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Best Approximation by Linear Superpositions (Approximate Nomography)
S. Ya. Khavinson, Moscow Civil Engineering Institute, Russia

This book deals with problems of approximation of continuous or bounded functions by linear superposition of functions that are from the same class and have fewer variables. The main topic is the space of linear superpositions $D$ considered as a subspace of the space of continuous functions $C(X)$ on a compact space $X$. Such properties as density of $D$ in $C(X)$, its closedness, proximity, etc. are studied in great detail. The approach to these and other problems based on duality and the Hahn-Banach theorem is emphasized. Also, considerable attention is given to the discussion of the Diliberto-Strass algorithm for finding the best approximation of a given function by linear superpositions.

Translations of Mathematical Monographs, Volume 159; 1997; 175 pages; Hardcover; ISBN 0-8218-0422-7; List $69; Individual member $44; Order code MMONO/159NA

Combined Membership List, 1996–1997

The Combined Membership List (CML) is a comprehensive directory of the membership of the American Mathematical Society, the American Mathematical Association of Two-Year Colleges, the Mathematical Association of America, and the Society for Industrial and Applied Mathematics.

There are two lists of individual members. The first is a complete alphabetical list of all members in all four organizations. The second is a list of individual members according to their geographic locations. The CML is an invaluable reference for keeping in touch with colleagues and for making connections in the mathematical sciences communities in the United States and abroad.

1996; 392 pages; ISBN 0-8218-0186-4; List $60; Individual member $45; Order code AMS/M/1997NA

Geometric Topology
William H. Kazez, University of Georgia, Athens

This is a two-part volume reflecting the proceedings of the 1993 Georgia International Topology Conference held at the University of Georgia during the month of August. The texts include research and expository articles and problem sets. The conference covered a wide variety of topics in geometric topology.

Features:
• Kirby’s problem list, which contains a thorough description of the progress made on each of the problems and includes a very complete bibliography, makes the work useful for specialists and non-specialists who want to learn about the progress made in many areas of topology. This list may serve as a reference work for decades to come.
• Gabai’s problem list, which focuses on foliations and laminations of 3-manifolds, collects for the first time in one paper definitions, results, and problems that may serve as a definitive source in the subject area.

Titles in this series are co-published with International Press, Cambridge, MA


American Mathematical Society
New Titles from the AMS

Integer-Valued Polynomials
Paul-Jean Cahen and Jean-Luc Chabert, Faculté de Science de St. Jerome, Marseille, France

Integer-valued polynomials on the ring of integers have been known for a long time and have been used in calculus. Polya and Ostrowski generalized this notion to rings of integers of number fields. More generally still, one may consider a domain $D$ and the polynomials (with coefficients in its quotient field) mapping $D$ into itself. They form a $D$-algebra—that is, a $D$-module with a ring structure. Appearing in a very natural fashion, this ring possesses quite a rich structure, and the very numerous questions it raises allow a thorough exploration of commutative algebra. Here is the first book devoted entirely to this topic.

Features:
• Through reviews of many published works.
• Self-contained text with complete proofs.
• Numerous exercises.

Mathematical Surveys and Monographs, Volume 48; 1997; 322 pages; Hardcover; ISBN 0-8218-0388-3; List $75; Individual member $55; Order code SURV/48NA

Stochastic Analysis: Random Fields and Measure-Valued Processes
Jean-Pierre Fouque, Ecole Polytechnic, CMAP, Palaiseau, France, Kenneth J. Hochberg and Ely Merzbach, Bar-Ilan University, Ramat-Gan, Israel

This volume contains papers on probability theory and stochastic analysis resulting from two international conferences held at the Department of Mathematics of Bar-Ilan University in 1993 and 1995. The work includes expository and advanced research presentations, presenting an accurate reflection of the nature, scope, and vibrancy of these conferences on stochastic analysis.

Israeli Mathematical Conference Proceedings series is published by Bar-Ilan University of Israel and distributed worldwide by the AMS.

Isreal Mathematical Conference Proceedings, Volume 10; 1996; 214 pages; Softcover; List $45; Individual member $27; Order code IMCP/10NA

Vertex Algebras for Beginners
Victor Kac, Massachusetts Institute of Technology, Cambridge

This book is an introduction to algebraic aspects of conformal field theory, which in the past decade revealed a variety of unusual mathematical notions. Vertex algebra theory provides an effective tool to study them in a unified way.

Here, a mathematician will encounter new algebraic structures that originated from Einstein’s special relativity postulate and Heisenberg’s uncertainty principle. A physicist will find familiar notions presented in a more rigorous and systematic way, which may lead to a better understanding of foundations of quantum physics.

