, 205 Computer Center, 686-4406, (houses computing journals, manuals, etc.)

Law library, 240 Law Center, 686-3088

Architecture & Allied Arts, 277 Lawrence, 686-3637

Bureau of Governmental Research & Service, Hendricks Hall, 686-3048

Local Information

Four city parks are recommended. Amazon Park, at 26th and Hilyard, is a typical recreational park and includes a public swimming pool. Hendricks Park is a woodsy scenic park and ideal for picnicking and hiking; to get to it, drive or walk east on 19th to Fairmount, go one block south to Summit, and then proceed eastward and upward into the park. Skinner's Butte Park is north of Skinner's Butte on Cheshire Avenue; it is reached by going north on High Street as far as possible and then turning left onto Cheshire. This is a recreational park bordering the Willamette River. There is also Alton Baker Park; to reach it drive over the Ferry Street Bridge and bear right. Alton Baker Park is a nice park for sun-bathing or wading in the Willamette.

A fine night or day view of Eugene can be obtained by walking or driving to the top of Skinner's Butte; take High Street north to behind the butte and follow signs to the top. The more substantial butte at the south end of town is Spencer's Butte. There are nice trails to the top, from which a spectacular view is available. The trails begin at Spencer's Butte Park out South Willamette Street about five miles south of downtown Eugene.

There are many miles of attractive running trails (including the famous "Pre's Trail") readily accessible from campus. Maps will be available at the Local Information section of the registration desk. During these meetings on the University's Hayward Field, there will be the 1984 National Master's Track and Field Championships. Those interested in competing can obtain further information from Oregon Track Club Masters, 1587 Agate, Eugene, Oregon 97403.

For the day tripper or overnight camper a variety of trails, including The Pacific Crest Trail through the Three Sisters Wilderness, are within easy driving distance of Eugene.

Some excellent walking trails are to be found at the Mountain Pisgah Arboretum. This 118 acre facility is about six miles from campus. More detailed information and directions to the arboretum will be available at the Local Information section of the registration desk.

Bicycles can be rented from Pedal Power Bicycles at Fifth Street. There are numerous bike paths; maps will be available at the Local Information section of the registration desk. Bikers and joggers are advised to travel in pairs and to watch out for roller skaters. Roller skates can be rented from the Outdoor Skate and Skateboard Shop, 1283 Lincoln Street (approximately 300 West 13th).

Canoes and kayaks can be rented at the Canoe House on the Millrace and bike path. It is located across Franklin Boulevard from the big Science Building on campus with address approximately 1200 Franklin Boulevard. Rentals are $2.50 per hour or $14 per day.

Sailboats can be rented at Dorena Lake, approximately 30 miles south of Eugene.

Several public golf courses are with a few miles of campus.

The Lane County Fair will take place August 14–19 at the fairgrounds, 13th and Monroe.

The Weyerhaeuser Lumber Company in Eugene's sister city, Springfield, has tours from 2:00 to 5:00 p.m. on Mondays, Wednesdays, and Fridays.

A fish hatchery open to the public is located at the EWEB Power Plant in Leaburg, approximately 18 miles east of Eugene. There are abundant opportunities for fishing within less than a one hour drive from Eugene; guides are available for those wishing to try the McKenzie River.

The new Hult Center for the Performing Arts opened in September 1982 and has made Eugene one of the most important cultural centers in the Northwest. Performances range from Bach to rock.

The University of Oregon Museum of Art offers continuous changing exhibitions, outstanding permanent collections devoted to oriental, Russian, and African, as well as contemporary Northwest and American art, and photography. The museum is open noon to 5:00 p.m. Wednesday through Sunday. Closed holidays. No admission charge.

Maude Kerns Art Center at 15th and Villard Streets offers local and traveling art shows and includes a gift shop. The Lane County Historical Museum has exhibits showing how western pioneers lived, dressed, traveled and cooked. To reach it, drive west on 11th to Monroe, left on Monroe to 13th to fairgrounds entrance, then left on 13th one block to the museum.

TIMETABLE

EMU = Erb Memorial Union

FRIDAY, August 17	American Mathematical Society	MAA and Other Organizations
11:00 a.m. - noon		MAA - THE EARLE RAYMOND HEDRICK LECTURES: Lecture I Lattices, sphere packings and applications Neil J. A. Sloane
noon - 1:00 p.m.		IIME - COUNCIL LUNCHEON
1:00 p.m. - 2:00 p.m.	COLLOQUIUM LECTURE II Minimax methods in critical point theory and applications to differential equations Paul H. Rabinowitz	
	SPECIAL SESSION	
1:00 p.m. - 4:20 p.m.	Geometry of configurations II	
2:15 p.m. - 3:05 p.m.		MAA - INVITED ADDRESS Mathematicians without mathematics Constance Reid
2:15 p.m. - 4:15 p.m.		IIME - CONTRIBUTED PAPER SESSION
2:15 p.m. - 4:15 p.m.		MAA - MINICOURSE #3 (Part A) Introductory computer science J. Arthur Seebach
2:15 p.m. - 4:15 p.m.		MAA - MINICOURSE #4 (Part B) (A COMET Minicourse) Teacher in-service programs Eugene A. Maier
	SESSION FOR CONTRIBUTED PAPERS	
2:15 p.m. - 4:25 p.m.	Analysis II	
	INVITED ADDRESS	
3:20 p.m. - 4:20 p.m.	Applications of homotopy theory to geometric problems Ralph L. Cohen	
4:35 p.m. - 5:35 p.m.		MAA - BUSINESS MEETING
5:45 p.m.	SALMON BAKE	
8:30 p.m. - 10:00 p.m.		AWM - PARTY

SATURDAY, August 18	AMS	MAA and Other Organizations
8:00 a.m. - 9:00 a.m.		IIME - DUTCH TREAT BREAKFAST
8:00 a.m. - 10:50 a.m.		MAA - MINICOURSE #1 (Part B) The intersection of mathematics and statistics Thomas R. Knapp
	SPECIAL SESSION	
8:00 a.m. - noon	Algebraic topology I	
	SESSION FOR CONTRIBUTED PAPERS	
8:30 a.m. - 10:40 a.m.	Set theory and contributions	
8:30 a.m. - 4:30 p.m.	REGISTRATION EMU 108-111	
8:30 a.m. - 4:30 p.m.	AMS BOOK SALE	MAA BOOK SALE
8:30 a.m. - 4:30 p.m.	EXHIBITS	
	INVITED ADDRESS	
8:40 a.m. - 9:40 a.m.	Higher codimension isoparametric submanifolds and their relation to the theory of Coxeter group Chuu-Lian Terng	
8:40 a.m. - 10:40 a.m.		MAA - MINICOURSE #2 (Part A) Applications of probability theory to the analysis and design of computer systems Robert Geist and Kishor Trivedi

Willamette Science and Technology Center (WISTEC) features hands-on exhibits and weekend planetarium shows. Open noon to 5:00 p.m. Tuesday through Sunday; planetarium shows at 1:00 and 3:00 p.m. Saturday and Sunday; $2/adults, $1/senior citizens, $0.75/children, under six years free; 2300 Centennial Boulevard, next to Autzen Stadium.

For shopping there is Eugene's Downtown Mall and the 101-store Valley River Center, a large indoor shopping mall. There is also the Fifth Street Public Market (at Fifth Street and High) with delicious food and unique items including crafts by Oregon artists. On Saturdays, hand-made and home-grown bargains can be found in the open air Saturday Market at 8th and Oak.

For further information about the area, call the Eugene-Springfield Convention and Visitors Bureau at 1-800-547-5445; inside Oregon call 1-800-452-3670.

Medical Services

Sacred Heart General Hospital is located one block west of campus at 1255 Hilyard. The emergency room is located at 705 East 13th. The emergency phone number is 503-686-6931. The campus emergency number is extension 3333.

Parking

Bean Complex parking lot is located at 15th and Moss Streets near Henderson Hall. There are no parking fees or stickers required.

Social Events

Salmon Bake

A salmon bake is being planned for Friday, August 17, from 5:45 to 7:30 p.m. in the Bean picnic area adjacent to the Bean Complex. The menu will consist of baked salmon, scalloped potatoes, corn-on-the-cob, green beans, cole slaw, relishes, French bread, fresh fruit, bar cookies, beer, soft drinks and coffee. Tickets are $12 for adults and $6.50 for children ages 6 through 15. There is no charge for children five years of age and under. Tickets should have been purchased through preregistration.

Wine Tasting

There will be a wine tasting on Thursday, August 16, from 8:00 p.m. to 10:00 p.m. in Gerlinger Lounge. The finest northwest wines will be featured together with California wines. Cheese and meat trays, bread and punch will also be served. Due to space limitations, the number of participants will be restricted. Tickets, priced at $7.50 per person, should have been purchased through preregistration.

Tours

The Local Arrangements Committee arranged for Great Western Travel Adventures, Inc. of Eugene, Oregon, to offer several trips and tours to participants at the Eugene meetings. The deadline for reservations for these tours was June 15.

Travel

In August, Eugene is on Pacific Daylight Saving Time. There is regular airline service to Eugene's Mahlon Sweet Airport by several major airline carriers. The airport is approximately 10 miles north and a little west of Eugene (a 20-minute ride). The Eugene Limousine Company provides seven- and nine-passenger vans and limousines as well as taxis. Rates for the vans and limousines are $9 per person and $5.50 for two or more passengers. The limousine will take passengers anywhere in Eugene. Persons staying in dorms should ask to be dropped off at Henderson Hall on 15th between Agate and Moss. Persons who wish to go the registration area should specify EMU (Erb Memorial Union) at 13th and University. Limousine rates for returning to the airport depend on the point of departure and are

TIMETABLE

EMU = Erb Memorial Union

SATURDAY, August 18	American Mathematical Society	MAA and Other Organizations
9:00 a.m. - 11:45 a.m.		IIME - CONTRIBUTED PAPER SESSION
9:45 a.m. - 10:45 a.m.	AMS-MAA INVITED ADDRESS Topology Raoul H. Bott	
11:00 a.m. - noon		MAA - THE EARLE RAYMOND HEDRICK LECTURES: Lecture II Lattices, sphere packings and applications Neil J. A. Sloane
1:00 p.m. - 1:50 p.m.		MAA - INVITED ADDRESS How to factor an integer Carl Pomerance
1:00 p.m. - 2:00 p.m.	COLLOQUIUM LECTURE III Minimax methods in critical point theory and applications to differential equations Paul H. Rabinowitz	
	SESSION FOR CONTRIBUTED PAPERS	
1:00 p.m. - 4:10 p.m.	Number theory and algebra	
	SPECIAL SESSIONS	
1:00 p.m. - 4:20 p.m.	Algebraic topology II	
2:00 p.m. - 4:20 p.m.	Geometry of configurations III	
2:10 p.m. - 4:20 p.m.		MAA - PANEL ON CURRICULUM AT TWO-YEAR COLLEGES Ronald M. Davis (moderator)
2:15 p.m. - 3:15 p.m.		MAA - PRESENTATION: Challenge of the unknown
2:15 p.m. - 4:15 p.m.		MAA - MINICOURSE #3 (Part B) Introductory computer science J. Arthur Seebach
4:30 p.m. - 6:00 p.m.	STEELE PRIZE SESSION AND BUSINESS MEETING	
6:15 p.m. - 8:15 p.m.		MAA - MINICOURSE #5 (Part B) Pascal for mathematicians Harley Flanders
6:15 p.m.		MAA - BANQUET FOR 25-YEAR MEMBERS
6:30 p.m. - 8:15 p.m.		IIME - BANQUET
8:30 p.m. - 9:30 p.m.		IIME - J. SUTHERLAND FRAME LECTURE The concept of plane area John L. Kelley

SUNDAY, August 19	AMS	Mathematical Association of America
	SPECIAL SESSIONS	
8:00 a.m. - 10:45 a.m.	Nonlinear problems I	
8:30 a.m. - 11:50 a.m.	Computational complexity I	
8:30 a.m. - 1:30 p.m.	ASSISTANCE & INFORMATION DESK Outside EMU Ballroom	
8:40 a.m. - 10:40 a.m.		MAA - MINICOURSE #6 (Part A) Introduction to computer graphics Joan Wyzkowski
8:40 a.m. - 10:40 a.m.		MAA - MINICOURSE #2 (Part B) Applications of probability theory to the analysis and design of computer systems Robert Geist and Kishor Trivedi
9:00 a.m. - 9:50 a.m.		MAA - INVITED ADDRESS How to fold polygons and do number theory, Part I Jean J. Pedersen

$4.50 from motels and hotels, $5.50 from campus. A cab to or from the airport will run $12 or $13.

Persons flying into Portland can get to Eugene as follows. A special bus system called DART goes from the airport to a few selected hotels, including the Portland Hilton. DART costs approximately $3. The Hilton is across the street from the Greyhound Bus Depot. Round trip to Eugene presently costs $26.05. The Greyhound Bus Depot in Eugene is about a mile west of campus. Eugene is also served by the Trailways Bus System.

AMTRAK station is located at 4th and Willamette about a mile from campus. There is daily service north to Seattle and south to Los Angeles, with connections to San Diego.

Persons approaching Eugene from the north or south on Interstate I-5 should follow the signs directing them to the University of Oregon. These routes lead to Franklin Boulevard which runs adjacent to campus. Several motels and restaurants are also located on Franklin Boulevard. Persons approaching Eugene from the east or west on state highway 126 should stay on this highway until it becomes Franklin Boulevard.

Weather

The expected high in the Eugene area is 81°F. The expected low is 50°F. The average rainfall in August is 0.58 inches. Humidity ranges from 74 percent at 10:00 a.m. to 60 percent at 4:00 p.m. Pollen problem: weeds.

TIMETABLE

EMU = Erb Memorial Union

SUNDAY, August 19	American Mathematical Society	Mathematical Association of America
9:00 a.m. - 9:55 a.m.	SESSION FOR CONTRIBUTED PAPERS Applied mathematics	
10:00 a.m. - 10:50 a.m.		MAA - INVITED ADDRESS How to fold polygons and do number theory, Part II Peter J. Hilton
11:00 a.m. - noon		MAA - THE EARLE RAYMOND HEDRICK LECTURES: Lecture III Lattices, sphere packings and applications Neil J. A. Sloane
1:00 p.m. - 1:50 p.m.		MAA - INVITED ADDRESS Applications of geometry to the social sciences Robert I. Jewett
1:00 p.m. - 2:00 p.m.	COLLOQUIUM LECTURE IV Minimax methods in critical point theory and applications to differential equations Paul H. Rabinowitz	
1:00 p.m. - 4:20 p.m.	SPECIAL SESSION Computational complexity II	
2:05 p.m. - 3:05 p.m.	INVITED ADDRESS Foundations of the theory of algorithms Yiannis N. Moschovakis	
2:10 p.m. - 4:55 p.m.	SPECIAL SESSION Nonlinear problems II	
2:15 p.m. - 4:15 p.m.		MAA - MINICOURSE #6 (Part B) Introduction to computer graphics Joan Wyzkowski
3:20 p.m. - 4:20 p.m.	INVITED ADDRESS Elliptic curves and L-functions Ralph Greenberg	

Program of the Sessions

The time limit for each contributed paper in the AMS general sessions is ten minutes. In the special sessions, the time limit varies from session to session and within sessions. To maintain the schedule, time limits will be strictly enforced.

Abstracts of papers presented in AMS sessions at this meeting will be found in the August 1984 issue of *Abstracts of papers presented to the American Mathematical Society*, ordered according to the numbers in parentheses following the listings below.

For papers with more than one author, an asterisk follows the name of the author who plans to present the paper at the meeting.

Thursday, August 16, 1984, 8:00 a.m.

Special Session on Structures of Graphs and Matroids, I

8:00– 8:20 (1) *Blocking sets and the Möbius function.* Preliminary report. THOMAS BRYLAWSKI, University of North Carolina, Chapel Hill (813-05-105)

8:30– 8:50 (2) *Remarks on forbidden minors.* JEFF KAHN, Rutgers University, New Brunswick (813-05-09)

9:00– 9:20 (3) *Growth rates of minor-closed classes of binary combinatorial geometries.* JOSEPH P. S. KUNG, North Texas State University (813-05-18)

9:30– 9:50 (4) *Clustered families of convex sets.* JIM LAWRENCE, George Mason University (813-05-29)

10:00–10:20 (5) *Circuit-cocircuit intersections in matroids.* JAMES G. OXLEY, Louisiana State University, Baton Rouge (813-05-19)

10:30–10:50 (6) *Recursive analysis of matroid decomposition.* KLAUS TRUEMPER, University of Texas, Dallas (813-05-17) (Introduced by Paul Seymour)

Thursday, August 16, 1984, 8:40 a.m.

Invited Address

8:40– 9:40 (7) *Unitary representations of semisimple Lie groups.* DAVID A. VOGAN, JR., Massachusetts Institute of Technology (813-99-146)

Thursday, August 16, 1984, 9:00 a.m.

Session on Geometry and Topology

9:00– 9:10 (8) *Some sphere packing formulas.* C. MUSÈS, Mathematics & Morphology Research Centre (813-52-111) (Introduced by K. Demys)

9:15– 9:25 (9) *Linear relations between covariant derivatives of tensors.* MARTIN K. ALBERT, DOMINA EBERLE SPENCER and SHAMA UMA*, University of Connecticut (813-53-72)

9:30– 9:40 (10) *On the Nash spaces.* PETRU PAPADOPOL, State University of New York, Albany (813-53-76)

9:45– 9:55 (11) *Invariant instantons on a Hopf surface.* Preliminary report. STEVEN G. HARRIS, Oregon State University (813-53-83)

10:00–10:10 (12) *Compact almost symplectic manifolds.* BILL WATSON, St. John's University, Jamaica (813-53-121) (Introduced by Robert O. Stanton)

10:15–10:25 (13) *Best approximation in metric spaces.* ROSHDI KHALIL, Kuwait University, Kuwait (813-54-04)

10:30–10:40 (14) *On the existence of exactly* $(2,1)$ *maps.* R. E. SMITHSON, University of Wyoming (813-54-15)

10:45–10:55 (15) *ω-connected continua and Jones' K function.* ELDON J. VOUGHT, California State University, Chico (813-54-63)

11:00–11:10 (16) *The multiple recurrence property.* Preliminary report. SCOTT W. WILLIAMS, State University of New York, Buffalo (813-54-87)

11:15–11:25 (17) *A compactification for convergence ordered spaces.* D. C. KENT*, Washington State University, and G. D. RICHARDSON, East Carolina University (813-54-93)

11:30–11:40 (18) *The comparisons of some C-completions and C-compactifications of any topological space.* HUEYTZEN J. WU, Texas A&I University (813-54-135)

11:45–11:55 (19) *Connectedness properties of lattices.* Preliminary report. REINO VAINIO, Åbo Akademi, Finland (813-54-64)

12:00–12:10 (20) *Black men and women in mathematical research.* PATRICIA C. KENSCHAFT, Montclair State College (813-01-89)

Thursday, August 16, 1984, 10:00 a.m.