University Lecture Series, Volume 10; 1997; 141 pages; Softcover; ISBN 0-8218-0643-2; List $25; All AMS members $20; Order code ULECT/10NA
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Differing Viewpoints on the Teaching of Mathematics

This editorial is a request to colleagues interested in mathematics instruction to give more attention to accommodating differing points of view. Mathematics is an exact science with provable truths—theorems and formulas—and exact methods of analysis and proof. On the other hand, the teaching of mathematics is a very inexact human endeavor involving a variety of interpersonal skills and a good intuition about human nature. Current arguments, at times passionate, about what constitutes good instructional style and good curriculum in the Notices and other publications are evidence of this inexactitude. Indeed, when many of us start to discuss teaching, the very intuitive, hard-to-quantify aspects of human nature that are central to communicating and motivating mathematical reasoning to our students can become a liability. They can cause us to feel a strong, personal involvement in validating viewpoints we espouse and an equally strong compulsion to attack and invalidate viewpoints which antagonize us.

In pursuing our viewpoints, it is human nature to upgrade personal preferences and opinions to the status of facts. For example, instead of saying, “I am not comfortable with the absence of epsilon-delta proofs in calculus reform texts,” it is easy to find one’s self saying, “Calculus reform is wrong-headed, because it omits epsilon-delta proofs.” It is common to see such statements expanded to become, “Calculus reform is very dangerous, because its lack of rigor and logical reasoning totally misrepresents what mathematics is all about.”

The new approaches to teaching calculus give a classic example of how personal preferences, actually the preferences of a group of people, have been upgraded to the level of fact. The very word reform in the phrase calculus reform is a big mistake. (Ron Douglas, father of the current movement to rethink calculus instruction, told me that he repeatedly tried to keep people from using the word reform.) Reform has a connotation of being progressive and improved. Someone who does not feel comfortable with reform calculus is implicitly unreformed, a word with quite negative connotations. When someone labels me unreformed, I am going to have trouble not wanting to fire back in fairly aggressive language.

Unfortunately, there are times when it is very hard to avoid turning opinions into facts. In a large freshman calculus course with dozens of sections, it may be imperative that a common text be used in all sections. In states like New York with its statewide Regents Exams (which lead to college scholarships), great commonality is imposed on course syllabi in all high schools. In these cases, some committee of people will make their opinions about what is a good curriculum into fact. In schools, the need to coordinate the overall curriculum over a dozen years along with the uneven preparation of teachers makes it essential that external bodies of “experts” develop curriculum standards. Such situations guarantee outcomes that are going to leave many thoughtful people upset.

The challenges we face in providing the best possible mathematics instruction for our students at all levels are daunting and too important for divisive infighting. I wish that the mathematics community would devote more effort to looking for ways to work together as harmoniously as possible while respecting the inevitable conflicts that our differing opinions will create.

—Alan Tucker
Letters to the Editor

On Plato and Logic
I was particularly interested in fact with Huber-Dyson's comments regarding Plato and logic as mentioned on page 837 of the August Notices. It seems Socrates's warnings from section 275 of Hamilton's translation of the Phaedrus and Letters VII and VIII were overlooked. Therein does Socrates advise Plato, "Then it shows great folly—as well as ignorance of the pronouncement of Ammon—to suppose that one can transmit or acquire clear and certain knowledge of an art through the medium of writing." Any logician would say that Plato's diligence at committing Socrates's insights to writing and paper is thus completely suspect on the premises or more precisely a perfect specimen of the contradiction.

I am sorry Huber-Dyson was so evidently unaware of Socrates's Phaedric position and recommend a review of that literary vehicle.

C. Felicitas
New York Academy of Sciences
(Received August 7, 1996)

Follow Ad Policy Indiscriminately
I write to point out an apparent violation of your classified ad policy (September 1996, Notices, p. 1067). Your own "positions available" rules state that ads from institutions outside the U.S. cannot be published unless they are accompanied by a statement that the institution does not discriminate on the basis of color, age, sex, race, religion, or national origin. The Uppsala University ad does not include such a statement and appears to be blatantly discriminatory with respect to sex. Please assure me that this was merely an oversight on the part of the editor rather than a gross example of "politically correct" hypocrisy.

Eric M. Freden
Utah State University
(Received August 20, 1996)

Editor's note: The advertisement in question was reviewed and approved by an officer of the Society before publication.

Comments on the Harvard Consortium Calculus Text
Calculus from the Harvard Consortium (CHC below) recently called forth a lively exchange of letters between Jerry Rosen and several consortium members. As a one-time Harvard professor, my first reaction was: "What, no epsilon delta at Harvard?" But it is not that simple.

The central notion of calculus is that of a limit, say limit as $h$ goes to zero. In the nineteenth century, mathematicians got it right: "For every positive epsilon there is a positive delta such that for all $h$ less than delta in absolute value..." There it is, in full glory with three alternating nested quantifiers—and this before the logicians, in the person of Gottlob Frege, got around to talking clearly about quantifiers. But that is a tough story to offer to freshman calculus. So we had better be user friendly; on page 138 of CHC reads

"We define $\lim_{h \to c} g(h) = L$ to mean that $g(h)$ can be made as close to the number $L$ as we like by choosing $h$ close enough to $c$.”

The third quantifier is obscured! One might have used a traditional phrase "becomes and remains"; I did not find that. Will the students understand that? I do not know. But I can ask if the authors of the book understand their own definition. On the next page the discussion of the continuity of $f(x)$ reads

"The closer $x$ gets to $a$, the closer $f(x)$ gets to $f(a)$"
False, the authors may have forgotten that famous function $x \sin(1/x)$.

The notion of a function is central to calculus—and hard.

In a box on page 121, I find, "One quantity $H$ is a function of another, $t$, if each value of $t$ has a unique value of $H$ associated with $t$...."

Here "quantity" indicates that we consider just numerical functions of numbers. Fair enough. The word "associated" is not defined, fair enough, so I imagined a physical situation where one can measure two different quantities $H$ and $t$. But then lower on the same page I find "Finding a function which represents a given situation is called making a mathematical model." What is going on here? Can I understand what a model is? Is there a function without a situation?

But the text has many merits. It is user friendly. After a careful three page discussion of instantaneous velocity as a limit, one finds this neatly formulated in a box (page 95), plus some reassurance "Be sure that you are not confused by the notation... you should realize that we have not introduced any new ideas in these definitions, we have simply found a compact way to write the ideas developed previously."

On page 121 (and later), there is a splendid statement and explanation of the Leibniz notation $dy/dx$. But then one reads at once that "many scientists and mathematicians really do think of $dy$ and $dx$ as separate entities representing infinitesimally small differences in $y$ and $x$, even though it is difficult to say exactly how small 'infinitesimal' is." This leaves me mystified.

Despite this, the book has many attractive features. There are elegant figures (e.g. of absolute values), and persuasive descriptions of intuition, "If the graph of $f$ looks more and more straight and nonvertical as the region near $x$ is magnified." There is a persuasive pictorial description of the Riemann sums, left and right: "for any function you are ever likely to meet the limits of the left- and right-hand sum will exist and be equal."

The historical notes are great. You join Galileo at the leaning Tower of Pisa and learn why Aristotle was all wrong about motion. There are very clear statements of the standard rules of differentiation—although there is no proof that the limit of a sum is the sum of the limits ("can you see that it is true?") p. 189).

Many results are not proved, but justified. This often means that an approximation is stated as $\approx$, the word "limit" is produced and the approximation becomes an equation. For example, in the "proof" of the Fundamental Theorem of the Calculus $a \approx$ on line -8 becomes $= = =$ on line -4.

I venture to suggest that the book needs a clear statement that a justification is not a proof and that there are indeed rigorous proofs which need to be learned. There might well be some students who would like to know this.

The book has many good exercises—perhaps a bigger collection of real world exercises than anywhere else.

Exercises are user friendly. On one page you are instructed how to measure the increase of affection between Romeo and Juliet. This will prepare you for a subsequent exercise, inviting you to set up a pair of DEs which will measure why a sequence of successive dates will or will not lead to a real relationship.

Advice to students who want action: Do not give up; if you persist to p. 551, you can help Admiral Horatio Nelson win the battle of Trafalgar, all this without standing on the poop deck of HMS Victory exposed to French sharpshooters. But the data for the numbers of ships in this problem is all wrong (Ency. Brit., 11th ed., has 27 British ships, 33 allies). Maybe the authors counted one ship-of-the-line (three gun decks) as equal to one frigate (one gun deck). The problem also misses the essentials of Nelson's strategy. Perhaps the next edition can dispose of Theiniaokles at Salamis, Don John of Austria at Lepanto and Nimitz and Fletcher at the Battle of Midway, complete with math-broken Japanese codes.

Now we can have real world problems really using differential equations. The sky is the limit, and not just for aircraft carriers.

Hold on, my yacht is off course. Hard a-lee and strike the sails. Discounting frigates does not harm the teaching of the calculus. This text represents much thought and work and presents many attractive features. They should be saved.

But when it comes to the central idea of the calculus, this text has

- Misstated the definition of the Limit.
- Confused the notion of a function.
- Left the notion of a proof obscured by a deep sea fog.

Sailors, like Horatio and Saunders, need warnings: Buoys and groaners.