Special Session on Applications of Gauge Theories, I

10:00–10:20 (21) *Moduli of Einstein-Hermitian bundles.* MARTIN LÜBKE, Universität Bayreuth, West Germany (813-99-147) (Introduced by Clifford H. Taubes)

10:30–10:50 (22) *Curvature and stability of holomorphic vector bundles.* SHOSHICHI KOBAYASHI, University of California, Berkeley (813-58-16)

11:00–11:20 (23) *$SO(3)$-connections and low dimensional topology.* RONALD FINTUSHEL*, Tulane University, and RONALD J. STERN, University of Utah (813-57-84)

11:30–11:50 (24) *Gauge theory and smoothing 4-manifolds.* ROBERT E. GOMPF, University of California, Berkeley (813-57-108)

Thursday, August 16, 1984, 11:00 a.m.

Invited Address

11:00–12:00 (25) *Generalizing Kuratowski's theorem.* PAUL SEYMOUR, Bell Communications Research, Inc. (813-05-117)

Thursday, August 16, 1984, 1:00 p.m.

Colloquium Lectures: Lecture I

1:00– 2:00 (26) *Minimax methods in critical point theory and applications to differential equations.* I. PAUL H. RABINOWITZ, University of Wisconsin, Madison

Thursday, August 16, 1984, 2:10 p.m.

Special Session on Applications of Gauge Theories, II

2:10– 2:30 (27) *Heat kernel asymptotics and path space.* Preliminary report. THOMAS H. PARKER, Brandeis University (813-58-107)

2:40– 3:00 (28) *Bidual spaces and the analysis of Yang-Mills and gravitational fields.* JAMES ISENBERG*, University of Oregon, and PHILIP YASSKIN, Texas A&M University, College Station (813-53-26)

4:30– 4:50 (29) *Quaternionic Kähler manifolds and their twistor spaces.* AHMAD ZANDI, University of California, Berkeley (813-53-82)

5:00– 5:20 (30) *Instantons on $S^1 \times S^3$.* Preliminary report. FRANK J. FLAHERTY, Oregon State University (813-53-55)

Thursday, August 16, 1984, 2:10 p.m.

Special Session on Structures of Graphs and Matroids, II

2:10– 2:30 (31) *Structural properties of cyclically 4-connected graphs.* N. ROBERTSON, Ohio State University, Columbus (813-05-129)

2:40– 3:00 (32) *Orthogonal colorings of graphs.* Preliminary report. DAN ARCHDEACON, University of Vermont (813-05-28)

3:10– 3:30 (33) *Permutation-pairs.* Preliminary report. SAUL STAHL, University of Kansas (813-05-20)

3:40– 4:00 (34) *A 3-colour perfect graph theroem.* K. CAMERON and J. EDMONDS*, University of Waterloo, Canada, and L. LOVÁSZ, Eötvös LoràND University, Hungary (813-05-128) (Introduced by Neil Robertson)

4:10– 4:30 (35) *Lambda-decomposition of a graph.* K. CAMERON* and J. EDMONDS, University of Waterloo, Canada, and L. LOVÁSZ, Eötvös LoràND University, Hungary (813-05-130) (Introduced by Neil Robertson)

4:40– 5:00 (36) *The structure of hypergraphs with no large independent set.* Preliminary report. GIL KALAI, Massachusetts Institute of Technology (813-05-70)

5:10– 5:30 (37) *Symmetries of labelled posets.* CURTIS GREENE, Haverford College (813-05-115)

Thursday, August 16, 1984, 2:10 p.m.

Session on Algebraic Topology and Manifolds

2:10– 2:20 (38) *Positive curvature and PL manifolds.* REGINA HUNTER MLADINEO, Rider College (813-55-25)

2:25– 2:35 (39) *The cofibre of the transfer map.* LARRY W. CUSICK, California State University, Fresno (813-55-85)

2:40– 2:50 (40) *Classifying spaces for foliations with isolated singularities.* PETER A. GREENBERG, North Dakota State University, Fargo (813-55-96)

2:55– 3:05 (41) *Derived invariants of linking.* Preliminary report. LOUIS KAUFFMAN, University of Illinois, Chicago (813-57-69)

3:10– 3:20 (42) *On the combinatorics of Kostant's partition function.* III. Preliminary report. ROBERT W. DECKHART, Northern Arizona University (813-22-120)

3:25– 3:35 (43) *A characterization of an affine conformal vector-field.* RAMESH SHARMA and K. L. DUGGAL*, University of Windsor, Canada (813-99-145)

Thursday, August 16, 1984, 3:00 p.m.

Session on Analysis, I

3:00– 3:10 (44) *Global approximation theorems for a Bernstein type operator.* I. Preliminary report. C. JAYASRI and Y. SITARAMAN*, University of Kerala, India (813-41-21) (Introduced by M. Satyanarayana)

3:15– 3:25 (45) *Global approximation theorems for a Bernstein type operator.* II. Preliminary report. C. JAYASRI* and Y. SITARAMAN, University of Kerala, India (813-41-22) (Introduced by M. Satyanarayana)

3:30– 3:40 (46) *Asymptotics for orthogonal polynomials defined by a recurrence equation.* ATTILA MÁTÉ*, Brooklyn College, City University of New York, PAUL NEVAI, Ohio State University, Columbus, and VILMOS TOTIK, Bolyai Institute, Hungary (813-42-45)

3:45– 3:55 (47) *The Poisson-Laguerre transform.* DEBORAH TEPPER HAIMO, University of Missouri, St. Louis (813-44-80)

4:00– 4:10 (48) *Coincidences into the dual and Kakutani's fixed point theorem.* STEPHEN SIMONS, University of California, Santa Barbara (813-46-62)

4:15– 4:25 (49) *Fredholm theory of operators on a Banach space which have an adjoint.* BRUCE A. BARNES, University of Oregon (813-47-91)

4:30– 4:40 (50) *Error analysis modeling of the parabolic mirror component of a laser bar gauge.* Preliminary report. FREDERICK D. CHICHESTER, Allied Bendix Aerospace (813-78-90) (Introduced by Frank T. Birtel)

4:45– 4:55 (51) *A new characterization of Euler's gamma function by the Gauss multiplication formula.* Preliminary report. HIROSHI HARUKI, University of Waterloo, Canada (813-99-148)

Thursday, August 16, 1984, 3:20 p.m.

Invited Address

3:20– 4:20 (52) *Applications of Gauge theories.* CLIFFORD H. TAUBES, University of California, Berkeley (813-58-143)

Friday, August 17, 1984, 8:00 a.m.

Special Session on Geometry of Configurations, I

8:00– 8:20 (53) *Balancing vectors in the* max *norm.* JOEL SPENCER, State University of New York, Stony Brook (813-05-123)

8:30– 8:50 (54) *Application of the covering lemma.* Preliminary report. WILLIAM T. TROTTER, JR., University of South Carolina, Columbia (813-51-134)

9:00– 9:20 (55) *Dissecting sets of points.* Preliminary report. HERBERT EDELSBRUNNER, Technical University of Graz, Austria (813-52-52) (Introduced by Richard Pollack)

9:30– 9:50 (56) *Art gallery theorems and algorithms.* JOSEPH O'ROURKE, Johns Hopkins University, Baltimore (813-51-112) (Introduced by Jacob E. Goodman)

10:00–10:20 (57) *Intersection of edges of a geometric graph by straight lines.* N. ALON*, Massachusetts Institute of Technology, and M. A. PERLES, Hebrew University of Jerusalem, Israel (813-51-53)

10:30–10:50 (58) *No angle is very popular in $E5$ (or $E4, E3$, or $E2$).* Preliminary report. GEORGE B. PURDY, Texas A&M University, College Station (813-05-133)

Friday, August 17, 1984, 9:00 a.m.

Session on Differential Equations

9:00– 9:10 (59) *Oscillation and nonoscillation for systems of two first-order linear differential equations with delay.* G. S. LADDE* and B. G. ZHANG, University of Texas, Arlington (813-34-95)

9:15– 9:25 (60) *A standard computational procedure for the treatment of all differential equations using multivariate polynomials.* MIKE MIKALAJUNAS, Montréal, Canada (813-35-05)

9:30– 9:40 (61) *Microlocal hypoellipticity on step two nilpotent Lie groups.* KENNETH G. MILLER, Wichita State University (813-35-23)

9:45– 9:55 (62) *Eigenvectors of cross-symmetric matrices.* JAMES R. WEAVER, University of West Florida (813-15-36)

10:00–10:10 (63) *Time dependent nonlinear implicit evolution equations.* KENNETH L. KUTTLER, JR., Michigan Technological University (813-35-44)

10:15–10:25 (64) *Capacity and 2nd order semilinear elliptic supersolutions.* VICTOR L. SHAPIRO, University of California, Riverside (813-35-61)

Friday, August 17, 1984, 9:40 a.m.

Special Session on Applications of Gauge Theories, III

9:40–10:00 (65) *Critical point theory and non-linear elliptic equations in* $\mathbf{R}^N$. HENRI BERESTYCKI, Université Paris XIII, France (813-99-144)

10:05–10:25 (66) *A new approach to curved twistor spaces.* Preliminary report. ADAM D. HELFER, University of Pittsburgh, Pittsburgh (813-83-27)

10:30–10:50 (67) *Yang-Mills plasmas.* RICHARD MONTGOMERY, University of California, Berkeley (813-82-67)

Friday, August 17, 1984, 1:00 p.m.

Colloquium Lectures: Lecture II

1:00– 2:00 (68) *Minimax methods in critical point theory and applications to differential equations.* II. PAUL H. RABINOWITZ, University of Wisconsin, Madison

Friday, August 17, 1984, 1:00 p.m.

Special Session on Geometry of Configurations, II

1:00– 1:20 (69) *Simplicial arrangements in projective* 3*-space.* BRANKO GRÜNBAUM*, University of Washington, and G. C. SHEPHARD, University of East Anglia, England (813-51-98)

1:30– 1:50 (70) *Coding planar ornaments by parametrized systems of Coxeter matrices.* ANDREAS DRESS, Universität Bielefeld, Federal Republic of Germany (813-05-59)

2:00– 2:30 (71) *Two "simple" spheres.* Preliminary report. DAVID W. BARNETTE, University of California, Davis (813-52-40) (Introduced by Jacob E. Goodman)

2:30– 2:50 (72) *Generalized Dehn-Sommerville relations for polytopes, spheres and Eulerian partially ordered sets.* MARGARET M. BAYER, Northeastern University, and LOUIS J. BILLERA*, Cornell University (813-52-122)

3:00– 3:20 (73) *An update on "Research problems in discrete geometry".* W. O. J. MOSER, McGill University, Canada (813-51-125)

3:30– 3:50 (74) *The Sylvester-Gallai-theory and its configurations.* STEN HANSEN, University of Copenhagen and Ordrup Gymnasium, Denmark (813-51-139)

4:00– 4:20 (75) *Extensions of Sylvester's problem.* PETER BORWEIN, Dalhousie University, Canada (813-51-12)

Friday, August 17, 1984, 2:15 p.m.

Session on Analysis, II

2:15– 2:25 (76) *Interpolation by infinitely differentiable function on the real line.* YEN TZU FU, Indiana State University, Evansville (813-26-92)

2:30– 2:40 (77) *Some inequalities for inverse functions in geometric function theory.* EUGENE RODEMICH, Jet Propulsion Laboratory (813-30-77)

2:45– 2:55 (78) *Stieltjes and Van Vleck polynomials and applications.* A. M. AL-RASHED* and N. ZAHEER, King Saud University, Saudi Arabia (813-30-03)

3:00– 3:10 (79) *Dirichlet integral and star-function inequalities.* J. R. QUINE, Florida State University (813-30-73)

3:15– 3:25 (80) *On admissable limits for M-subharmonic functions.* J. A. CIMA* and CHARLES STANTON, University of North Carolina, Chapel Hill (813-31-01)

3:30– 3:40 (81) *The partial sums of the Laurent series.* MICHAEL J. HOFFMAN, California State University, Los Angeles (813-30-138)

3:45– 3:55 (82) *The Painlevé transcendents refer to egg-shaped ovals.* Preliminary report. C. MUSÈS and K. DEMYS*, Mathematics & Morphology Research Centre (813-33-140)

4:00– 4:10 (83) *Principal solutions of discrete linear systems and Riccati transformations.* C. D. AHLBRANDT, University of Missouri, Columbia, and J. W. HOOKER*, Southern Illinois University, Carbondale (813-39-136)

4:15– 4:25 (84) *Convergence of the transform-iterative method for nonlinear problems.* ABDUL J. JERRI, Clarkson University (813-65-137)

Friday, August 17, 1984, 3:20 p.m.

Invited Address

3:20– 4:20 (85) *Applications of homotopy theory to geometric problems.* RALPH L. COHEN, Stanford University (813-55-74)

Saturday, August 18, 1984, 8:00 a.m.

Special Session on Algebraic Topology, I

8:00– 8:20 (86) *A strong nonimmersion theorem for real projective spaces.* DONALD M. DAVIS, Lehigh University (813-57-13)

8:30– 8:50 (87) *The space of maps of Moore spaces to spheres.* F. R. COHEN*, University of Kentucky, H. E. A. CAMPBELL, New York University, F. P. PETERSON, Massachusetts Institute of Technology, and PAUL S. SELICK, University of Western Ontario, Canada (813-55-65)

9:00– 9:20 (88) *On the Steinberg module, representations of the symmetric groups, and the Steenrod algebra.* STEPHEN MITCHELL, Princeton University (813-55-101)

9:30– 9:50 (89) *Equivariant cohomology and cyclic theory.* PAUL BAUM*, JEAN-LUC BRYLINSKI and ROBERT MACPHERSON, Brown University (813-55-51)

11:10–11:30 (90) *Group actions on homology spheres.* JAMES F. DAVIS*, University of Notre Dame, and SHMUEL WEINBERGER, Princeton University (813-57-103)

11:40–12:00 (91) *On $H^*(\Omega^n QS^0)$ for n small.* Preliminary report. F. R. COHEN, University of Kentucky, and F. P. PETERSON*, Massachusetts Institute of Technology (813-55-54)

Saturday, August 18, 1984, 8:30 a.m.

Session on Set Theory and Contributions

8:30– 8:40 (92) *Thomas Jefferson and Douwe's method for determining latitude.* Preliminary report. JAMES J. TATTERSALL, Providence College (813-01-37)

8:45– 8:55 (93) *The theory of definably lawless sequences.* JOAN RAND MOSCHOVAKIS, Occidental College (813-03-48)

9:00– 9:10 (94) *Interpretations of many-sorted theories.* JULIAN L. HOOK, Florida International University (813-03-58)

9:15– 9:25 (95) *A simple proof of the diamond lemma.* GEORGE BUTLER* and DALLAS S. LANKFORD, Louisiana Tech University (813-05-07)

9:30– 9:40 (96) *A poset which is shellable but not lexicographically shellable.* JAMES W. WALKER, University of South Carolina, Columbia (813-05-24)

9:45– 9:55 (97) *An extension of E. G. Straus' perfect Latin 3-cube of order seven.* JOSEPH ARKIN, Spring Valley, New York (813-05-38)

10:00–10:10 (98) *A new method for constructing magic squares.* E. MAHMOODIAN, Sharif University of Technology, Iran (813-05-68)

10:15–10:25 (99) *The Johnson and Hamming graphs and root systems.* Preliminary report. PAUL M. TERWILLIGER, Ohio State University, Columbus (813-05-127)

10:30–10:40 (100) *Bridge and cycle degrees of vertices in graphs.* GARY CHARTRAND and FARROKH SABA*, Western Michigan University, and NICHOLAS C. WORMALD, The University of New Castle, England (813-99-141)

Saturday, August 18, 1984, 8:40 a.m.

Invited Address

8:40– 9:40 (101) *Higher codimension isoparametric submanifolds and their relation to the theory of Coxeter group.* CHUU-LIAN TERNG, Northeastern University (813-53-113)

Saturday, August 18, 1984, 1:00 p.m.

Colloquium Lectures: Lecture III

1:00– 2:00 (102) *Minimax methods in critical point theory and applications to differential equations.* III. PAUL H. RABINOWITZ, University of Wisconsin, Madison

Saturday, August 18, 1984, 1:00 p.m.

Special Session on Algebraic Topology, II

1:00– 1:20 (103) *The oozing conjecture for odd dimensional manifolds.* Preliminary report. R. JAMES MILGRAM, Stanford University (813-55-100)

1:30– 1:50 (104) *Segal's conjecture for infinite complexes.* Preliminary report. GUNNAR CARLSSON, University of California at San Diego, La Jolla (813-55-81)

2:00– 2:20 (105) *A generalization of the lambda algebra.* W. LELLMAN and M. MAHOWALD*, Northwestern University (813-55-119)

2:30– 2:50 (106) *Equivariant smoothing, bundles and obstructions.* RICHARD LASHOF, University of Chicago and University of California, Berkeley (813-57-66)

3:00– 3:20 (107) *The* mod p *Whitehead conjecture.* STEWART B. PRIDDY, Northwestern University (813-55-99)

3:30– 3:50 (108) *Cobordism and characteristic classes revisited.* Preliminary report. DAVID J. PENGELLEY, New Mexico State University, Las Cruces, and DOUGLAS C. RAVENEL*, University of Washington (813-55-102)

4:00– 4:20 (109) *Inverse systems of spectra and generalizing a theorem of W. H. Lin.* S. A. WEGMANN, University of Washington (813-55-114) (Introduced by Ralph Cohen)

Saturday, August 18, 1984, 1:00 p.m.