May I urge Harvard Consortium to anchor those needed groaners: A clear supplementary statement correcting the major errors and the minor slips.

At first I was worried that the epsilon trouble happened at Harvard. But then I remembered that there is nothing new under the sun. When I listened to Gilbert A. Bliss lecture on his beloved Calculus of Variations at the University of Chicago, I noticed that he realized that most of his graduate students were not all that attentive—so he just dropped the epsilons from his existence proofs. He was user friendly in the best modern sense. Then I was brash, and bearded Bliss in his office only to see that he knew how to find the beloved delta for every errant epsilon. I learned something. Students can learn big ideas.

At Harvard in the old days (1910), William Fogg Osgood was a world authority on functions of one and of several complex variables (a subject exemplifying rigor). But Foggy knew well the intellectual limitations of the Harvard undergraduates, and wrote his texts on calculus accordingly. After his retirement we still used one of these texts for Math A. I recommended the appointment of one Leonidas Alaoglu, Ph.D. Chicago, whose merits were known to me. He came as a Benjamin Peirce instructor, and was of course set to teaching Math A. In that distant time, undergraduate women students did not at-
tend classes in the Harvard Yard. So on one late October day Leon came to his class in Sever Hall,

"Gentlemen, we now come to Chapter IV, differentials and infinitesimals. Take pages 138 to 184 between the thumb and fingers of the right hand. Tear them from the book!" He did so.

So weak students and the related troubles are not new to Harvard. In this present age, despite the elegant exposition which CHC present on localization, the current trouble can not be localized in any one chapter. So corrections are badly needed. Till they are at hand, any users are at risk.

P.S. August 16, 1996

I have just received from the publishers a new copy of the book. The definition of limit on page 138 now reads: "we define \( \lim_{h \to c} g(h) \) to be a number \( L \) (if one exists) such that \( g(h) \) can be made as close to \( L \) as we please whenever \( h \) is sufficiently close to \( c \) (but \( h \neq c \))."

That lost third quantifier is now reborn as a sickly "whenever". But the application to continuity on the next page is unchanged.

Saunders Mac Lane
University of Chicago
(Received August 21, 1996)

Affirmative Action, Then and Now

In the July 1996 Notices (pp. 669-670), in a reminiscence of Professor Carl Herz, W. H. J. Fuchs wrote:

[Herz] felt that it was a betrayal of the university's sacred mission to adopt criteria other than intellectual ability for the admission of minority students.

This is a most unfortunate characterization of the implementation of affirmative action programs in college and university admission programs. Were this merely the report of a political view from twenty-five years ago or the singular opinion of Professor Herz, I could let the mischaracterization pass. However, the reshaping and very continuation of affirmative action programs, particularly at colleges and universities, is an important contemporary issue which affects mathematics departments and mathematicians. Moreover, the almost syllogistic style of the quoted opinion, without regard to the historical setting of the question, is quite typical of the way some mathematicians (and others) deal with legal and societal issues.

The quoted view presupposes that until the adoption of affirmative action programs in the 1970s "intellectual ability" was the sole criterion for university admissions. However, most admission offices have always used criteria other than intellectual achievement to inform decisions. Admission to an individual institution has traditionally been based on a variety of factors, including prior academic success, athletic prowess, musical achievement, and family ties to the institution. Admission offices often consider a candidate's ability to overcome obstacles of a personal, family, or social nature. Selective institutions, for most of this century, have sought to assemble classes of students who are diverse in geography, interests, ethnicity, and, in recent decades, color.

Also presupposed is that intellectual activity is the sole mission of colleges and universities. Successful graduates achieve their success in various realms within and beyond the intellectual world, including business, government, the arts, and community leadership. College admission offices often recognize this diversity of personal trajectories and base admission decisions on a host of factors. Indeed, most institutions have broad missions to educate "the whole person", missions which include, but are not limited to, the support of predominantly intellectual pursuits such as scientific research. Thus, affirmative action programs in admission that explicitly recognize factors other than prior academic achievement are well within the tradition of most institutions' practices and in support of their missions.

We must never forget that for most of this country's history African-Americans were denied admission to higher education (indeed, were denied freedom) precisely because of their color; other ethnic groups and women have suffered serious discrimination as well. Affirmative action programs were adopted to remedy these historical circumstances and must be discussed in the context of history, not as a matter of pure logic.

The very complex affirmative action debate cannot be thoroughly explored in the pages of the Notices. Nevertheless, considering the challenges now facing those colleges and universities which consider the development of an inclusive society an important aspect of their mission, I did not want the mischaracterization of affirmative action cited in the Fuchs article to go unchallenged.