Session on Number Theory and Algebra

1:00– 1:10 (110) *Distributive properties of quasi ordered sets.* ELIAS DAVID, Leicester Polytechnic, England (813-06-42)

1:15– 1:25 (111) *A conjecture for commutator-finite orthomodular lattices.* Preliminary report. RICHARD GREECHIE* and LOUIS HERMAN, Kansas State University (813-06-110)

1:30– 1:40 (112) *New unitary amicable couples.* MARIANO GARCIA, Hostos Community College, City University of New York (813-10-39)

1:45– 1:55 (113) *Numbers having m small m-th roots* mod p. RAPHAEL M. ROBINSON, University of California, Berkeley (813-10-43)

2:00– 2:10 (114) *Analogs of Dedekind sums.* DON REDMOND*, Southern Illinois University, Carbondale, R. SITARAMACHANDRA RAO, University of Toledo, and R. SIVARAMAKVISHNAN, University of Calicut, India (813-10-60)

2:15– 2:25 (115) *Factorization of the "most wanted" integers.* Preliminary report. J. A. DAVIS* and D. B. HOLDRIDGE, Sandia National Laboratories (813-10-86) (Introduced by Robert J. Thompson)

2:30– 2:40 (116) *On the least common multiple of some binomial coefficients.* Preliminary report. HUGH M. EDGAR, San Jose State University (813-10-88)

2:45– 2:55 (117) *Polynomial evaluation of symmetric finite sums which involve the greatest integer function* $[u]$. DAVID ZEITLIN, Minneapolis, Minnesota (813-10-97)

3:00– 3:10 (118) *Finding fundamental units in totally real fields.* Preliminary report. T. W. CUSICK, State University of New York, Buffalo (813-12-02)

3:15– 3:25 (119) *On the adele rings of radical extensions of the rationals.* WILLIAM YSLAS VELEZ, University of Arizona (813-12-94) (Introduced by D. J. Madden)

3:30– 3:40 (120) *Locally injective torsion modules.* WILLY BRANDAL, University of Idaho (813-13-56)

3:45– 3:55 (121) *On C-separable abelian groups.* K. M. RANGASWAMY, University of Colorado, Colorado Springs (813-20-109)

4:00– 4:10 (122) *Algorithms to compute basic and cobasic right congruences.* Preliminary report. HAROLD DAVENPORT, University of Arkansas, Little Rock (813-20-57)

Saturday, August 18, 1984, 2:00 p.m.

Special Session on Geometry of Configurations, III

2:00– 2:20 (123) *Abstract convexity.* BERNARD KORTE and LÁSZLÓ LOVÁSZ*, University of Bonn, Federal Republic of Germany (813-52-124) (Introduced by Richard Pollack)

2:30– 2:50 (124) *Geometry and the Mobius function of the weak Bruhat order of the symmetric group.* Preliminary report. PAUL H. EDELMAN, University of Pennsylvania (813-06-14)

3:00– 3:20 (125) *Perpendicular dissections and the voltage lift matroid.* Preliminary report. THOMAS ZASLAVSKY, Ohio State University, Columbus (813-51-10)

3:30– 3:50 (126) *Motions in bar-and-body frameworks.* NEIL L. WHITE*, University of Florida, and WALTER WHITELEY, Champlain Regional College, Canada (813-05-71)

4:00– 4:20 (127) *Spaces of linear and geodesic triangulations—a survey.* DAVID W. HENDERSON, Cornell University (813-52-46)

Sunday, August 19, 1984, 8:00 a.m.

Special Session on Nonlinear Problems, I

8:00– 8:45 (128) *Critical point theory and instability of stationary solitary waves in nonlinear Schrodinger equations.* HENRI BERESTYCKI, Université Paris XIII, France (813-35-35)

9:00– 9:45 (129) *Remarks on the mapping degree and its applications.* FELIX E. BROWDER, University of Chicago (813-35-34)

10:00–10:45 (130) *Periodic solutions of Hamilton's equations and local minima of the dual action.* FRANK H. CLARKE, Université de Montréal, Canada (813-35-33)

Sunday, August 19, 1984, 8:30 a.m.

Special Session on Computational Complexity, I

8:30– 8:50 (131) *On the lattice basis reduction algorithm.* A. M. ODLYZKO, AT&T Bell Laboratories (813-68-106)

9:00– 9:20 (132) *On the complexity of computation.* ZVI GALIL, Columbia University (813-99-152) (Introduced by Eugene M. Luks)

9:30– 9:50 (133) *Determining the structure of commutative algebras.* KATALIN FRIEDL, Institute for Computers and Automation, Hungary (813-68-132) (Introduced by Eugene M. Luks)

10:00–10:20 (134) *The traveling salesman problem made easy.* EUGENE L. LAWLER, University of California, Berkeley (813-68-131) (Introduced by Eugene M. Luks)

10:30–10:50 (135) *A new polynomial-time algorithm for linear programming.* NARENDRA K. KARMARKAR, AT&T Bell Laboratories, Murray Hill (813-99-149) (Introduced by Eugene M. Luks)

11:00–11:20 (136) *Optimal parallel algorithms for graph connectivity.* JOHN REIF, Harvard University (813-99-142) (Introduced by Eugene M. Luks)

11:30–11:50 (137) *Diameter algorithm.* F. R. K. CHUNG, Bell Communications Research (813-05-75)

Sunday, August 19, 1984, 9:00 a.m.

Session on Applied Mathematics

9:00– 9:10 (138) *The solution of an evolution equation describing certain types of mechanical and chemical interaction.* KENNETH L. KUTTLER, JOHN W. HILGERS* and THOMAS H. COURTNEY, Michigan Technological University (813-70-79)

9:15– 9:25 (139) *Numerical calculations of critical frequencies using a Bouguer-Altar-Appleton-Bremmer approximation.* DALLAS S. LANKFORD, Louisiana Tech University (813-78-08)

9:30– 9:40 (140) *A very elementary derivation of the relativistic addition of velocities and* $E = mc^2$. ALEXANDER ABIAN, Iowa State University (813-83-78)

9:45– 9:55 (141) *Brain systems as fibrations.* Preliminary report. WILLIAM C. HOFFMAN, Oakland University (813-92-50)

Sunday, August 19, 1984, 1:00 p.m.

Colloquium Lectures: Lecture IV

1:00– 2:00 (142) *Minimax methods in critical point theory and applications to differential equations.* IV. PAUL H. RABINOWITZ, University of Wisconsin, Madison

Sunday, August 19, 1984, 1:00 p.m.

Special Session on Computational Complexity, II

1:00– 1:20 (143) *Randomized algorithms for searching and sorting.* RICHARD M. KARP, University of California, Berkeley (813-99-154)

1:30– 1:50 (144) *Some recent results in communication protocols.* ANDREW YAO, Stanford University (813-99-151)

2:00– 2:20 (145) *A topological view of some problems in complexity theory.* MICHAEL SIPSER, Massachusetts Institute of Technology (813-68-118) (Introduced by Maria Klawe)

2:30– 2:50 (146) *Lines in 3-dimensional space.* FRANCES YAO, Xerox Palo Alto Research Center (813-99-150)

3:00– 3:20 (147) *Loss of precision and the computational complexity of real functions.* LENORE BLUM*, Mills College, and MICHAEL SHUB, City University of New York, Graduate School and University Center (813-68-116)

3:30– 3:50 (148) *Refined complexity analysis for heap operations.* Preliminary report. MICHAEL L. FREDMAN, University of California, San Diego (813-68-47) (Introduced by Eugene M. Luks)

4:00– 4:20 (149) *Knowledge complexity: A theory of cryptographic protocols and interactive proof systems.* SHAFI GOLDWASSER and SILVIO MICALI*, Massachusetts Institute of Technology, and CHARLES RACKOFF, University of Toronto, Canada (813-99-153) (Introduced by Eugene M. Luks)

Sunday, August 19, 1984, 2:05 p.m.

Invited Address

2:05– 3:05 (150) *Foundations of the theory of algorithms.* YIANNIS N. MOSCHOVAKIS, University of California, Los Angeles (813-03-49)

Sunday, August 19, 1984, 2:10 p.m.

Special Session on Nonlinear Problems, II

2:10– 2:55 (151) *Unbounded viscosity solutions of Hamilton-Jacobi equations of first order.* MICHAEL CRANDALL*, University of Wisconsin, Madison, and PIERRE-LOUIS LIONS, Université de Paris IX, Dauphine, France (813-35-32)

3:10– 3:55 (152) *A Morse index for periodic solutions to convex Hamiltonian systems: theory and applications.* I. EKELAND, Université de Paris IX, Dauphine, France (813-35-31)

4:10– 4:55 (153) *Hamiltonian hierarchies on semi-simple Lie algebras.* D. H. SATTINGER, University of Minnesota, Minneapolis (813-35-30)

Sunday, August 19, 1984, 3:20 p.m.

Invited Address

3:20– 4:20 (154) *Elliptic curves and L-functions.* RALPH GREENBERG, University of Washington (813-12-104)

New Orleans, Louisiana

Frank T. Birtel
Associate Secretary

Presenters of Papers

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Minneapolis, November 2–3, 1984, University of Minnesota

Second Announcement of the 814th Meeting

The eight hundred and fourteenth meeting of the American Mathematical Society will be held at the University of Minnesota, Minneapolis, on Friday and Saturday, November 2 and 3, 1984.

Invited Addresses

By invitation of the 1983 Committee to Select Hour Speakers for Central Sectional Meetings, there will be four invited one-hour addresses. The speakers, their affiliations, their titles, and the scheduled times of presentation are as follows:

JERRY L. BONA, University of Chicago, *Development in the mathematical theory of nonlinear wave motion*, 11:15 a.m. Saturday.

I. MARTIN ISAACS, University of Wisconsin, Madison, *Characters of solvable groups*, 1:45 p.m. Saturday.

NARESH C. JAIN, University of Minnesota, Minneapolis, *Occupation times of random walks*, 11:15 a.m. Friday.

STEPHEN C. MILNE, Texas A & M University, College Station, *Summation theorems for multiple hypergeometric series*, 1:30 p.m. Friday.

All of the above invited addresses will take place in the Mayo Memorial Auditorium.

Special Sessions

By invitation of the same committee, there will be five special sessions of selected twenty-minute papers. The topics of these special sessions, names of the organizers, and partial lists of speakers, are as follows:

Nonlinear problems in mechanics, CHARLES AMICK, University of Chicago, and WEI-MING NI, University of Minnesota, Minneapolis. The tentative list of speakers includes N. D. Alikokos, Charles Amick, I. J. Bakelman, H. A. Levine, P. J. Olver, W. G. Pritchard, M. Reed, R. L. Sachs, P. Sacks, J. Sylvester, R. E. L. Turner, J.-M. Vanden-Broeck.

Variational methods in partial differential equations and applications, ROBERT HARDT, University of Minnesota, Minneapolis, and WILLIAM P. ZIEMER, Indiana University, Bloomington. The tentative list of speakers includes Luis Caffarelli, Lawrence C. Evans, Morton Gurtin, William Hrusa, Robert Jensen, Robert Kohn, Dan Phillips, and Ed Stredulinsky.

Mathematical logic–applications to analysis, physical theory and computer science, MARIAN B. POUR-EL, University of Minnesota, Minneapolis. The tentative list of speakers includes Harvey Friedman, Solomon Feferman, Erwin Engeler, Juris Hartmanis, Yiannis Moschovakis, Marian B. Pour-El, Ian Richards, M. M. Richter, Lee Rubel, Andrej Scedrov, Dana Scott, and Rich Smith.

Algebraic geometry, JOEL L. ROBERTS, University of Minnesota, Minneapolis, and ROBERT SPEISER, Brigham Young University, Provo, Utah. The tentative list of speakers includes Igor Dolgachev, Craig Huneke, William Lang, William Messing, and Niels Nygaard.

Enumerative combinatorics, DENNIS WHITE, University of Minnesota, Minneapolis. The tentative list of speakers includes Janet Beissinger, David Bressoud, Paul Edelman, Adriano Garsia, Ira Gessel, Ira Goulden, Curtis Greene, David Jackson, Robert Proctor, Jeffrey Remmel, Bruce Sagan, Richard Stanley, Dean Sturtevant, Michelle Wachs, and Thomas Zaslavsky.

Most of the papers to be presented at these special sessions will be by invitation. However, anyone submitting an abstract for the meeting who feels that his or her paper would be particularly appropriate for one of these special sessions should indicate this clearly on the abstract form and submit it by **August 7, 1984**, three weeks before the deadline for contributed papers, in order that it may be considered for inclusion. Each abstract submitted must be accompanied by payment in the amount of $15 to cover a portion of the processing costs. (Please refer to the rules on the page preceding the program for the Eugene meeting in this issue of the *Notices*.) In addition, a charge of $12 is imposed for retyping abstracts that are not in camera-ready form.

Contributed Papers

There will also be sessions for contributed ten-minute papers. Abstracts should be prepared on the standard AMS form available from the AMS office in Providence or in departments of mathematics. Abstracts should be sent to Abstracts, Editorial Department, American Mathematical Society, P. O. Box 6248, Providence, Rhode Island 02940, so as to arrive prior to the **abstract deadline of August 28, 1984**. These abstracts must also be accompanied by payment of the $15 processing charge.

Registration

The meeting registration desk will be located in Room 120 Vincent Hall (the mathematics building). The desk will be open from 8:00 a.m. to 3:30 p.m. on Friday and from 8:00 a.m. to 11:00 a.m. on Saturday. The registration fees are $10 for members, $16 for nonmembers, and $5 for students or unemployed mathematicians.

Petition Table

A petition table will be set up in the registration area. Additional information can be found in a box on page 491 in the Eugene meeting announcement in this issue of the *Notices*.

Accommodations

Although rooms have not been blocked at the following locations, all have promised to provide the rates listed below. Participants should make their own arrangements directly with the hotel or motel of

their choice and identify themselves as attending the AMS meeting when making reservations.

The Cricket Inn, Imperial 400, and Best Western University Inn are located about four blocks from the east side of campus (approximately ten-minutes walk). The Gopher Campus Motor Lodge is within walking distance on the west side of campus, but is approximately a twenty-minute walk. The Guest House Motel and Minneapolis Plaza Hotel are located downtown, about two miles from campus, but participants staying there may take the #16 bus to the campus.

Best Western University Inn
2600 University Avenue S. E.
Minneapolis 55414
Telephone: 612-379-2313
Single $34 Double $40

Cricket Inn
2407 University Avenue S. E.
Minneapolis 55414
Telephone: 612-623-3999 or 800-622-3999
Single $25.95 Double $32.95

Gopher Campus Motor Lodge
925 S. E. 4th Street
Minneapolis 55414
Telephone: 612-331-3740
Single $27 Double $31
Triple $36

Guest House Motel
704 4th Avenue S.
Minneapolis 55415
Telephone: 612-370-1444
Single $32.50 Double $36.50

Imperial 400
2500 University Avenue S. E.
Minneapolis 55414
Telephone: 612-331-6000 or 800-368-4400
Single $26.95 Double $32.95

Minneapolis Plaza Hotel
315 Nicollet Mall
Minneapolis 55401
Telephone: 612-332-4000
Single or Double $60

Food Service

Sandwich shops and several cafeterias are open on weekdays during daytime hours in the Coffman Memorial Union, which is a five-minute walk from Vincent Hall. The Faculty Campus Club is also located in Coffman Memorial Union, where individuals may dine as the "guest" of a member. Several restaurants of varying cuisines are within a 10 or 15 minute walk from Vincent Hall; some of these are east of campus on Washington Avenue, and others are north of campus in the "Dinkytown" area. A map indicating locations will be available at the meeting registration desk.

Travel

The Minneapolis campus of the University of Minnesota is just off (east-west) U. S. Interstate Route 94, and (north-south) U. S. Interstate Route 35W. From the former, participants should take the University of Minnesota exit, and from the latter take the 4th Street/University Avenue exit. Vincent Hall is at 127 Church Street S. E., just off Washington Avenue S.E.

The Minneapolis-St. Paul International Airport is served by most major airlines, as well as by Amtrak. The Airport Taxi picks up passengers at the airport who have called for service from the airport and, depending upon destination, the cost ranges from $12 to $20. The Airport Limousine Service will take passengers to any motel in the southeast area (where the University is located) for a fee of $5 per person. Reservations **must be made in advance** by calling 612-378-3907. Other taxicabs are available at taxi stands at the airport; fares range from $12 to $16.

Parking

The University of Minnesota is a commuter campus. Therefore, parking is difficult and regulations are strictly enforced. Since several motels are within a 15 minute walk to the campus, participants are advised to leave their cars parked at the motel and walk to the meeting. Several pay parking lots are located on campus, but the rates vary and those with cheaper rates fill up very early. The hourly rate lots would cost several dollars to park for the day; however, there should be less of a problem on Saturday when the parking lots are not as congested.

Robert M. Fossum
Urbana, Illinois Associate Secretary

San Diego, November 9–10, 1984, San Diego State University

Second Announcement of the 815th Meeting

The eight hundred and fifteenth meeting of the American Mathematical Society will be held at San Diego State University in San Diego, California, on Friday and Saturday, November 9 and 10, 1984. This meeting will be held in conjunction with a meeting of the Mathematical Association of America (MAA).

Invited Addresses

By invitation of the Committee to Select Hour Speakers for Far Western Sectional Meetings, there will be two invited one-hour addresses. The speakers, their affiliations, and their titles are as follows:

JOHN GUCKENHEIMER, University of California at Santa Cruz, *Transitions to chaos and beyond.*

DRAGAN MILICIC, University of Utah, *Representation theory and $\mathcal{D}$-modules.*

Special Sessions

By invitation of the same committee, there will be six special sessions of selected twenty-minute papers. The topics of these special sessions, the names and affiliations of the mathematicians organizing them, and partial lists of speakers, are as follows:

Classical harmonic analysis, SUN-YUNG ALICE CHANG, University of California, Los Angeles. The speakers include A. Carbery, J. Garnett, D. Marshall, H. Helson, S. Hudson, K.-C. Lin, D. Sarason, B. Smith, G. Verchota, T. Wolff, M. Wilson and M. Zafran.

Graph theory and applications, J. D. ELWIN, San Diego State University. The speakers include Edward A. Bender, P. Z. Chinn, J. Donald, J. D. Elwin, R. A. Hager, A. K. Kevorkian, H. Minc, P. Salamon, and S. G. Williamson.

Representations of semi-simple Lie groups, TOM ENRIGHT, University of California, San Diego, and JOSEPH WOLF, University of California, Berkeley.

Complex analysis in honor of Stefan Warschawski, CARL H. FITZGERALD, University of California, San Diego, and F. DAVID LESLEY, San Diego State University. The speakers will include L. Ahlfors, A. Baernstein II, D. Brannan, S. Fisher, Carl H. FitzGerald, D. Hamilton, W. Hengartner, D. Lesley, L. Liao, A. Marden, D. Minda, K. Oikawa, B. Palka, Edgar Reich, B. Rodin, P. C. Rosenbloom, G. Schober, D. Shaffer, N. Suita, and E. Sylvia.

Differential geometry and mathematical physics, PETER SALAMON, San Diego State University. The speakers include R. Blattner, M. Freedman, R. Hermann, E. Ihrig, J. Nulton, G. Ruppeiner, and Peter Salamon.

Most of the papers to be presented at these special sessions will be by invitation. However, anyone submitting an abstract for the meeting who feels that his or her paper would be particularly appropriate for one of these special sessions should indicate this clearly on the abstract form and submit it by **August 17, 1984**, two weeks before the deadline for contributed papers, in order that it may be considered for inclusion. Each abstract submitted must be accompanied by payment in the amount of $15 to cover a portion of the processing costs. (Please refer to the rules on the page preceding the program for the Eugene meeting in this issue of the *Notices*.) In addition, a charge of $12 is imposed for retyping abstracts that are not in camera-ready form.

Contributed Papers

There will also be sessions for contributed ten-minute papers. Abstracts should be prepared on the standard AMS form available from the AMS office in Providence or in departments of mathematics. Abstracts should be sent to Abstracts, Editorial Department, American Mathematical Society, P. O. Box 6248, Providence, Rhode Island 02940, so as to arrive prior to the abstract deadline of **August 31, 1984**. These abstracts must also be accompanied by payment of the $15 processing charge.

MAA Program

EVERETT BULL of Pomona College will deliver an address on Saturday entitled, *Why don't you just get a bigger computer?* There will be an additional hour speaker to be announced. The Saturday luncheon will feature an invited speaker as well.

Registration

Due to the length of the program, sessions will take place all day on Friday and Saturday, November 9–10. The meeting will be primarily located at the Aztec Center, although sessions on Friday afternoon will be held in the Business Administration and Mathematics Building.

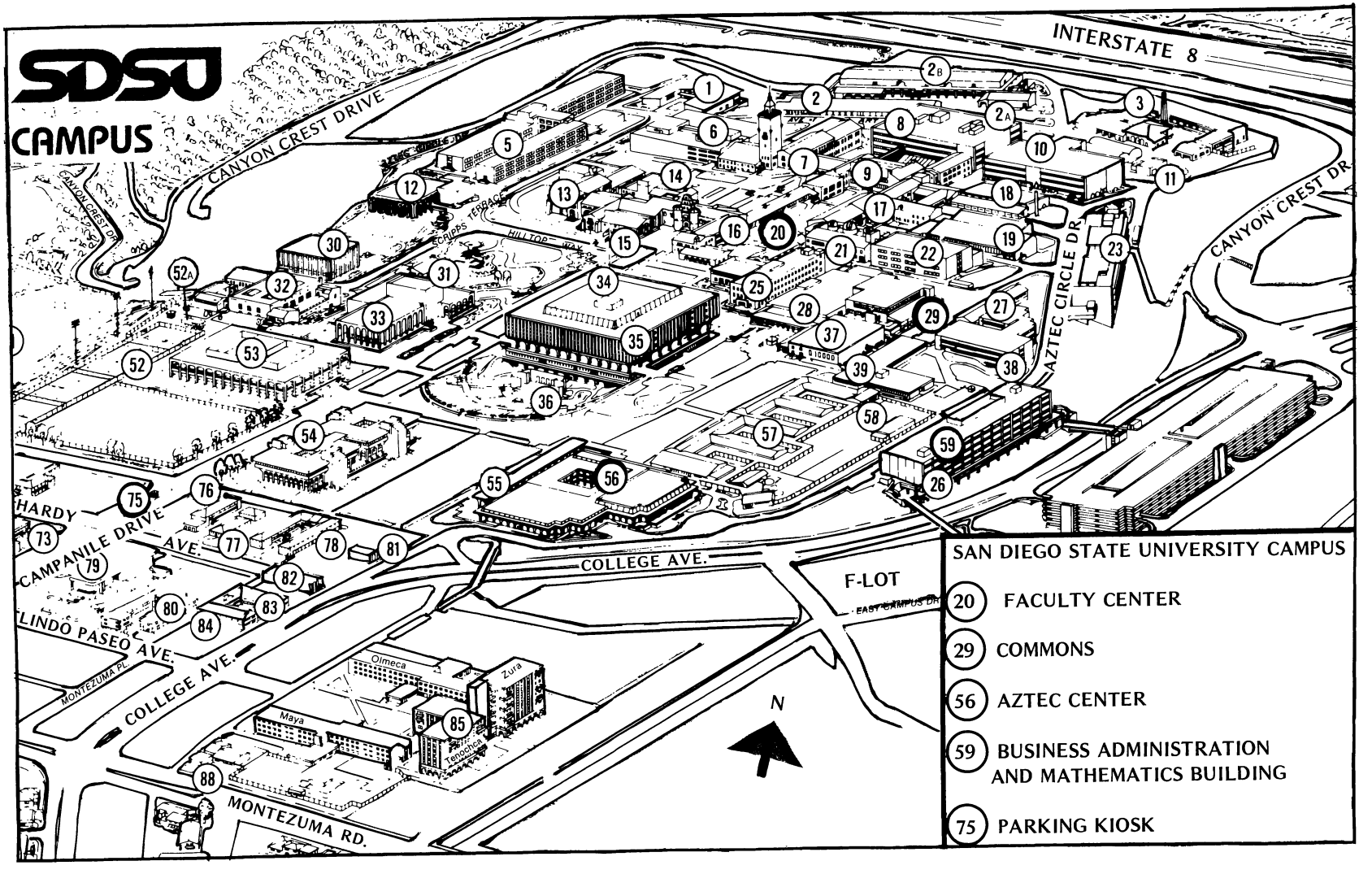
The registration desk will be located in the Aztec Center, and will be open on Friday and Saturday from 8:00 a.m. until 12:30 p.m. The registration fees are $6 for members of the AMS or MAA, $8 for nonmembers, and $2 for students or unemployed mathematicians.

Petition Table

A petition table will be set up in the registration area. Additional information can be found in a box in the Eugene meeting announcement on page 491 in this issue of the *Notices*.

Accommodations

Many motels are located six to eight miles away on the west end of Interstate Route 8, including the Ramada Inn, and several are two miles or less from campus, including the other three motels listed below. Participants should make their own reservations and identify themselves as taking part in the mathematics meeting at SDSU. On Friday and Saturday morning a van will shuttle participants, who do not have their own transportation, from the Ramada Inn to the


SDSU
CAMPUS
INTERSTATE 8
CANYON CREST DRIVE
CANYON CREST DR
AZTEC CIRCLE DR
SCRIPPS TERRACE
HILLTOP
HARDY
CAMPANILE DRIVE
AVE.
LINDO PASEO AVE.
COLLEGE AVE.
MONTEZUMA PL.
MONTEZUMA RD.
F-LOT
EAST CAMPUS DR
Olmeca
Zura
Maya
Tenochca
N
SAN DIEGO STATE UNIVERSITY CAMPUS
20 FACULTY CENTER
29 COMMONS
56 AZTEC CENTER
59 BUSINESS ADMINISTRATION AND MATHEMATICS BUILDING
75 PARKING KIOSK

campus and will return to the Ramada Inn at the end of the day.

Howard Johnson's Motor Lodge (2.0 miles)
4545 Waring Road at I-8
San Diego, CA 92120
Telephone: 619-286-7000
Single $36 Double $45

Lamplighter Inn Motel (1.5 miles)
6474 El Cajon Boulevard
San Diego, CA 92115
Telephone: 619-582-3088
Single $28 Double $33

Ramada Inn (7.75 miles)
2151 Hotel Circle South
San Diego, CA 92108
Attention: Judy Robertson
Telephone: 619-291-6500
Single $36 Double $42
Triple $47

Vagabond Inn (1.4 miles)
6440 El Cajon Boulevard
San Diego, CA 92115
Telephone: 619-286-2040
Single $36 Double $36

Social Events

Meals on Friday and Saturday can be purchased at the Commons and the Faculty-Staff Center on campus. A luncheon banquet will take place on Saturday; the cost is $7.25 per person, and tickets may be purchased at the registration desk.

Area restaurant guides and tourist booklets will also be available at the registration desk. It is hoped that discount coupons for the main tourist attractions, including the San Diego Zoo, Wild Animal Park, and Sea World will be available as well.

Travel and Local Information

San Diego is served by Amtrak and most of the major airlines. Several car rental agencies, including Avis, Budget, Greyhound, Hertz, and National, have counters at the airport terminal.

There is a bus service called ATS which offers almost periodic service (30–60 minutes) to Hotel Circle at $5 per person. The bus stop is just outside the air terminal. Taxi fares (for up to 5 people) are as follows: Airport–Hotel Circle $8, Airport–San Diego State University $15.

San Diego is reached from the north by I-5 or I-15 and from the east by I-8. Hotel Circle is near the I-5/I-8 interchange while SDSU is 10 miles east of it on I-8. Persons traveling on I-8 should take College Avenue to the south, go about one-half mile to Linda Paseo Avenue, turn right and go two blocks to Campanile Drive, turn right again and go two short blocks to the "Parking Kiosk" and obtain a free two-day guest parking permit. Then retrace the route to F-lot to park.

San Diego is well known as a tourist center. The weather in early November should be mild (high of 20°C) with rain possible but not likely. Attractions include the famous San Diego Zoo; the Wild Animal Park; Sea World; Mission Bay Park; and Tijuana, Mexico; as well as the Pacific Ocean.

Hugo Rossi
Associate Secretary

Salt Lake City, Utah

Invited Speakers and Special Sessions

Invited Speakers at AMS Meetings

The individuals listed below have accepted invitations to address the Society at the times and places indicated. For some meetings, the list of speakers is incomplete.

Minneapolis, November 1984

Jerry L. Bona
I. Martin Isaacs
Naresh C. Jain
Stephen C. Milne

San Diego, November 1984

John Guckenheimer
Dragan Milicic

Anaheim, January 1985

Ruth M. Charney
Lawrence Craig Evans
Dorian Goldfeld
Daniel Gorenstein (Colloquium Lecturer)
William Kantor
William Hamilton Meeks III
Michael Rabin (Gibbs Lecturer)
Laurence C. Siebenmann
W. Hugh Woodin

Chicago, March 1985

Michael Marcus
J. Marshall Osborn
Roger Penrose

Tucson, April 1985

George M. Bergman
Gregory Brumfiel

Worcester, April 1985

William Abikoff
Ira Gessel
Robert Thomason
Stephen Yau

Organizers and Topics of Special Sessions

The list below contains all the information about Special Sessions at meetings of the Society available at the time this issue of the *Notices* went to the printer.

The section below entitled **Information for Organizers** describes the timetable for announcing the existence of Special Sessions.

November 1984 Meeting in Minneapolis

Central Section

Deadline for organizers: Expired
Deadline for consideration: August 7, 1984

Charles Amick and Wei-Ming Ni, *Nonlinear problems in mechanics*

Robert Hardt and William P. Ziemer, *Variational methods in partial differential equations and applications*

Marian B. Pour-El, *Mathematical logic–applications to analysis, physical theory and computer science*

Joel L. Roberts and Robert Speiser, *Algebraic geometry*

Dennis White, *Enumerative combinatorics*

November 1984 Meeting in San Diego

Far Western Section

Deadline for organizers: Expired
Deadline for consideration: August 17, 1984

Sun-Yung Alice Chang, *Classical harmonic analysis*

J. D. Elwin, *Graph theory and applications*

T. Enright and J. A. Wolf, *Representations of semi-simple Lie groups*

Carl H. FitzGerald and F. David Lesley, *Complex analysis in honor of Stefan Warschawski*

Peter Salamon, *Differential geometry and mathematical physics*

Fall 1984 Meeting

Eastern Section

No Meeting Will Be Held

Fall 1984 Meeting

Southeastern Section

No Meeting Will Be Held

January 1985 Meeting in Anaheim

Associate Secretary: Hugo Rossi

Deadline for organizers: Expired
Deadline for consideration: September 26, 1984

R. Charney, *Teichmuller theory for surfaces, graphs and hyperbolic manifolds*

Murray Gerstenhaber, *Algebraic deformation theory*

K. K. Uhlenbeck, Peter Li, and W. Meeks, *Differential geometry*

March 1985 Meeting in Chicago

Central Section

Deadline for organizers: August 15, 1984
Deadline for consideration: To be announced

April 1985 Meeting in Tucson

Far Western Section

Deadline for organizers: August 15, 1984
Deadline for consideration: To be announced

Ross Beaumont, *Abelian group theory*

Daniel J. Madden, *The arithmetic of algebraic function fields of one variable*

April 1985 Meeting in Worcester

Eastern Section

Deadline for organizers: Extended to September 15, 1984
Deadline for consideration: To be announced

Spring 1985 Meeting

Southeastern Section

Deadline for organizers: August 15, 1984
Deadline for consideration: To be announced

Information for Organizers

Special Sessions at Annual and Summer meetings are held under the general supervision of the Program Committee. They are administered by the Associate Secretary in charge of the meeting with staff assistance from the Society office in Providence.

Send Proposals for Special Sessions to the Associate Secretaries

The programs of sectional meetings are arranged by the Associate Secretary for the section in question:

Far Western Section (Pacific and Mountain)
Hugo Rossi, Associate Secretary
Department of Mathematics
Institute for Advanced Study
Princeton, NJ 08540
(Telephone 609-734-8157)

Central Section
Robert M. Fossum, Associate Secretary
Department of Mathematics
University of Illinois
1409 West Green Street
Urbana, IL 61801
(Telephone 217-333-3975)

Eastern Section
W. Wistar Comfort, Associate Secretary
Department of Mathematics
Wesleyan University
Middletown, CT 06457
(Telephone 203-347-9411)

Southeastern Section
Frank T. Birtel, Associate Secretary
Department of Mathematics
Tulane University
New Orleans, LA 70118
(Telephone 504-865-5646)

As a general rule, members who anticipate organizing Special Sessions at AMS meetings are advised to seek approval at least nine months prior to the scheduled date of the meeting. No Special Sessions can be approved too late to provide adequate advance notice to members who wish to participate.

Some Special Sessions arise from an invitation to a proposed organizer issued through the Associate Secretary. Others are spontaneously proposed by interested organizers or participants. Such proposals are welcomed by the Associate Secretaries.

The number of Special Sessions at a Summer or Annual Meeting is limited to twelve. Proposals, invited or offered, which are received at least nine months prior to the meeting are screened for suitability of the topic and of the proposed list of speakers, and for possible overlap or conflict with other proposals (specific deadlines for requesting approval for Special Sessions at national meetings are given above). If necessary, the numerical limitation is enforced.

Proposals for Special Sessions should be submitted directly to the Associate Secretary in charge of the meeting (at the address given in the accompanying box). If such proposals are sent to the Providence office, addressed to the *Notices*, or directed to anyone other than the Associate Secretary, they will have to be forwarded and may not be received before the quota is filled.

In accordance with an action of the Executive Committee of the Council, no Special Session may be arranged so late that it may not be announced in the *Notices* early enough to allow any member of the Society, who wishes to do so, to submit an abstract for consideration for presentation in the Special Session before the deadline for such consideration.

Special Sessions are effective at Sectional Meetings and can usually be accommodated. They are arranged by the Associate Secretary under the supervision of the Committee to Select Hour Speakers for the section. The limitation on the number of sessions depends on the space and time available. The same restriction as for national meetings applies to the deadline for announcing Special Sessions at sectional meetings: no Special Session may be approved too late for its announcement to appear in time to allow a reasonable interval for members to prepare and submit their abstracts prior to the special early deadline set for consideration of papers for Special Sessions.

The Society reserves the right of first refusal for the publication of proceedings of any special session. These proceedings appear in the book series *Contemporary Mathematics.*

Information for Speakers

A great many of the papers presented in Special Sessions at meetings of the Society are invited papers, but any member of the Society who wishes to do so may submit an abstract for consideration for presentation in a Special Session, provided it is received in Providence prior to the special early deadline announced above and in the announcements of the meeting at which the Special Session has been scheduled.

Abstracts of papers submitted for consideration for presentation at a Special Session must be received by the Providence office (Editorial Department, American Mathematical Society, Post Office Box 6248, Providence, RI 02940) by the special deadline for Special Sessions, which is usually three weeks earlier than the deadline for contributed papers for the same meeting. The Council has decreed that no paper, whether invited or contributed, may be listed in the program of a meeting of the Society unless an abstract of the paper has been received in Providence prior to the deadline.

January 1985 Meeting in Anaheim

Special Sessions received after deadline for organizers

M. Aschbacher, *Finite group theory*

W. A. Harris and George R. Sell, *Ordinary differential equations*

J. P. Henderson and D. J. Garity, *Infinite dimensional topology*

N. D. Hulkover, *Celestial mechanics*

Mark Pinsky, *Stochastic differential geometry*

Special Meetings

THIS SECTION contains announcements of meetings of interest to some segment of the mathematical public, including *ad hoc*, local, or regional meetings, and meetings or symposia devoted to specialized topics, as well as announcements of regularly scheduled meetings of national or international mathematical organizations. (Information on meetings of the Society, and on meetings sponsored by the Society, will be found inside the front cover.)

AN ANNOUNCEMENT will be published in the *Notices* if it contains a call for papers, and specifies the place, date, subject (when applicable), and the speakers; a second full announcement will be published only if there are changes or necessary additional information. Once an announcement has appeared, the event will be briefly noted in each issue until it has been held and a reference will be given in parentheses to the month, year and page of the issue in which the complete information appeared.