Donald Y. Goldberg
Occidental College
(Received August 29, 1996)

On the "Lost Generation" of Chinese Mathematicians

During the cultural revolution most Chinese mathematics students were forced to leave the universities to work in mines, factories, or farms. After ten years, some of them returned to continue to do mathematics, to teach, and to do research. Some of them have published in international refereed journals. Furthermore, since there was no mechanism to give degrees at that time, many of these Chinese mathematicians do not have a Ph.D., even though they have written over a dozen papers, more than many of our own Ph.D. graduates.

This spring I visited China for about four weeks, and I met some of these mathematicians. I am writing this letter for two reasons.

1. History: Some of our students are writing their Ph.D. thesis on the history of mathematics. The history of this lost generation of Chinese mathematicians should be told. It would be interesting to know the driving force that made many of them return to mathematics. They should be interviewed before their stories are lost. I am sure their stories would be an
Letters to the Editor

("Teaching at the University Level", Notices 43, p. 863) inspiration to future mathematicians. It would also be important to recognize their contributions to the mathematical community.

2. Official University Recognition: As noted above, many of these Chinese mathematicians do not have a Ph.D., and this now affects their career. One way that the American mathematical community can recognize their contributions is to invite them to visit our universities and, if possible, to give some official university title such as research professor or even, perhaps, some type of honorary degree.

I hope this letter has interested some people in the AMS to help recognize the contribution of our Chinese colleagues.

Seymour Lipschutz
Temple University
(Received September 3, 1996)

On Student Ratings of Instructors

There is something in my article that I feel needs clarification. I wrote, "Other things being equal, an easy course will rate higher than a demanding one." The "other things" include the instructor and the students. As such, the whole course evaluation process can be manipulated in a simple and predictable way.

It does not say, however, that a person who got high ratings in some course had to have taught the course at a low level. Rather, it only means that (in the usual range of possibilities) the ratings of a fixed professor in a calculus course would be a decreasing function of the demands (level of instruction, amount of material) he or she chose to place upon the students. By the way, I asked several upper-class science and engineering majors about this point, and they felt it was obvious.

The context of the article is clearly freshmen in calculus courses. I know that there have been studies done that show that, overall, undergraduates (all levels) tend to prefer a challenging course (all subjects) to an easy one. This does not imply anything about freshmen, nor anything about math courses, nor (evidently!) anything about freshmen in math courses. I might add that when I asked my department chair whether he knew of any studies on the last item, he replied, "You don't need a study to know that freshmen tend to want an easy calculus course! It's obvious from years of experience."

Steven Zucker
Johns Hopkins University
(Received September 15, 1996)

Editor's note: The Notices regrets that authors William Yslas Veléz and Evans M. Harrell II's names were misspelled in the October 1996 issue. The correct spellings are as above. Prof. Harrell's e-mail address (also incorrectly listed in the October issue) is harrell@math.gatech.edu.)


Steven Zucker
Johns Hopkins University
(Received September 15, 1996)
A Tale of Two Sieves

Carl Pomerance

(This paper is dedicated to the memory of my friend and teacher, Paul Erdős)

It is the best of times for the game of factoring large numbers into their prime factors. In 1970 it was barely possible to factor “hard” 20-digit numbers. In 1980, in the heyday of the Brillhart-Morrison continued fraction factoring algorithm, factoring of 50-digit numbers was becoming commonplace. In 1990 my own quadratic sieve factoring algorithm had doubled the length of the numbers that could be factored, the record having 116 digits.

By 1994 the quadratic sieve had factored the famous 129-digit RSA challenge number that had been estimated in Martin Gardner's 1976 Scientific American column to be safe for 40 quadrillion years (though other estimates around then were more modest). But the quadratic sieve is no longer the champion. It was replaced by Pollard's number field sieve in the spring of 1996, when that method successfully split a 130-digit RSA challenge number in about 15% of the time the quadratic sieve would have taken.

In this article we shall briefly meet these factoring algorithms—these two sieves—and some of the many people who helped to develop them.

In the middle part of this century, computational issues seemed to be out of fashion. In most books the problem of factoring big numbers was largely ignored, since it was considered trivial. After all, it was doable in principle, so what else was there to discuss? A few researchers ignored the fashions of the time and continued to try to find fast ways to factor. To these few it was a basic and fundamental problem, one that should not be shunted to the side.