IN GENERAL, announcements of meetings held in North America carry only date, title of meeting, place of meeting, names of speakers (or sometimes a general statement on the program), deadlines for abstracts or contributed papers, and source of further information. Meetings held outside the North American area may carry more detailed information. All communications on special meetings should be sent to the Editor of the *Notices*, care of the American Mathematical Society in Providence.

DEADLINES for entries in this section are listed on the inside front cover of each issue. In order to allow participants to arrange their travel plans, organizers of meetings are urged to submit information for these listings early enough to allow them to appear in more than one issue of the *Notices* prior to the meeting in question. To achieve this, listings should be received in Providence SIX MONTHS prior to the scheduled date of the meeting.

October 2, 1983–September 29, 1984. **Mathematisches Forschungsinstitut Oberwolfach** (Weekly Conferences), Federal Republic of Germany. (October 1983, p. 669; January 1984, p. 82)

1984. **European Mechanics Colloquia**, Various locations. (November 1983, p. 798)

August 21, 1984–May 20, 1985. **Special Year in Logic**, University of Illinois, Urbana, Illinois.

Program: Visitors for the year will include A. Macintyre, M. Yasumoto, G. Higman, and J. Knight. There will be other visitors for shorter periods of time.

Information: Carl G. Jockusch, Jr., Department of Mathematics, University of Illinois, 1409 West Green Street, Urbana, Illinois 61801, 217-333-2042.

September 1, 1984–August 31, 1985. **Program on Continuum Physics and Partial Differential Equations**, Institute for Mathematics and its Applications, University of Minnesota, Minneapolis, Minnesota.

Program: There will be several conferences held during the year. Topics include: Equilibrium and Stability Questions in Continuum Physics and Partial Differential Equations; Homogenization and Effective Moduli of Materials and Media; Oriented Polymers and Liquid Crystals; Amorphous Polymers and Non-Newtonian Fluids; Oscillation Theory, Computation, and Methods of Compensated Compactness; Metastability and Incompletely Posed Problems; and Dynamical Problems in Continuum Physics.

Information: Susan Anderson, Institute for Mathematics and its Applications, 514 Vincent Hall, 206 Church Street S.E., University of Minnesota, Minneapolis, Minnesota 55455, 612-373-0355.

1984–1985. **Academic Year Devoted to Nonlinear Differential Equations**, The Mittag-Leffler Institute, Djursholm, Sweden. (February 1984, p. 194)

1984–1985. **Special Year Devoted to Reacting Flows: Combustion and Chemical Reactors**, Center for Applied Mathematics, Cornell University, Ithaca, New York. (April 1984, p. 333)

Spring 1985. **Special Semester in the Theory of Singularities**, Banach Center, Warsaw, Poland.

Information: S. Lojasiewicz, Institute of Mathematics UJ, 30059 Krakow, Reymonta 4, Poland.

AUGUST 1984

1–3. **Second Workshop on Hadronic Mechanics**, Center A. Volta, Villa Olmo, Como Lake, Italy. (February 1984, p. 198)

1–3. **Fifth ASCE–EMD Specialty Conference: Engineering Mechanics in Civil Engineering**, University of Wyoming, Laramie, Wyoming. (November 1983, p. 800)

1–15. **Second Meeting on Nonstandard Analysis**, Qinhuangdao, Hebei Province, People's Republic of China.

Information: Department of Mathematics, Tianjin Teacher's University, Tianjin 300071, People's Republic of China.

2–3. **Conference on Lattice Path Combinatorics and Applications**, McMaster University, Ontario, Canada. (June 1984, p. 396)

5–8. **Fourth Workshop on Maximum Entropy and Bayesian Methods in Applied Statistics: Maximum Entropy Methods in Inversion**, University of Calgary, Calgary, Alberta, Canada. (June 1984, p. 396)

6–10. **International Conference on Approximation Theory and Applications**, Memorial University of Newfoundland, St. John's, Newfoundland, Canada. (February 1984, p. 198)

6–26. **International Conference on Infinite Group Theory and Related Areas**, Crete, Greece. (February 1984, p. 198)

13–17. **Twelfth Australasian Conference on Combinatorial Mathematics and Computing**, Perth, Australia. (April 1984, p. 336)

13–18. **Nineteenth Nordic Congress of Mathematicians**, Reykjavík, Iceland. (February 1984, p. 198)

15–25. **Romanian-Japanese Colloquium on Finsler Geometry**, Iaşi, Braşov, and Bucharest, Romania.

Information: Radu Miron, Faculty of Mathematics, University of Iaşi, 6600 Iaşi, Romania.

19–25. **Sixteenth International Congress of Theoretical and Applied Mechanics**, Lyngby, Denmark. (October 1983, p. 673)

19–September 5. **XIVeme École d'Été de Calcul des Probabilités**, Saint-Flour, Cantal, France. (February 1984, p. 199)

20–24. **Second Latin-American Congress on Operational Research and Systems Engineering**, Buenos Aires, Argentina.

Information: Hugo Scolnik, 1145 Santa Fe, 1059 Buenos Aires, Argentina.

20–25. **Conference on Geometry and Operator Algebras**, Berkeley, California.

Information: Mathematical Sciences Research Institute, 2223 Fulton Street, Room 603, Berkeley, California 94720, 415-642-0143.

20–25. **Fourth International Conference on Representations of Algebras**, Carleton University, Ottawa, Canada. (February 1984, p. 199)

24–30. **Fifth International Congress on Mathematics Education**, University of Adelaide, Australia. (June 1982, pp. 331, 376; November 1983, p. 800)

26–September 4. **Conference on Buildings and the Geometry of Diagrams**, Como, Italy.

Invited Lecturers: Francis Buekenhout (Université Libre de Bruxelles); William M. Kantor (University of Oregon); Jacques Tits (Collège de France).

Information: Director, Fondazione C.I.M.E., c/o Istituto Matematico "U. Dini", Viale Morgagni, 67/A, I-50134 Firenze, Italy.

26–September 4. **Conference on Schrödinger Operators**, Como, Italy.

Chairmen: S. Agmon, Jerusalem; V. Enss, Berlin; B. Simon, Pasadena.

Information: Fondazione C.I.M.E., c/o Istituto Matematico "U. Dini", Viale Morgagni, 67/A, I-50134 Firenze, Italy.

27–29. **Third ACM SIGACT-SIGOPS Symposium on Principles of Distributed Computing (PODC)**, Vancouver, Canada. (February 1984, p. 199)

27–31. **COMPSTAT 1984: Sixth Symposium on Computational Statistics**, Prague, Czechoslovakia. (November 1983, p. 800)

27–September 1. **Journées d'Algèbre Non Commutative**, CIRM-Luminy, France. (June 1984, p. 396)

27–September 14. **Tunis Summer School of Harmonic Analysis**, Tunis, Tunisia. (June 1984, p. 397)

28–31. **International Conference on Vector and Parallel Processors in Computational Science II**, Keble College, Oxford, England. (April 1984, p. 336)

SEPTEMBER 1984

3–7. **Mathematics of Multicriteria Optimisation**, Udine, Italy. (June 1984, p. 397)

3–7. **Sixteenth European Meeting of Statisticians**, Marburg, Federal Republic of Germany. (February 1984, p. 199)

3–8. **Eleventh International Symposium on Mathematical Foundations of Computer Science**, Prague, Czechoslovakia.

Information: Vaclav Koubek, Charles University, 25 Malostranske, CS-11800 Prague 1, Czechoslovakia.

4–6. **Colloque International du CNRS: La Modélisation de l'Accumulation et de la Répartition des Patrimoines**, Paris, France.

Information: C.N.R.S., Dir. Rel. Ext., Bureau Aff. Gén., 15 quai Anatole France, 75700 Paris, France.

5–15. **Workshop on Contemporary Problems in Continuum Physics and Partial Differential Equations**, University of Minnesota, Minneapolis, Minnesota. (June 1984, p. 397)

6–9. **Conference on Applied Mathematics I**, Bratislava, Czechoslovakia. (June 1984, p. 397)

6–11. **Journées sur la Théorie Algébrique des Graphes**, Le Mans, France. (June 1984, p. 397)

10–14. **VIII Escola de Álgebra**, Rio de Janeiro, Brazil. (April 1984, p. 336)

10–14. **Second International Congress of Biomathematics**, Buenos Aires, Argentina. (February 1984, p. 199)

10–15. **Journées sur les Méthodes Semiclassiques en Mécanique Quantique**, CIRM-Luminy, France. (June 1984, p. 397)

10–16. **International Conference on Stochastic Optimisation**, Kiev, Russia. (June 1984, p. 397)

11–13. **Fourth IMA International Conference on Control Theory**, University of Cambridge, England. (April 1984, p. 336)

12–17. **Tenth International Conference on Nonlinear Oscillations**, Varna, Bulgaria. (February 1984, p. 199)

16–23. **Tenth International Conference on Nonlinear Oscillations**, The International House of Scientists "J. Curie", Varna, Bulgaria. (January 1984, p. 86)

18–19. **Conference on Computer Arithmetic and Programming Languages for Scientific Computation**, Mathematics Research Center, University of Wisconsin, Madison, Wisconsin.

Topics: Conference topics will include the theory of optimal computer arithmetic, accurate solution of algebraic problems and evaluation of expressions, solution of functional equations and optimization problems with guaranteed bounds; the sequencing problem in high accuracy algorithms and the implementation of an optimal arithmetic in hardware and software; software for scientific computation: Pascal-SC, the ACRITH package, and an extension of FORTRAN (a scientific computation module for FORTRAN 8X).

Invited Lecturers: U. Kulisch, Ch. Ullrich, G. Bohlender, E. Kaucher, J. Wolff van Gudenberg, University of Germany; J. Bleher, A. Roeder, H. Boehm, S. Rump, IBM Germany Research and Development; H. J. Stetter, W. Auzinger, Technical University of Vienna; W. Miranker, IBM T. J. Watson Research Laboratory; G. Corliss, Marquette University; L. Rall, Mathematics Research Center, University of Wisconsin, Madison.

Information: Mrs. Gladys Moran, Conference Secretary, Mathematics Research Center, University of Wisconsin-Madison, 610 Walnut Street, Madison, Wisconsin 53705, 608-263-2661.

18–21. **Tenth Undergraduate Mathematics Conference**, University of Nottingham, England.

Information: Sheila Dwyer, Shell Centre for Mathematical Education, University of Nottingham, Nottingham NG7 2RD, England.

23–October 6. **Course on Computation Theory**, Udine, Italy. (February 1984, p. 199)

24–27. **Fourth Kärntner Symposium für Didaktik der Mathematik: Empirische Untersuchungen zum Lernen und Lehren in der Mathematik**, Klagenfurt, Austria.

Information: Fourth Kärntner Symposium für Didaktik und Mathematik, Institut für Mathematik, Universität für Bildungswissenschaften, Universitätsstrasse 65, A-9010 Klagenfurt, Austria.

24–28. **VII Congreso de Ecuaciones Diferenciales y Aplicaciones**, University of Granada, Granada, Spain. (April 1984, p. 336)

25–27. **Second Symposium Simulationstechnik**, Wien, Austria.

Chairmen: F. Breitenecker, Wien; W. Kleinert, Wien.

Information: W. Kleinert, Hybridrechenzentrum, Technische Universität Wien Gusshausstrasse 27-29, A-1040 Wien, Austria.

26–29. **Fifth Aachen Symposium on Mathematical Methods in Signal Processing**, Aachen, Federal Republic of Germany. (February 1984, p. 199)

26–30. **Conference on Renaissance Mathematics**, Keble College, Oxford, England. (April 1984, p. 337)

28–29. **Twelfth Annual Mathematics and Statistics Conference**, Miami University, Oxford, Ohio. (February 1984, p. 199)

28–29. **Ohio Delta Chapter of Pi Mu Epsilon Eleventh Annual Student Conference**, Miami University, Oxford, Ohio. (February 1984, p. 199)

OCTOBER 1984

1–3. **Congrès International sur l'Intelligence Artificielle et Potentiel d'Applications**, Chartreuse de Villeneuve les Avignon, France.

Information: Fond. M. Mérieux, 17 rue Bourgelat, 69002 Lyon, France.

6–10. **NSF-CBMS Regional Conference on Minimal Surfaces and their Applications to Low-Dimensional Topology**, Oklahoma State University, Stillwater, Oklahoma.

Principal Speaker: William Meeks (Rice University).

Invited Speakers: Joel Hass (University of Michigan, Ann Arbor), H. Blaine Lawson (SUNY, Stony Brook), Richard Schoen (Stanford University).

Support: A grant has been received from the National Science Foundation. Funds for travel and subsistence will be available to approximately 25 participants.

Deadline for Applications: August 20, 1984.

Information and Applications: James W. Maxwell, Conference Coordinator, Department of Mathematics, Oklahoma State University, Stillwater, Oklahoma 74078.

8–10. **Journées d'Arithmétique et Analyse Harmonique**, Paris, France.

Organizers: P. Gérardin, F. Rodier.

Information: Société Mathématique de France, Boîte postale 126-05, 75226 Paris Cedex 05, France.

8–10. **Association for Computing Machinery 1984 Annual Conference**, San Francisco Hilton Hotel, San Francisco, California. (February 1984, p. 200)

10–12. **Symposium on Multi-Objective Optimisation**, University of Nebraska, Lincoln, Nebraska.

Sponsors: University of Nebraska Water Resources Center, Department of Mathematics and Statistics, Department of Industrial and Management Systems Engineering.

Information: Ann Bleed, Water Resources Center, 310 Agricultural Hall, University of Nebraska, Lincoln, Nebraska 68583-0710, 402-472-3305.

10–12. **International Conference on Special Functions: Theory and Computation**, University of Turin, Turin, Italy. (April 1984, p. 337)

10–13. **VI Convegno Nasionale di Relatività Generale e Fisica della Gravitasione**, Firenze, Italy.

Information: R. Fabbri, Comitato Org. VI Conv. Relat. Gener., Ist. Fis. Sup., 3 via S. Maria, I-50139 Firenze, Italy.

11–16. **Workshop on Surfaces**, Berkeley, California.

Information: Mathematical Sciences Research Institute, 2223 Fulton Street, Room 603, Berkeley, California 94720, 415-642-0143.

12–13. **Symposium on *Flatland* and the Fourth Dimension**, Brown University, Providence, Rhode Island. (April 1984, p. 337)

12–13. **Fourth Southeastern-Atlantic Regional Conference on Differential Equations**, Wake Forest University, Winston-Salem, North Carolina. (April 1984, p. 337)

13–14. **Sixteenth Midwest Partial Differential Equations Conference**, University of Illinois, Chicago, Illinois.

Information: David S. Tartakoff or Jeff Lewis, Department of Mathematics, University of Illinois at Chicago, P. O. Box 4348, Chicago, Illinois 60680.

15–17. **Society of Engineering Science Annual Meeting**, Blacksburg, Virginia. (November 1983, p. 800)

15–18. **International Symposium on Orthogonal Polynomials and their Applications**, Bar-le-Duc, France. (October 1983, p. 673)

16–18. **Symposium on Viscoelasticity and Rheology**, Mathematics Research Center, University of Wisconsin, Madison, Wisconsin. (April 1984, p. 337)

17–19. **Congresso Annuale AICA: Innovasione Tecnologica e Innovasione nella Società**, Rome, Italy. (June 1984, p. 397)

19–20. **Sixth Midwest Probability Symposium**, Northwestern University, Evanston, Illinois. (June 1984, p. 397)

22–24. **ASA-IASC-SIAM Conference on Frontiers in Computational Statistics**, Boston Park Plaza Hotel, Boston, Massachusetts. (April 1984, p. 337)

22–26. **Journées d'Étude en Statistique**, CIRM-Luminy, France. (June 1984, p. 397)

22–26. **Workshop on Homogenisation and Effective Moduli**, University of Minnesota, Minneapolis, Minnesota. (June 1984, p. 397)

22–26. **PROTEXT I: First International Conference, Exhibition and Workshop on Text Processing Systems**, Gresham Hotel, Dublin, Ireland. (April 1984, p. 337)

24–26. **Twenty-fifth Annual IEEE Symposium on Foundations of Computer Science**, Singer Island, West Palm Beach, Florida. (June 1984, p. 397)

25–28. **American Mathematical Association of Two-Year Colleges' Annual Convention**, New York, New York. (November 1983, p. 800)

29–November 2. **Second Southeast Asian Logic Conference**, Bangkok, Thailand. (April 1984, p. 337)

NOVEMBER 1984

7–9. **Symposium on Foundations of Computer Science**, Tucson, Arizona. (February 1984, p. 200)

7–10. **Journées d'Arithmétique et Analyse Harmonique**, Université Paris VII, Paris, France.

Topic: Automorphic forms on reductive and metaplectic groups, and their relations with arithmetic on local and global fields.

Participants: C. Bushnell, A. Frohlich, G. Harder, U. Jannsen, P. Kutzko, J. Mennicke, H. Opolka, S. J. Patterson, J. Schwermer, U. Stuhler, M. Tadic.

Information and Applications: François Rodier, U.E.R. de Mathématiques, Université Paris 7, Tour 45-55, 5e étage, 2, Place Jussieu, 75251 Paris Cedex 05, France.

12–December 14. **Autumn Course on Semigroups, Theory and Applications**, Miramare-Trieste, Italy.

Information: International Centre for Theoretical Physics, Autumn Course on Semigroups, P. O. Box 586, I-34100 Trieste, Italy.

14–19. **Computer Graphics '85**, Dallas Convention Center, Dallas, Texas. (April 1984, p. 337)

17–19. **Symposium on Complexity of Approximately Solved Problems**, Columbia University, New York, New York. (April 1984, p. 338)

22–23. **Fifth Rencontre Franco-Belge de Statistique**, CIRM-Luminy, France. (June 1984, p. 389)

26–December 7. **Workshop on the Theory of Valuated Abelian Groups**, University of Colorado, Colorado Springs, Colorado.

Program: There will be a series of ten lectures by Roger Hunter and Elbert Walker of the New Mexico State University. There will also be talks by other participants.

Information: K. M. Rangaswamy, Department of Mathematics, University of Colorado at Colorado Springs, Colorado Springs, Colorado 80933.

DECEMBER 1984

10–12. **Journées Probabilistes**, CIRM-Luminy, France. (June 1984, p. 398)

10–20. **Second International Conference on Algebraic Geometry**, La Rabida, Spain. (June 1984, p. 398)

JANUARY 1985

7–11. **NSF-CBMS Regional Conference on Multivariate Estimation**, University of Florida, Gainesville, Florida. (June 1984, p. 398)

7–18. **Workshop on Three-Manifolds**, Berkeley, California.

Information: Mathematical Sciences Research Institute, 2223 Fulton Street, Room 603, Berkeley, California 94720, 415-642-0143.

10–19. **Conference on Solitons and Coherent Structures**, The Institute for Theoretical Physics, University of California, Santa Barbara, California.

Program: The conference will focus on models which are (nearly) integrable and represent physical systems which exhibit some form of coherent structure.

Speakers: M. Ablowitz (Clarkson University), R. Baxter (Australian National University, Canberra), F. K. Browand (U.S.C.), F. Calogero (University of Rome), V. J. Emery (Brookhaven), H. Flaschka (University of Arizona), D. Finkelstein (Georgia Tech.), J. Golub (Haverford College), J. Greene (G. A. Tech., La Jolla), D. Haldane (U.S.C.), R. Hirota (Hiroshima), D. Kaup (Clarkson University), A. Luther (NORDITA), J. Marsden (University of California at Berkeley), E. Newman (University of Pittsburgh), S. Orszag (Princeton University), G. Wilson (Oxford University), and N. Zabusky (University of Pittsburgh).

Coordinators: D. K. Campbell, M. Kruskal, A. Newell, R. Schrieffer, and H. Segur.

Deadline for Abstracts: October 15, 1984.

Information: The Director, Institute for Theoretical Physics, University of California, Santa Barbara, California 93106.

21–24. **SEG-SIAM-SPE Conference on Mathematical and Computational Methods in Seismic Exploration and Reservoir Modeling**, Houston, Texas.

Invited Speakers: Sven Treitel (Amoco Production Company); William W. Symes (Michigan State University); N. Bleistein (Colorado School of Mines); Howard L. Taylor (Cray Research, Dallas); Donald W. Peaceman (Exxon Production Research Company); Kahlid Aziz (Stanford University); James G. Glimm (Courant Institute of Mathematical Sciences); Thomas F. Russell (Marathon Oil Company); Jim Douglas Jr. (University of Chicago); Andrew H. Sherman (J. S. Nolen & Associates); Martin H. Schultz (Yale University).

Deadline for Abstracts: September 4, 1984.

Information: Society for Industrial and Applied Mathematics, 117 South 17th Street, Suite 1405, Philadelphia, Pennsylvania 19103, 215-564-2929.

FEBRUARY 1985

18–21. **Conference on Mathematical Analysis and its Applications**, Kuwait University, Kuwait.

Topics: Suggested topics include differential equations, numerical analysis, approximation theory, and functional analysis.

Deadline for Abstracts: October 1, 1984.

Information: Department of Mathematics, Kuwait Universtiy, P.O. Box 5969, Kuwait, Kuwait.

MARCH 1985

26–28. **M. C. Escher: An Interdisciplinary Congress**, University of Rome, Rome, Italy.

Topics: Escher and symmetry, Escher and geometry, Escher and visual perception, Escher and mathematical education, Escher and the history of art.

Invited Speakers: Speakers will include H. S. M. Coxeter, R. Penrose, R. Gregory, D. Macgillavry, D. Hofstadter, G. Rigault, A. M. Liquori, R. Grünbaum, D. Schattschneider.

Deadline for Papers: November 30, 1984.

Information: M. Emmer, Dip. to di Matematica, Ist. "G. Castelnuovo", Università "La Sapienza", Piazzale A. Moro, 00100 Rome, Italy.

APRIL 1985

17–19. **Symposium on Complexity of Approximately Solved Problems**, Columbia University, New York, New York.

Topics: Suggested topics include distributed computation, approximate solution of hard problems, applied mathematics, signal processing, numerical analysis, computer vision, remote sensing, fusion of information, prediction, estimation, control, decision theory, mathematical economics, optimal recovery, seismology, information theory, design of experiments, stochastic scheduling.

Invited Speakers: L. Blum (Mills College); L. Hurwicz (University of Minnesota); J. Kadane (Carnegie-Mellon University); H. T. Kung (Carnegie-Mellon University); M. Milanese (Politecnico di Torino); J. Pearl (UCLA); S. Reiter (Northwestern University); K. Sikorski (Columbia University); J. F. Traub (Columbia University); A. G. Werschulz (Fordham University); J. Halpern (IBM); D. Johnson (AT&T-Bell Laboratories); R. Karp (Berkeley); D. Lee (Columbia University); C. H. Papadimitriou (Stanford University); M. Rabin (Harvard University, Hebrew University); A. Schönhage (University of Tübingen); S. Smale (Berkeley); G. Wasilkowski (Columbia University, University of Warsaw); H. Woźniakowski (Columbia University, University of Warsaw).

Deadline for Abstracts: January 15, 1985.

Information: Computer Science Department, Columbia University, New York, New York 10027.

MAY 1985

1–3. **Alaska Statistics Conference**, Juneau, Alaska.

Call for Papers: Papers in all areas of applied, theoretical and methodological statistics are welcome, as well as papers in other areas which deal with the use of statistical techniques in the solution of real-world problems.

Deadline for Papers: December 31, 1984.

Information: Amir D. Aczel, School of Business and Public Administration, University of Alaska, Juneau, 1108 F Street, Juneau, Alaska 99801.

16–21. **Workshop on Differential Geometry**, Berkeley, California.

Information: Mathematical Sciences Research Institute, 2223 Fulton Street, Room 603, Berkeley, California 94720, 415-642-0143.

23–June 1. **Workshop on Four-Manifolds and Geometry**, Berkeley, California.

Information: Mathematical Sciences Research Institute, 2223 Fulton Street, Room 603, Berkeley, California 94720, 415-642-0143.

26–June 2. **International Conference on Functional-Differential Systems and Related Topics IV**, Jachranka, Poland.

Information: Danuta Przeworska-Rolewicz, Mathematical Institute, Polish Academy of Sciences, Śniadeckich 8, 00-950 Warsaw, Poland.

JUNE 1985

5–14. **Conference on Geometry and Operator Algebras**, Berkeley, California.

Information: Mathematical Sciences Research Institute, 2223 Fulton Street, Room 603, Berkeley, California 94720, 415-642-0143.

19–21. **Fourth International Conference on the Numerical Analysis of Semiconductor Devices and Integrated Circuits**, Dublin, Ireland. (June 1984, p. 398)

24–28. **Aspects of Positivity in Functional Analysis**, Mathematisches Institut der Universität Tübingen, Federal Republic of Germany.

Invited Speakers: T. Ando (Sapporo); H. Bauer (Erlangen); E. B. Davies (London); J. Goldstein (Tulane); T. Kato (Berkeley); H. König (Saarbrücken); J. Lindenstrauss (Jerusalem); H. P. Lotz (Urbana); G. Lumer (Mons); W. A. J. Luxemburg (Pasadena).

Program: There will be workshops on one-parameter semigroups of positive operators on function spaces and operator algebras.

Information: Mathematisches Institut der Universität Tübingen, Auf der Morgenstelle 10, D-7400 Tübingen, Federal Republic of Germany.

JULY 1985

16–19. **Second International Conference on the Teaching of Mathematical Modelling**, University of Exeter, Exeter, England.

Information: Sally Williams, Conference Secretary, University of Exeter, St. Lukes, Exeter, EX1 2LU, England.

31–August 8. **Symposium on the Transmission of Mathematical Science**, Berkeley, California. (June 1984, p. 398)

SEPTEMBER 1985

2–12. **NATO Advanced Study Institute: Advances in Microlocal Analysis**, Il Ciocco, Castelvecchio-Pascoli, Italy.

Program: The institute will cover recent applications of microlocal analysis to linear and nonlinear questions.

Lecturers: G. Bengel (West Germany); L. Cattabriga (Italy); G. Duff (Canada); F. G. Friedlander (United Kingdom); P. Laubin (Belgium); G. Lebeau (France); R. Melrose (U.S.A.); P. Schapira (France); J. Sjostrand (France), S. Wakabayashi (Japan).

Support: Limited support is available from NATO.

Deadline for Application: June 15, 1985. Participation is limited to 80.

Information: H. G. Garnir, Department of Mathematics, University of Liège, 15, avenue des Tilleuls, B-4000 Liège, Belgium.

17–19. **International Symposium on Numerical Analysis**, Madrid, Spain.

Organizers: Charles University of Prague, Polytechnical University of Madrid.

Invited Speakers: W. Hackebusch (Germany); Yu. Kuznetsov (USSR); J.-L. Lions (France); G. I. Marchuk (USSR); E. L. Ortiz (United Kingdom); O. Pironneau (France); J. Whiteman (United Kingdom).

Deadline for Papers: January 31, 1985.

Information: Carlos Vega, Faculty of Computer Sciences, Polytechnical University of Madrid, Carretera de Valencia, km 7, Madrid-31, Spain.

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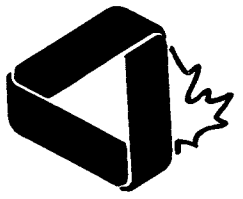
AUGUST 1986

3–11. **International Congress of Mathematicians**, Berkeley, California. (February 1984, p. 159)



CONFERENCE PROCEEDINGS OF THE CANADIAN MATHEMATICAL SOCIETY
(ISSN 0731-1036)

Second Edmonton Conference on Approximation Theory

Zeev Ditzian, Amram Meir, Sherman D. Riemenschneider, and Ambikeshwar Sharma, Editors

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1980 *Mathematics Subject Classifications*: 41-06; 41A10, 41A15, 41A20, 42A10

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Africa

• Nigerian Mathematical Society

Apply to: Christopher O. Imoru (Secretary), Nigerian Mathematical Society, Department of Mathematics, University of Ife, Ile-Ife, Nigeria.

Dues: $10; payable to the Treasurer, Nigerian Mathematical Society, Department of Mathematics, University of Benin, Benin City, Nigeria.

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Asia

• Allahabad Mathematical Society

Apply to: S. R. Sinha, Secretary, Allahabad Mathematical Society, 5, C. Y. Chintamani Road, Allahabad-211002, India.

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About the author:

William Arveson received degrees from the California Institute of Technology (B.S.) and the University of California, Los Angeles (M.A., Ph.D.). He was a Benjamin Peirce instructor at Harvard University and has been at the University of California, Berkeley since 1968, where he is currently professor of mathematics. He has held fellowships or visiting positions at the University of Newcastle, the University of California, San Diego, and the Mittag-Leffler Institute, and has been a Guggenheim fellow and a Miller research professor at Berkeley. His research interests include operator algebras, automorphism groups, and the probabilistic aspects of quantum theory; he has published many papers on operator algebras, and a book on C^*-algebras.

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Numerical Analysis

Gene H. Golub and Joseph Oliger, Editors

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Stefan A. Burr, Editor

Proceedings of Symposia in Applied Mathematics
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Introduction to the Theory of Linear Nonselfadjoint Operators

I. C. Gohberg and M. G. Kreĭn

translated by **A. Feinstein**

Translations of Mathematical Monographs
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Personal Items

A. T. Bharucha-Reid, distinguished Professor of Mathematics, Department of Mathematics and Computer Science, The Atlanta University, has been awarded an honorary doctor of science degree by Syracuse University.

M. R. Chowdhury of Jahangirnagar University, Savar, Dhaka (Bangladesh) has moved to the University of Dhaka.

Mark G. Davidson of the University of California, Irvine, has been appointed to an assistant professorship at Louisiana State University, Baton Rouge.

J. Robert Dorroh of Louisiana State University, Baton Rouge, will assume the duties of Chairman of the Department of Mathematics at that institution in August 1984.

William G. Dwyer of the University of Notre Dame will assume the duties of Chairman of the Department of Mathematics at that institution in August 1984.

Lawrence C. Eggan of Illinois State University has been appointed Professor and Chairman of Applied Computer Science at that institution.

Leo A. Goodman, Charles L. Hutchinson Distinguished Service Professor of Statistics and Sociology at the University of Chicago, had the honorary degree of Doctor of Science conferred upon him by Syracuse University at commencement ceremonies in May. This honor was bestowed on Professor Goodman in recognition of his distinguished contributions in the fields of statistics and sociology.

John A. Hildebrant of Louisiana State University, Baton Rouge, has been promoted to a professorship at that institution.

J. William Hoffman of Louisiana State University, Baton Rouge, has been promoted to an associate professorship at that institution.

Joan Hutchinson has been promoted to the rank of Associate Professor of Mathematics at Smith College.

David L. Johnson of Texas A&M University, College Station, has been appointed to an associate professorship at Lehigh University.

John P. Nolan of the University of Zambia has been appointed to an assistant professorship at Kenyon College.

Leonard F. Richardson of Louisiana State University, Baton Rouge, has been promoted to a professorship at that institution.

Randolph J. Schilling of Courant Institute of Mathematical Sciences, New York University, has been appointed to an assistant professorship at Louisiana State University, Baton Rouge.

Stan Wagon has been promoted to the rank of Associate Professor of Mathematics at Smith College.

Lutz Weis of the University of Kaiserslautern has been appointed to an associate professorship at Louisiana State University, Baton Rouge.

Daniel J. Yaniro, Jr., of Northwestern University has been appointed to an assistant professorship at Lehigh University.

Joseph E. Yukich of Strasbourg University, France, has been appointed to an assistant professorship at Lehigh University.

Deaths

J. Richard Büchi, Professor of Mathematics and Computer Sciences at Purdue University, died on April 11, 1984 at the age of 60. He was a member of the Society for 34 years.

George L. Gross of Huntington, New York, died on October 24, 1980 at the age of 69. He was a member of the Society for 43 years.

Norman Miller of Kingston, Ontario, Canada, died on May 31, 1984 at the age of 94. He was a member of the Society for 64 years.

Gladys Cecilia Mol of Minneapolis, Minnesota died on December 10, 1983 at the age of 31. She was a member of the Society for 1 year.

Charles Bradfield Morrey, Jr., Professor Emeritus of the University of California, Berkeley, died on April 29, 1984 at the age of 77. He was a member of the Society for 51 years. (See the News and Announcements section in this issue of the *Notices*.)

Merrill Edward Shanks, Professor Emeritus of Mathematics and Aerodynamics, Purdue University, died on April 28, 1984, in Tempe, Arizona, at the age of 72. He was a member of the Society for 49 years.

George Y. Sosnow, of Miami Beach, Florida, died on September 1, 1982. He was a member of the Society for 55 years.

Emmet C. Stopher, Professor Emeritus at the State University of New York, College at Oswego, died on September 1, 1983 at the age of 73. He was a member of the Society for 48 years.

Robert Tates of Purdys, New York, died on December 24, 1983 at the age of 57. He was a member of the Society for 28 years.

Stanislaw M. Ulam, Professor of Biomathematics, University of Colorado Medical School, died on May 13, 1984 in Santa Fe, New Mexico, at the age of 75. He was a member of the Society for 48 years.

Visiting Mathematicians
(*Supplementary List*)

The following lists of visiting mathematicians include both foreign mathematicians coming to the United States and Canada, and Americans visiting abroad. The original lists appeared on pages 403–405 of the June 1984 *Notices*.

American Mathematicians Visiting Abroad

Name and Home Country	Host Institution	Field of Special Interest	Period of Visit
Anderson, Douglas R. (U.S.A.)	Odense University, Denmark	Topology	1/85 - 5/85
Bruen, Aiden A. (Canada)	Technical University of Eindhoven, The Netherlands	Combinatorics and Finite Geometries	9/84 - 12/84
	Technische Universitat Braunschweig, West Germany	Combinatorics and Finite Geometries	1/85 - 6/85
Korányi, Adam (U.S.A.)	University of Strasbourg, France	Harmonic Analysis	8/84 - 5/85
Shapiro, Jack (U.S.A.)	Israel Institute of Technology	Algebra	1/85 - 5/85

Visiting Foreign Mathematicians

Åberg, Hans (Sweden)	Institute for Advanced Study	Homology of Abstract Groups	9/84 - 4/85
Andersen, Henning H. (Denmark)	Institute for Advanced Study	Algebraic Groups	9/84 - 4/85
Arazy, Jonathan (Israel)	Washington University	Functional Analysis	8/84 - 12/84
Bar-Lev, Shaul K. (Israel)	State University of New York at Buffalo	Statistical Inference	9/84 - 6/86
Berkes, I. (Hungary)	Texas A&M University	Probability	9/84 - 5/85
Bochnak, Jacek (The Netherlands)	University of Toronto	Real Algebraic Geometry	9/84 - 10/84
Borell, Christer (Sweden)	Case Western Reserve University	Probability, Functional Analysis	8/84 - 6/85
Cifuentes, P. (Spain)	Texas A&M University	Harmonic Analysis	9/84 - 5/85
Clerc, Jean-Louis (France)	Washington University	Harmonic Analysis	1/85 - 5/85
Costa, Sueli Irene Rodrigues (Brazil)	Institute for Advanced Study	Differential Topology	1/85 - 4/85
Deshouillers, Jean-Marc (France)	Institute for Advanced Study	Number Theory	9/84 - 12/84
Dijkstra, Jan J. (The Netherlands)	Louisiana State University	Infinite-dimensional Topology	1/85 - 6/85
Dobrowolski, T. (Poland)	Texas A&M University	Topology	9/84 - 5/85
Doi, Koji (Japan)	Princeton University	Classical Theory of Modular Functions	9/84 - 5/85
Figiel, T. (Poland)	Texas A&M University	Functional Analysis	9/84 - 5/85
Frankl, Peter (France)	California Institute of Technology	Combinatorics	10/84 - 1/85
Fröhlich, Jürg M. (Switzerland)	Institute for Advanced Study	Mathematical Physics	9/84 - 4/85
Gallavotti, Giovanni (Italy)	Institute for Advanced Study	Renormalization Group Methods; Field Theory	9/84 - 4/85
Good, Anton (Switzerland)	Institute for Advanced Study	Analytic Number Theory	9/84 - 4/85
Hegereeldt, Gerhard (West Germany)	California Institute of Technology	Mathematical Physics	8/84 - 10/85
Ichihara, Kanji (Japan)	Louisiana State University	Probability and Diffusion Theory	9/84 - 6/85
Kanevsky, Dmitry (West Germany)	Institute for Advanced Study	Algebraic Geometry	9/84 - 4/85
Kassel, Christian (France)	Institute for Advanced Study	Algebraic K-theory	9/84 - 4/85
Kato, Shin-ichi (Japan)	Institute for Advanced Study	Representation Theory of Algebraic Groups	9/84 - 4/85
Kitada, Hitoshi (Japan)	California Institute of Technology	Mathematical Physics	7/84 - 7/85
Kwapień, Stanislaw (Poland)	Case Western Reserve University	Probability, Functional Analysis	8/84 - 6/85
Laugwitz, Detlef (West Germany)	California Institute of Technology	Nonstandard Analysis	10/84 - 12/84
Lempert, Laszlo (Hungary)	Princeton University	Complex Functions	9/84 - 6/85
Løw, Erik (Norway)	Princeton University	Several Complex Variables	9/84 - 6/85