But times change. In the last few decades we have seen the advent of accessible and fast computing power, and we have seen the rise of cryptographic systems that base their security on our supposed inability to factor quickly (and on other number theoretic problems). Today there are many people interested in factoring, recognizing it not only as a benchmark for the security of cryptographic systems, but for computing itself. In 1984 the Association for Computing Machinery presented a plaque to the Institute for Electrical and Electronics Engineers (IEEE) on the occasion of the IEEE centennial. It was inscribed with the prime factorization of the number $2^{251} - 1$ that was completed that year with the quadratic sieve. The president of the ACM made the following remarks:

About 300 years ago the French mathematician Mersenne speculated that $2^{251} - 1$ was a composite, that is, a factorable number. About 100 years ago it was proved to be factorable, but even 20 years ago the computational load to factor the number was considered insurmountable. Indeed, using conventional machines and traditional search algorithms, the search time

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Supported in part by National Science Foundation grant number DMS-9206784.
was estimated to be about $10^{20}$ years. The number was factored in February of this year at Sandia on a Cray computer in 32 hours, a world record. We've come a long way in computing, and to commemorate IEEE's contribution to computing we have inscribed the five factors of the Mersenne composite on a plaque. Happy Birthday, IEEE.

Factoring big numbers is a strange kind of mathematics that closely resembles the experimental sciences, where nature has the last and definitive word. If some method to factor $n$ runs for awhile and ends with the statement "$d$ is a factor of $n"$, then this assertion may be easily checked; that is, the integers have the last and definitive word. One can thus get by quite nicely without proving a theorem that a method works in general. But, as with the experimental sciences, both rigorous and heuristic analyses can be valuable in understanding the subject and moving it forward. And, as with the experimental sciences, there is sometimes a tension between pure and applied practitioners. It is held by some that the theoretical study of factoring is a freeloader at the table (or as Hendrik Lenstra once colorfully put it, paraphrasing Siegel, "a pig in the rose garden"), enjoying undeserved attention by vapidly giving various algorithms labels, be they "polynomial", "exponential", "random", etc., and offering little or nothing in return to those hard workers who would seriously compute. There is an element of truth to this view. But as we shall see, theory played a significant role in the development of the title's two sieves.

A Contest Problem
But let us begin at the beginning, at least my beginning. When I give talks on factoring, I often repeat an incident that happened to me long ago in high school. I was involved in a math contest, and one of the problems was to factor the number 8051. A time limit of five minutes was given. It is not that we were not allowed to use pocket calculators; they did not exist in 1960, around when this event occurred! Well, I was fairly good at arithmetic, and I was sure I could trial divide up to the square root of 8051 (about 90) in the time allowed. But on any test, especially a contest, many students try to get into the mind of the person who made it up. Surely they would not give a problem where the only reasonable approach was to try possible divisors frantically until one was found. There must be a clever alternate route to the answer. So I spent a couple of minutes looking for the clever way, but grew worried that I was wasting too much time. I then belatedly started trial division, but I had wasted too much time, and I missed the problem.

So can you find the clever way? If you wish to think about this for a moment, delay reading the next paragraph.

Fermat and Kraitchik
The trick is to write 8051 as $8100 - 49$, which is $90^2 - 7^2$, so we may use algebra, namely, factoring a difference of squares, to factor 8051. It is $83 \times 97$.

Does this always work? In fact, every odd composite can be factored as a difference of squares: just use the identity $ab = \left( \frac{1}{2}(a+b) \right)^2 - \left( \frac{1}{2}(a-b) \right)^2$. Trying to find a pair of squares which work is, in fact, a factorization method of Fermat. Just like trial division, which has some very easy cases (such as when there is a small prime factor), so too does the difference-of-squares method have easy cases. For example, if $n = ab$ where $a$ and $b$ are very close to $\sqrt{n}$, as in the case of $n = 8051$, it is easy to find the two squares. But in its worst cases, the difference-of-squares method can be far worse than trial division. It is worse in another way too. With trial division, most numbers fall into the easy case; namely, most numbers have a small factor. But with the difference-of-squares method, only a small fraction of numbers have a divisor near their square root, so the method works well on only a small fraction of possible inputs. (Though trial division allows one to begin a factorization for most inputs, finishing with a complete factorization is usually far more difficult. Most numbers resist this, even when a combination of trial division and difference-of-squares is used.)

In the 1920s Maurice Kraitchik came up with an interesting enhancement of Fermat's difference-of-squares technique, and it is this enhancement that is at the basis of most modern factoring algorithms. (The idea had roots in the work of Gauss and Seelhoff, but it was Kraitchik who brought it out of the shadows, introducing it to a new generation in a new century. For more on the early history of factoring, see [23].) Instead of trying to find integers $u$ and $v$ with $u^2 - v^2$ equal to $n$, Kraitchik reasoned that it might suffice to find $u$ and $v$ with $u^2 - v^2$ equal to a multiple of $n$, that is, $u^2 \equiv v^2 \pmod{n}$. Such a congruence can have uninteresting solutions, those where $u \equiv \pm v \pmod{n}$, and interesting solutions, where $u \not\equiv \pm v \pmod{n}$. In fact, if $n$ is odd and divisible by at least two different primes, then at least half of the solutions to $u^2 \equiv v^2 \pmod{n}$, with $uv$ coprime to $n$, are of the interesting variety. And for an interesting solution $u$, $v$, the greatest common factor of $u - v$ and $n$, denoted $(u - v, n)$, must be a nontrivial factor of $n$. Indeed, $n$ divides $u^2 - v^2 = 8100 - 49$.
(u − v)(u + v) but divides neither factor. So n must be somehow split between u − v and u + v.