Name and Home Country	Host Institution	Field of Special Interest	Period of Visit
Lu, Qi-keng (People's Republic of China)	Institute for Advanced Study	Complex Geometry; Mathematical Physics	9/84 - 4/85
Mostowski, Tadeusz (Poland)	University of Toronto	Singularity Theory	9/84 - 12/84
Noguchi, Junjiro (Japan)	University of Notre Dame	Several Complex Variables	8/84 - 8/85
Øksendal, Bernt (Norway)	California Institute of Technology	Stochastic Differential Equations	9/84 - 1/85
Papadopoulos, Athanase (France)	Institute for Advanced Study	Differential Topology	9/84 - 4/85
Prestini, Elena (Italy)	Institute for Advanced Study	Harmonic Analysis	9/84 - 4/85
Rao, T. R. S. S. K. (India)	Texas A&M University	Functional Analysis	9/84 - 5/85
Read, Charles (England)	Louisiana State University	Functional Analysis	9/84 - 12/84
Rigoli, Marco (Italy)	Washington University	Differential Geometry	8/84 - 12/84
Rohlfs, Jürgen (West Germany)	Institute for Advanced Study	Cohomology of Arithmetic Groups; Automorphic Forms	9/84 - 4/85
Sakai, Makoto (Japan)	Institute for Advanced Study	Complex Analysis; Potential Theory	1/85 - 4/85
Soffer, Avraham (Israel)	California Institute of Technology	Mathematical Physics	9/84 - 9/86
Straughan, Brian (Scotland)	University of Wyoming	Partial Differential Equations and Applied Mathematics	9/84 - 9/85
Utreras, F. (Chile)	Texas A&M University	Approximation Theory	9/84 - 5/85
Weissauer, Rainer (West Germany)	Institute for Advanced Study	Siegel Modular Forms	9/84 - 4/85
Yang, Lo (People's Republic of China)	Institute for Advanced Study	Nevanlinna Theory; H^p Space and Iteration	9/84 - 4/85
Yang Zhong-hua (People's Republic of China)	California Institute of Technology	Numerical Analysis and Computing	9/82 - 9/84

Backlog of Mathematics Research Journals

Backlog. Information on the backlog of papers for research journals, primarily those published in North America, is reported to the Providence Office by those editorial boards which elect to participate. The figures are an estimate of the number of printed pages which have been accepted, but are in excess of the number required to maintain copy editing and printing schedules.

Observed Waiting Time. The quartiles give a measure of normal dispersion. They do not include extremes which may be misleading. Waiting times are measured in months from receipt of manuscript in final form to publication of the issue. When a paper is revised, the waiting time between an editor's receipt of the final revision and its publication may be much shorter than is the case otherwise, so these figures are low to that extent.

The observations are made from the latest issue published before the deadline for this issue of the *Notices* from journals that have actually been received by a subscriber in the Providence, Rhode Island, area; in some cases this may be two months later than publication abroad. If the waiting time as defined above is not given in the journal, if no new issue has been received since the last survey, or if the latest issue is for some reason obviously not typical, no times are given in this report and such cases are marked NA (not available or not applicable).

Journal	Number Issues per Year	Approximate Number Pages per Year	Backlog of Printed Pages 5/31/84	Backlog of Printed Pages 12/15/83	Editor's Estimated Time for Paper Submitted Currently to be Published (In Months)	Observed Waiting Time in Latest Published Issue (In Months) Q_1	M	Q_3
Acta. Inform.	6	768	0	0	7	12	13**	23
Aequationes Math.	6	640	133	NR	12	10	11	13
Amer. J. Math.	6	1350	1350	1800	24	9	12	26
Ann. of Math.	6	1200	300	250	12	8	9	16
Ann. Probab.	4	1200	150	300	15	7	8	10
Ann. Sci. École Norm. Sup.	4	600	NR	NR	NR	11	12	13
Ann. Statist.	4	1500	0	0	10-12	7	7	8
Appl. Math. Optim.	6	576	250	30	6-12	6	8***	11
Applicable Anal.	8	800	NR	200	6		NA	
Arch. Hist. Exact Scis.	4	400	0	0	14	14	18	26
Arch. Rational Mech. Anal.	16	1600	0	0	10-11	10	11	13
Bull. Soc. Math. France	4	NR	NR	NR	NR	11	11	13
Canad. J. Math.	6	1150	100	0	15	14	17	18
Canad. Math. Bull.	4	512	192	192	15	13	14	15
Comm. Algebra	24	3120	1797	1863	10	12	17	18
Comm. Math. Phys.	20	3040	0	0	5	5	6	7
Comm. Partial Diff. Equations	15	1700	500	500	7-8	11	13	14
Computing	8	768	0	0	7	10	13	15
Duke Math. J.	4	1100	0	0	9	9	11	13
Houston J. Math.	4	600	150	150	12	16	19	23
Illinois J. Math.	4	704	NR	1406	NR	30	31	32
Indiana Univ. Math. J.	6	928	200	200	15	22	23	23
Internat. J. Math. Math. Sci.	4	832	NR	NR	5	9	12	17
Invent. Math.	12	2304	0	0	8	8	11	13
Israel J. Math.	12	1200	100	100	12	5	8	12
J. Amer. Statist. Assoc.	4	1000	NR	0	NR	7	8	10
J. Assoc. Comput. Mach.	4	1000	NR	600	NR	9	10	12
J. Comput. System Sci.	6	1000	600	200	12	10	10	11
J. Differential Geom.	4	1300	900	650	9	8	10	11
J. Math. Biol.	9	1152	0	0	6	5	7	7
J. Math. Phys.	12	3800	390	1000	3-5	10	12**	13
J. Nigerian Math. Soc.	1	110	0	NR	8		NA	
J. Operator Theory	4	800	400	400	12	13	16	20
J. Symbolic Logic	4	1200	200	140	18	20	20	26
Linear Algebra Appl.	8	2400	300	300	12-14	14	14	15
Linear and Multilinear Algebra	6	540	400	540	12	9	13	15
Manuscripta Math.	12	1200	0	0	4	6	7	9
Math. Ann.	12	1730	0	0	8	7	8	13
Math. Biosci.	10	1500	100	20	5	7	16	17
Math. Comp.	4	1300	80	0	12	11	12	19
Math. Oper. Res.	4	640	590	356	17	16	17	21
Math. Programming	9	1080	NR	NR	12	12	13	15
Math. Systems Theory	4	384	NR	97	NR	9	10	11

Journal	Number Issues per Year	Approximate Number Pages per Year	Backlog of Printed Pages 5/31/84	Backlog of Printed Pages 12/15/83	Editor's Estimated Time for Paper Submitted Currently to be Published (In Months)	Observed Waiting Time in Latest Published Issue (In Months) Q_1	M	Q_3
Math. Z.	12	1740	0	0	9	7	8	9
Mem. Amer. Math. Soc.	6	2880	256	260	5	9	11	17
Michigan Math. J.	3	384	125	100	8-14	8	9	11
Monatsh. Math.	8	704	0	25	6	8	8	11
Numer. Funct. Anal. Optim.	6	720	0	NR	7	6	6	8
Numer. Math.	6	960	6	0		6	6	7
Oper. Res.	6	1300	700	NR	22		NA	
Pacific. J. Math.	12	3000	NR	NR	9	21	24	30
Proc. Amer. Math. Soc.	12	2000	150	50	11	10	11	15
Quart. Appl. Math.	4	512	128	128	18	13	16	20
Resultate Math.	2	224	0	*	15	15	25	29
Rocky Mountain J. Math.	4	768	750	250	24		NA	
Semigroup Forum	9	1152	128	NR	6	10	11	12
SIAM J. Algebraic Discrete Methods	4	560	509	363	19	12	12	13
SIAM J. Appl. Math.	6	1350	0	99	7	12	13	14
SIAM J. Comput	4	900	538	458	17	10	14	16
SIAM J. Control Optim.	6	975	106	289	10	13	14	15
SIAM J. Math. Anal.	6	1225	796	1044	16	13	14	16
SIAM J. Numer. Anal.	6	1200	415	140	13	10	11	15
SIAM J. Sci. Statist. Comput.	4	1000	625	591	17	15	16	17
SIAM Rev.	4	560	0	0	4	8	8	10
Topology Appl.	6	330	260	690	5	12	13	14
Trans. Amer. Math. Soc.	12	5000	100	400	13	12	14	15
Z. Wahrsch. Verw. Gebiete	12	1920	0	0	9	6	8	10

NR means no response received.
NA means not available or not applicable.
*This journal is new to the listing; backlog as of 12/31/83 not known.
**From date of first receipt of manuscript. This journal does not give dates for revisions.
***From date of acceptance (this journal does not give the received date).

Recent Appointments

Committee members' terms of office on standing committees expire on December 31 of the year given in parentheses following their names, unless otherwise specified.

The Trustees *Committee on Abuse of Subscriptions* has been discharged with thanks.

The Trustees *Committee on Trustees' Operations* has been discharged with thanks.

Steve Armentrout has been appointed chairman of the *Committee on Staff and Services* by Cathleen S. Morawetz, chairman of the Board of Trustees. Other members of the committee are Franklin P. Peterson and Paul J. Sally, Jr.

Hyman Bass, Ronald L. Graham, Melvin Hochster, Franklin P. Peterson and Everett Pitcher have been appointed by Cathleen S. Morawetz, Chairman of the Board of Trustees, to a new *Committee on Long Range Planning.* Professor Hochster will serve as chairman.

Hyman Bass, Felix E. Browder, Philip A. Griffiths, John W. Milnor, and Cathleen S. Morawetz have been appointed to the *Centennial Program Committee* a subcommittee of the *Centennial Committee.* Professor Browder will serve as chairman.

Michael Schlessinger (1985) has been appointed by President Julia B. Robinson to the *Committee to Select Hour Speakers for Southeastern Sectional Meetings.* Continuing members of the committee are A. T. Bharucha-Reid (1984), Frank T. Birtel (ex officio), Carl Pomerance (1984), chairman, and Leonard L. Scott, Jr. (1985).

George E. Andrews (1985) has been appointed chairman of the *AMS Research Fellowship Committee* by President Julia B. Robinson. Continuing members of the committee are H. Jerome Keisler (1985) and Alan D. Weinstein (1985). Terms expire on June 30.

Richard J. Griego (AMS) has been appointed to a new joint AMS-IMS-SIAM *Committee on Scientific Collaboration with Latin American Countries* by President Julia B. Robinson. Professor Griego has also been appointed chairman.

Paul R. Garabedian, Louis N. Howard and Gerald B. Whitham have been appointed to the AMS-SIAM *Committee to Select the Winner of the Wiener Prize for 1985* by Presidents Julia B. Robinson AMS and Hirsh G. Cohen SIAM in consulation with AMS President Elect Irving Kaplansky. Professor Garabedian will serve as chairman.

Officers and Committee Members of the Society

Terms expire on December 31 of the year given unless otherwise specified.

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	W. Wistar Comfort	1984
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Melvin Hochster	1986	Elias M. Stein	1984
Irving Kaplansky (*ex officio*)	1987		
Everett Pitcher (*ex officio*)			

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David Eisenbud	1986	Michael Shub	1985
Peter A. Fillmore	1984	Elias M. Stein	1984
Susan J. Friedlander	1985	Hector J. Sussmann	1984
Paul R. Halmos	1985	Olga Taussky-Todd	1985
Robin Hartshorne	1985	Jean Taylor	1986
Melvin Hochster	1986	William P. Thurston	1986
Carlos E. Kenig	1986		

Publications and Communications Committees

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(Except for Associate Editors, members of these Committees are members of the Council, *ex officio*)

American Journal of Mathematics, Society's Representatives

Spencer Bloch	1985	Richard B. Melrose	1986

Bulletin (New Series)

Hyman Bass	1986	Calvin C. Moore	1984
Meyer Jerison, chairman	1985		

Associate Editors for Research Announcements

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Ronald L. Graham	1984	Harold M. Stark	1984
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Felix E. Browder	1986	John W. Milnor	1985
S. S. Chern	1984	Gian-Carlo Rota	1984
Frederick W. Gehring	1984	Wilfried Schmid	1986
Benedict H. Gross	1986		

Colloquium

Barry Mazur	1986	Louis Nirenberg, chairman	1985
John W. Milnor	1984		

Mathematical Reviews

Robert G. Bartle	1985	Morton Lowengrub	1984
Melvin Hochster, chairman	1986		

Mathematical Surveys and Monographs

Donald W. Anderson, chairman	1984	Gian-Carlo Rota	1986
		R. O. Wells, Jr.	1985

Associate Editor

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Adriano M. Garsia	1985		1986
		Irving Reiner	1986

Mathematics of Computation

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		Hugh C. Williams	1985
John E. Osborn	1986		

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Proceedings

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Andrew M. Odlyzko	1985		

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Transactions and Memoirs

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William B. Johnson	1985		1986
Tilla Klotz Milnor	1987	Lance W. Small	1986
Walter David Neumann	1985	Joel A. Smoller	1987

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Peter W. Jones	1987	R. O. Wells, Jr.	1986

Communications

(Only the Chairman of this Committee is a member, ex officio, of the Council.)

Monitor Problems in Communication

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W. Wistar Comfort	1985	Robert W. Ritchie	1985
Susanne Fedunok, consultant		Lynn A. Steen, chairman	1986
William J. LeVeque (ex officio)		Guido L. Weiss	1984

Internal Organisation of the American Mathematical Society

Standing Committees

Committee on Committees

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Melvin Hochster	1984	Marc A. Rieffel	1984

Nominating Committee

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O. Carruth McGehee	1984	James D. Stasheff	1984

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Ralph P. Boas	1984	Bertram Walsh	1984
Lincoln K. Durst (ex officio)		Daniel Zelinsky	1986
Raymond L. Johnson	1986		
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Standing Committees

Program Committee for National Meetings

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		Karen Uhlenbeck	1985
Robion C. Kirby	1984	William P. Ziemer	1986

Central Sectional Meetings (Select Hour Speakers for)

Eric D. Bedford	1985	William B. Johnson, chairman	1984
Robert M. Fossum (ex officio)		Bhama Srinivasan	1985
Israel N. Herstein	1984		

Eastern Sectional Meetings (Select Hour Speakers for)

W. Wistar Comfort (ex officio)		Yum Tong Siu	1984
		Richard P. Stanley, chairman	1984
George R. Kempf	1985		
		Floyd L. Williams	1985

Far Western Sectional Meetings (Select Hour Speakers for)

Paul J. Cohen, chairman	1984	Tsit-Yuen Lam	1984
		Hugo Rossi (ex officio)	
Ramesh A. Gangolli	1985	Masamichi Takesaki	1985

Southeastern Sectional Meetings (Select Hour Speakers for)

A. T. Bharucha-Reid	1984	Michael Schlessinger	1985
Frank T. Birtel (ex officio)		Leonard L. Scott, Jr.	1985
Carl Pomerance, chairman	1984		

Agenda for Business Meetings

Everett Pitcher, chairman		David A. Sanchez	1984
Marian B. Pour-El	1984	Guido L. Weiss	1984

Gibbs Lecturers for 1985 and 1986, Committee to Select

Jim Douglas, Jr.	Marion B. Pour-El, chairman
Samuel Karlin	

Status of the Profession

Standing Committees

Academic Freedom, Tenure, and Employment Security

Martin D. Davis, chairman	1984	Charlotte Lin	1986
Edward George Effros	1986	Robert R. Phelps	1986
James E. Joseph	1984	Halsey L. Royden	1985

AMS Research Fellowship (Terms expire on June 30)

George E. Andrews, chairman	1985	Alan D. Weinstein	1985
H. Jerome Keisler	1985		

Employment and Educational Policy

Lida K. Barrett	1985	Irwin Kra	1984
Stefan A. Burr	1986	Donald C. Rung, chairman	1984
Lisl Novak Gaal	1985		
Gerald J. Janusz	1986		

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Human Rights of Mathematicians

Lenore Blum	1986	Peter J. Hilton	1984
Chandler Davis, chairman	1986	Joshua A. Leslie	1986
		John Nohel	1985
Leon A. Henkin	1985	Eduardo D. Sontag	1984

Opportunities in Mathematics for Disadvantaged Groups

Manuel P. Berriozabal	1985	Gloria F. Gilmer	1985
James A. Donaldson, chairman	1984	Harold J. Stolberg	1984
		----------	1986
Roland F. Esquerra	1984		

Professional Ethics

Leonard Gillman	1984	John C. Oxtoby	1984
Paul R. Halmos	1985	Murray H. Protter, chairman	1986
Anneli Lax	1985		

Science Policy

Hyman Bass	1984	William J. LeVeque (*ex officio*)	
Felix E. Browder, chairman	1984	Cathleen S. Morawetz	1985
Ronald G. Douglas	1986	Julia B. Robinson (*ex officio*)	
Louis N. Howard	1986	Hugo Rossi	1985
Irving Kaplansky (*ex officio*)		I. M. Singer	1984
Joseph J. Kohn	1985	Guido L. Weiss	1985

Service to Mathematicians in Developing Countries

Raymond G. Ayoub, chairman	James Eells
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	Marshall H. Stone

Translations from Chinese

Sun-Yung Alice Chang	Tai-Ping Liu
Tsit-Yuen Lam, chairman	Franklin P. Peterson
Chia-Chiao Lin	

Prizes and Awards

Standing Committees

Prizes

Ralph P. Boas	1985	Gail S. Young, Jr.	1985
Dorothy M. Stone, chairman	1984		

National Awards and Public Representation

William Browder	1985	Julia B. Robinson, chairman	1985
Irving Kaplansky	1987		
Everett Pitcher (*ex officio*)			

Steele Prizes (Terms expire on June 30)

Richard W. Beals	1987	Yiannis N. Moschovakis, chairman	1985
Charles W. Curtis	1986		
Harold M. Edwards	1986	Lawrence E. Payne	1987
Frederick W. Gehring	1986	George B. Seligman	1986
H. Jerome Keisler	1985	Patricia Lilaine Sipe	1986

Ad Hoc Committee

1985 Cole Prize

Michael Aschbacher, chairman	Melvin Hochster
	Bhama Srinivasan

Institutes and Symposia

Standing Committee

Summer Institutes (Terms expire on February 28)

Michael Artin	1985	Judith D. Sally	1986
Thomas H. Brylawski	1985	----------	1987
Hui-Hsiung Kuo	1986	----------	1987

Ad Hoc Committees

1984 Summer Institute on Geometric Measure Theory and the Calculus of Variations

William K. Allard, co-chairman	Robert M. Hardt
	H. Blaine Lawson, Jr.
Frederick J. Almgren, Jr., co-chairman	Jon T. Pitts
	Richard Schoen
Enrico Bombieri	William P. Ziemer

1984 AMS-SIAM Summer Seminar on Nonlinear Systems of PDE in Applied Mathematics

Darryl Holm	Basil Nicolaenko, chairman
James M. Hyman	

Joint Committees

AMS-ASL-IMS Committee on Translations from Russian and Other Foreign Languages

(Terms expire on September 30)

Lawrence Zalcman (AMS), chairman 1984

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David V. Chudnovsky	1986	Donald E. Sarason	1985
Jack K. Hale	1986	Boris M. Schein	1985
Raymond L. Johnson	1984	Boris Weisfeiler	1986
Neal I. Koblitz	1984	Lawrence Zalcman, chairman	1984
Andrew M. Odlyzko	1984		
Marian B. Pour-El	1985	----------	1986

ASL Subcommittee Members

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Solomon Feferman	1984	Gregory Minc	1984
James P. Jones	1984		

IMS Subcommittee Members

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Johan H. B. Kemperman, (IMS) chairman	

AMS-IMS-SIAM Committee on Joint Summer Research Conferences in the Mathematical Sciences

(Terms expire on June 30)

Ronald L. Graham	1987	James McKenna	1986
Benedict H. Gross	1986	Tilla Klotz Milnor	1987
Malcolm R. Leadbetter	1986	Evelyn Nelson	1987
		Katsumi Nomizu	1986
Angus J. Macintyre	1987	R. O. Wells, Jr., chairman	1985
Jerrold E. Marsden	1986		
John R. Martin	1987		

AMS-IMS-SIAM Committee on Scientific Collaboration with Latin American Countries

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---------- (AMS)
---------- (IMS)
---------- (SIAM)

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R. Creighton Buck (MAA)
I. N. Herstein (MAA)
Frank A. James (NAM)
Ted Sykes (NAM)

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Raymond G. Ayoub (AMS) 1986
Gloria C. Hewitt (MAA) 1986
John L. Kelley (AMS) 1984
Barbara Keyfitz (SIAM) 1984
Julia Knight (AMS) 1986
Carol B. LaCampagne (AMS, MAA), chairman 1984
Dianne P. O'Leary (SIAM) 1985
Linda Petzold (SIAM) 1986
Judith Roitman (AMS) 1986
Alice T. Schafer (MAA) 1986
---------- (NCTM) 1986
---------- (NCTM) 1986
---------- (NCTM) 1986

AMS-MAA-SIAM Congressional Science Fellowship Selection Panel (Terms expire on March 1)

Richard D. Anderson (MAA) 1984
Burton H. Colvin (SIAM) 1984
Thomas R. Kramer, chairman 1984
Louise A. Raphael (AMS) 1986
Marcia P. Sward (CBMS) 1987

AMS-MAA-SIAM Committee on Employment Opportunities (Terms expire on October 31)

Wilfred E. Barnes (MAA) 1984
Richard E. Ewing (SIAM) 1986
Patrick Hagan (SIAM) 1985
Calvin T. Long (MAA) 1986
John W. Petro (AMS) 1985
Donald C. Rung (AMS), chairman 1984

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Joint Policy Board of Mathematics
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Cambridge, MA 02139
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Washington Office
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1529 Eighteenth Street, N.W., Washington, DC 20036
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Constantine M. Dafermos 1986
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George C. Papanicolaou, chairman 1986
Robert F. Warming 1984

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Gail A. Carpenter 1986
Kenneth L. Lange 1987
Robert M. Miura, chairman 1984
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John Rinzel 1986

AMS-SIAM Committee to Screen Applicants for Graduate Study from the People's Republic of China

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Mei-Chang Shen
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Conference Board of the Mathematical Sciences

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Fulkerson Prize Committee

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Section A of the American Association for the Advancement of Science (Term expires on May 27)

Martin D. Davis 1986

U.S. National Committee on Theoretical and Applied Mechanics (Term expires on October 31)

Stuart S. Antman 1988

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POSITIONS AVAILABLE

UNIVERSITY OF IOWA
Department of Mathematics

Applications are encouraged for anticipated tenure-track, tenured positions, and visiting positions at all levels for the academic year 1985-86. Application, vita, and three letters of recommendation should be sent to Robert H. Oehmke, Department of Mathematics, University of Iowa, Iowa City, Iowa, 52242. Selections will be based on evidence of the applicants' effective teaching and research achievements and potential; instructional needs of the Department; and the potential for interaction with the faculty at the research level. Special attention will be given to applicants in differential equations. The selection process will begin on December 18, 1984. The University of Iowa is an Affirmative Action and Equal Opportunity Employer and specifically encourages applications from women and minorities.

In anticipation of the possibility of tenure track positions becoming available in the next few years, the Mathematics Department invites applications for NSERC University Research Fellowships beginning July 1, 1985. Candidates should have demonstrated high potential for research. In the past, successful candidates for NSERC University Research Fellowships have had at least one year of post-doctoral experience. Under NSERC regulations, candidates must be Canadian citizens or permanent residents of Canada at the time of nominations. Normally, the fellowships are for three years and renewable for an additional two years. A University Research Fellow receives the same salary as an Assistant Professor with comparable qualifications but teaches, at most, one course. Applications including CV, list of publications and three letters of recommendation should be sent to:

Dr. M. Sion, Head
Department of Mathematics
1984 Mathematics Road
University of British Columbia
Vancouver, B.C. V6T 1Y4

Postdoctoral Fellowship in the History of Mathematics at the Institute for the History and Philosophy of Science and Technology of the University of Toronto. Recent Ph.D.'s and students in the last stages of their dissertations, working in the history of mathematics, are invited to apply for a Kenneth O. May Fellowship for 1984-85. The period of the award may be between four and twelve months, for a grant of $2,000 per month. Send c.v., names of two or more references, and brief description of proposed research before November 15, 1984 to Prof. Craig Fraser, IHPST, Victoria College, 73 Queen's Park Crescent E., Toronto, Ontario M5S 1K7

DEPARTMENT OF MATHEMATICS
ILLINOIS INSTITUTE OF TECHNOLOGY

Nominations and applications are invited for the position of chairman, Department of Mathematics. Qualifications include an earned doctorate, teaching and research experience as a university faculty member, preferably in an area of applied mathematics (including statistics), leadership potential for departmental development as related to current trends in education and research and the ability to attract funded research. The starting date for this position is August 1985.

The Mathematics Department enjoys close cooperation with the research activities of the rest of the University, as well as with the other organizations forming IIT Center.

Applicants should submit a complete résumé. Applications, nominations and inquiries should be sent to:

Professor Harold N. Spector
Chairman, Search Committee
Department of Physics
Lewis College of Sciences and Letters
Illinois Institute of Technology
Chicago, IL 60616

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NICHOLLS STATE UNIVERSITY
Thibodaux, LA 70310

Tenure track position beginning August 1984. Ph.D. in mathematics or statistics with preference given to persons with training in numerical analysis, optimization techniques, statistics, or computer science. Recruit and teach in undergraduate program and M.S. Program in applied mathematics. Research encouraged and supported. Salary and rank are negotiable and competitive. Send résumé and transcripts to Department of Mathematics, Nicholls State University, Thibodaux, LA 70310. Nicholls State University is an equal opportunity employer.

UNIVERSITY OF CALIFORNIA, LOS ANGELES
DEPARTMENT OF MATHEMATICS

Three or four E. R. Hedrick Assistant Professors. Applicants must show strong promise in research and must have received the Ph.D. after 1 January 1984 (but may be of any age); no restrictions as to field; anticipated salary $30,000. Three year appointment; research supplement, $3,333 first summer. Teaching load: 4 quarter courses per year, including one advanced course in candidates field. Deadline for applications is January 15, 1985. To apply, write to Yiannis N. Moschovakis, Chair, Los Angeles, CA, 90024.

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POSITIONS AVAILABLE

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Dunedin – New Zealand
CHAIR OF MATHEMATICS

The University Council invites applications for appointment to the Chair of Mathematics at present occupied by Professor D. B. Sawyer, who will retire at the end of 1984.

Applicants should possess a substantial research record and good administrative and teaching ability. Candidates in any area of specialisation will be considered but preference will be given to candidates whose interests are centered in the main body of mathematics.

Professorial salaries at present provide for a salary within the range of NZ$41,937 per annum to NZ$52,182 per annum. In addition, a cost of living allowance of NZ$417 per annum will be paid.

Further particulars are available from the Secretary-General, Association of Commonwealth Universities (Appointments), 36 Gordon Square, London WC1H OPF England, or from the Registrar, University of Otago, P. O. Box 56, Dunedin, New Zealand.

Applications quoting reference number A84/19 close in New Zealand and England on 31 August 1984.

UNIVERSITY OF CALIFORNIA, LOS ANGELES
DEPARTMENT OF MATHEMATICS

Subject to administrative approval, a few assistant professorships, with special attention given to candidates in applied mathematics, algebraic number theory/modular forms, several complex variables and topology. Strong research and teaching background required. Sufficiently outstanding candidates in other fields and/or at higher levels will also be considered. Anticipated salary $25,000 for academic year. Teaching load: 5 quarter courses per year. Also several positions for visitors and lecturers. To apply, write to Yiannis N. Moschovakis, Chair, Los Angeles, CA, 90024.

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DEPARTMENT OF MATHEMATICS

Subject to administrative approval, a few adjunct assistant professorships; two year appointment only; strong research and teaching background; no restriction as to field. Anticipated salary $25,000 for academic year. Teaching load: 5 quarter courses per year. To apply, write to Yiannis N. Moschovakis, Chair, Los Angeles, CA, 90024.

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UNIVERSITY OF TORONTO
DEPARTMENT OF MATHEMATICS

The Department has an opening (subject to budgetary approval) at the level of Professor with tenure in the field of mathematical quantum mechanics. The duties will consist of research, and teaching at the graduate and undergraduate levels. The salary range is $50,000 to $55,000.

Candidates should have completed their Ph.D. within the last ten years, and should have established a leading international reputation for the originality and significance of their research. The Department seeks candidates whose research has already made deep and fundamental contributions to the central problems in the field, and candidates are asked to include a brief description of such contributions in their application.

Applications should be sent to: Professor T. Bloom, Chairman, Department of Mathematics, University of Toronto, Toronto, Ontario, Canada M5S 1A1, and should include a complete curriculum vitae, the description of their research mentioned above, and the names of six referees (two of whom can appraise the teaching ability of the candidate). The deadline is October 15, 1984.

DEPARTMENT OF MATHEMATICS, STATISTICS, AND COMPUTER SCIENCE
UNIVERSITY OF ILLINOIS AT CHICAGO

Associate Professorship in the area of Mathematics and Computer Education, to begin anytime between January 1, 1985 and September 1, 1985. Ph.D. required. Applicants must present evidence of excellence in teaching and research. Duties include teaching in the B.S. in Teacher Education, M.S.T., and Doctor of Arts programs, coordination of secondary practice teaching, and research in mathematics/computer education. Salary competitive, commensurate with qualifications. Applications accepted until September 30, 1984 or until position is filled. Send résumé and have at least 3 letters of recommendation sent to Dr. Louise Hay, Head, Department of Mathematics, Statistics, and Computer Sciences, m/c 249, University of Illinois at Chicago, Box 4348, Chicago, IL 60680. An Affirmative Action/Equal Opportunity Employer.

BROOKLYN COLLEGE (CUNY)
DEPARTMENT OF MATHEMATICS

Applications are invited for anticipated tenure-track professorial position(s) for February or September, 1985. Ph.D. required. Applicants must demonstrate commitment to research and to teaching. Rank and salary dependent on qualifications.

Vita and three letters of recommendation should be sent to George Shapiro, Chairperson, Department of Mathematics, Brooklyn College, Brooklyn, N.Y. 11210. Applications for February, 1985 must be received by September 28, 1984.

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THE OHIO STATE UNIVERSITY
CHAIR IN APPLIED MATHEMATICS

The Department of Mathematics of The Ohio State University has been awarded a Chair in Scientific Computation. This Chair is funded jointly by the Ohio Eminent Scholars Program and The Ohio State University and has an initial endowment of $1,000,000.

The Department seeks applicants with outstanding credentials in Computational Mathematics and Scientific Computation to fill this Chair. The recipient will hold the academic rank of Professor of Mathematics and will also serve as the Director of a newly established Center of Scientific Computation.

The University has also committed funds to purchase the computing equipment required for the center and the Mathematics Department has allocated four new junior positions to be filled by young researchers working in this or closely related areas.

Individuals interested in this position should contact

Professor James M. Greenberg, Chairman
Eminent Scholar Search Committee
The Ohio State University
Department of Mathematics
231 West 18th Avenue
Columbus, Ohio 43210
Telephone: 614/422-5255

Applications are invited for a tenure track position beginning August 1984. A Ph.D. in statistics or mathematics is required with preference given to persons in statistics, numerical analysis, or optimization techniques. Duties include recruiting and teaching in the undergraduate and M.S. Program in applied mathematics. Research is encouraged and supported. Salary and rank are negotiable and competitive. Send résumé and transcripts to Department of Mathematics, Nicholls State University, Thibodaux, LA 70310. Nicholls State University is an equal opportunity employer.

POSITIONS AVAILABLE

The Department of Mathematics and Statistics at McGill University wishes to sponsor a strong candidate for the NSERC 1984-1985 University Research Fellowship Competition. These Fellowships are five year research positions (with a review in the third year), in the nature of Research Assistant Professorships, and carry a teaching load of at most one course throughout the academic year. Applicants should have shown some substantial research ability beyond their doctoral thesis. They should be Canadian Citizens or landed immigrants by October 15, 1984.

Interested candidates should send their curricula vitae to:

Professor Michael Herschorn
Department of Mathematics and Statistics
McGill University
805 Sherbrooke Street West
Montreal, Quebec, Canada H3A 2K6

They should also arrange for at least two letters of reference from competent referees to be sent directly to the same address. All documentation should reach the department by September 1, 1984. Preference may, however, be given to those whose files are complete by July 1, 1984. The department will make its recommendations to NSERC early in October 1984. NSERC announces its final choice by March in each year.

FOR SALE

MATH SCI PRESS, 53 Jordan Rd., Brookline MA 02146, 617-738-0307. Just published: *Proceedings of the Berkeley-Ames Conference on Nonlinear Problems in Control and Fluid Dynamics*, L. R. Hunt and C. F. Martin, (Eds.), 450 pages, $50. (*Lie Groups; Systems Information and Control*, vol. II). *Topics in the Geometric Theory of Linear Systems*, by Robert Hermann, $50. (*Interdisciplinary Mathematics*, vol. 22). In press: *Topics in the Geometric Theory of Integrable Systems*, by Robert Hermann. Special Sale: *Development of Mathematics in the 19th Century*, by Felix Klein, $20. Write or call for other special prices on back list.

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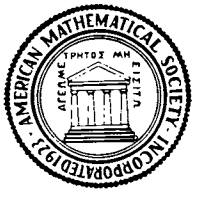

COLLOQUIUM PUBLICATIONS

The Geometric Topology of 3-Manifolds

R. H. Bing

The book starts with a treatment of some of the geometric and topological properties of the plane. This treatment is expanded to study such fundamental properties of 3-space as the PL Schoenflies theorem, Dehn's lemma, the loop theorem, and the side approximation theorem. Applications of these fundamental results are made to develop further properties of 3-manifolds.

The Table of Contents provides a general summary of the book's major points.

This book is most meaningful to a mathematician interested in geometry who has had at least a beginning graduate course in topology. While a student can start the book with less preparation, the chances are that those with weaker backgrounds will bog down if they work without the benefit of discussion.

The book belongs in both graduate and undergraduate libraries. It can serve as a useful reference for a graduate student in topology or a researcher in topology. A study of the book should provide the reader with a better understanding of the physical properties of Euclidean 3-space—the space in which we presume we live. The reader should learn of some unsolved problems that continue to baffle researchers.

The most profound result in the volume is the side approximation theorem. However, as a reference tool some of the preliminary results and some of the applications may be used more frequently.

Contents

Preface
1. Planar complexes
2. PL planar maps
3. The Schoenflies theorem
4. Wild 2-spheres
5. The generalized Schoenflies theorem
6. The fundamental group
7. Mapping onto spheres
8. Linking
9. Separation

1980 *Mathematics Subject Classification*: 57-XX
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Chung-Chun Yang, Editor

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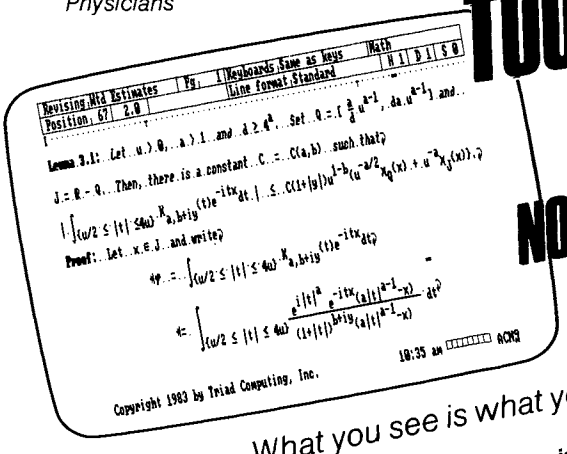

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