As an aside, it should be remarked that finding the greatest common divisor (a, b) of two given numbers a and b is a very easy task. If 0 < a ≤ b and if a divides b, then (a, b) = a. If a does not divide b, with b leaving a remainder r when divided by a, then (a, b) = (a, r). This neat idea of replacing a larger problem with a smaller one is over two thousand years old and is due to Euclid. It is very fast: it takes about as much time for a computer to find the greatest common divisor of a and b as it would take to multiply them together.

Let us see how Kraitchik might have factored n = 2041. The first square above n is 46² = 2116. Consider the sequence of numbers Q(x) = x² − n for x = 46, 47,... We get

75, 168, 263, 360, 459, 560,...

So far no squares have appeared, so Fermat might still be searching. But Kraitchik has another option: namely, he tries to find several numbers x with the product of the corresponding numbers Q(x) equal to a square. For if Q(x₁) · · · Q(xₖ) = v² and x₁ · · · xₖ = u, then

u² = x₁² · · · xₖ² ≡ (x₁² − n) · · · (xₖ² − n) = Q(x₁) · · · Q(xₖ) = v² mod n;

that is, we have found a solution to u² ≡ v² mod n. But how to find the set x₁,...,xₖ? Kraitchik notices that some of the numbers Q(x) factor very easily:

75 = 3 × 5², 168 = 2³ × 3 × 7,
360 = 2³ × 3² × 5, 560 = 2⁴ × 5 × 7.

From these factorizations he can tell that the product of these four numbers is 2¹⁰ × 3³ × 5⁴ × 7², a square! Thus he has u² ≡ v² mod n, where

u = 46 · 47 · 49 · 51 = 311 mod 2041,

v = 2⁵ · 3² · 5² · 7 ≡ 1416 mod 2041.

He is now nearly done, since 311 ≡ ±1416 mod 2041. Using Euclid's algorithm to compute the greatest common factor (1416 − 311, 2041), he finds that this is 13, and so 2041 = 13 × 153.

Continued Fractions

The essence of Kraitchik's method is to "play" with the sequence xᵢ² − n as x runs through integers near √n to find a subsequence with product a square. If the square root of this sequence is v and the product of the corresponding x values is u, then u² ≡ v² mod n, and there is now a hope that this congruence is "interesting", namely, that u ≡ ±v mod n. In 1931 D. H.

Lehmer and R. E. Powers suggested replacing Kraitchik's function Q(x) = x² − n with another that is derived from the continued-fraction expansion of √n.

If aᵰ/bᵰ is the i-th continued fraction convergent to √n, let Qᵰ = aᵰ² − bᵰ². Then Qᵰ ≡ aᵰ² mod n. Thus, instead of playing with the numbers Q(x), we may play with the numbers Qᵰ, since in both cases they are congruent modulo n to known squares. Although continued fractions can be ornery beasts as far as computation goes, the case for quadratic irrationals is quite pleasant. In fact, there is a simple iterative procedure (see [16]) going back to Gauss and perhaps earlier for computing what is needed here, namely, the sequence of integers Qᵰ and the residues aᵰ mod n.

But why mess up a perfectly simple quadratic polynomial with something as exotic as continued fractions? It is because of the inequality |Qᵰ| < 2√n. The numbers Qᵰ are smaller in absolute value than the numbers Q(x). (As x moves away from √n, the numbers Q(x) grow approximately linearly, with a slope of 2√n.) If one wishes to "play" with numbers to find some of them with product a square, it is presumably easier to do this with smaller numbers than with larger numbers. So the continued fraction of Lehmer and Powers has an apparent advantage over the quadratic polynomial of Kraitchik.

How to "Play" with Numbers

It is certainly odd to have an instruction in an algorithm asking you to play with some numbers to find a subset with product a square. I am reminded of the cartoon with two white-coated scientists standing at a blackboard filled with arcane notation, and one points to a particularly delicate juncture and says to the other that at this point a miracle occurs. Is it a miracle that we were able to find the numbers 75, 168, 360, and 560 in Kraitchik's sequence with product a square? Why should we expect to find such a subsequence, and, if it exists, how can we find it efficiently?

A systematic strategy for finding a subsequence of a given sequence with product a square was found by John Brillhart and Michael Morrison, and, surprisingly, it is at heart only linear algebra (see [16]). Every positive integer m has an exponent vector ν(m) that is based on the prime factorization of m. Let pᵰ denote the i-th prime, and say m = ∏ pᵰνᵰ. (The product is over all primes, but only finitely many of the exponents νᵰ are nonzero.) Then ν(m) is the vector (ν₁, ν₂,...). For example, leaving off the infinite string of zeros after the fourth place, we have

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we should be reducing exponents modulo 2. For our purposes the exponent vectors give vectors is the zero vector mod 2. The mod 2 re-

Morrison suggest that note that their sum is the zero vector! Thus the squares, and since a positive integer is simply a subset sum equaling the 0-vector. And primes.

is not congruent to a square, since such primes are not negative. However, we can put an extra coordinate in each exponent vector, one that is 0 for positive numbers and 1 for negative numbers. (It is as if we are including the "prime" -1 in the factor base.) So allowing the auxiliary numbers to be negative just increases the dimension of the problem by 1.

For example, let us consider again the number 2041 and try to factor it via Kraitchik's polynomial, but now allowing negative values. So with $Q(x) = x^2 - 2041$ and the factor base 2, 3, and 5, we have

$$Q(43) = -192 = -2^6 \cdot 3 \rightarrow (1, 0, 1, 0)$$

$$Q(44) = -16 = -2^4 \rightarrow (1, 0, 0, 0)$$

$$Q(45) = -16 = -2^4 \rightarrow (1, 0, 0, 0)$$

$$Q(46) = 75 = 3 \cdot 5^2 \rightarrow (0, 0, 1, 0),$$

where the first coordinate corresponds to the exponent on -1. So, using the smaller factor base of 2, 3, and 5 but allowing also negatives, we are especially lucky, since the three vectors assembled so far are dependent. This leads to the congruence $(43 \cdot 45 \cdot 46)^2 \equiv (-192)(-16)(75) \mod 2041$, or $1247^2 \equiv 480^2 \mod 2041$. This again gives us the divisor 13 of 2041, since $(1247 - 480, 2041) = 13$.

Does the final greatest common divisor step always lead to a nontrivial factorization? No it does not. The reader is invited to try still another assemblage of a square in connection with 2041. This one involves $Q(x)$ for $x = 41, 45,$ and 49 and gives rise to the congruence $601^2 \equiv 1440^2 \mod 2041$. In our earlier terminology, this congruence is uninteresting, since $601 \equiv -1440 \mod 2041$. And sure enough, the greatest common divisor $(601 - 1440, 2041)$ is the quite uninteresting divisor 1.

Smooth Numbers and the Stirrings of Complexity Theory

With the advent of the RSA public key cryptosystem in the late 1970s, it became particularly important to try to predict just how hard factoring is. Not only should we know the state of the art at present, we would like to predict just what it would take to factor larger numbers beyond what is feasible now. In particular, it seems empirically that dollar for dollar computers double their speed and capacity every one and a half to two years. Assuming this and no new factoring algorithms, what will be the state of the art in ten years?

It is to this type of question that complexity theory is well suited. So how then might one analyze factoring via Kraitchik's polynomial or the Lehmer-Powers continued fraction? Richard Schroeppel, in unpublished correspondence in the late 1970s, suggested a way. Essentially, he begins by thinking of the numbers $Q_j$ in the continued-fraction method or the numbers $Q(x)$ in
Kraitchik’s method as “random”. If you are presented with a stream of truly random numbers below a particular bound $X$, how long should you expect to wait before you find some subset with product a square?

Call a number $Y$-smooth if it has no prime factor exceeding $Y$. Thus a number which completely factors over the primes up to $p_B$ is $p_B$-smooth.) What is the probability that a random positive integer up to $X$ is $Y$-smooth? It is $\psi(X, Y)/X = \psi(X, Y)/|X|$, where $\psi(X, Y)$ is the number of $Y$-smooth numbers in the interval $[1, X]$. Thus the expected number of random numbers that must be examined is about $\psi(X, Y)/X$. The expected number of steps is $\pi(Y)^2 X/\psi(X, Y)$.

It is now a job for analytic number theory to choose $Y$ as a function of $X$ so as to minimize the expression $\pi(Y)^2 X/\psi(X, Y)$. In fact, in the late 1970s the tools did not quite exist to make this estimation accurately.

This was remedied in a paper in 1983 (see [4]), though preprints of this paper were around for several years before then. So what is the minimum? It occurs when $Y$ is about $\exp(\sqrt{\log X} \log \log X)$ and the minimum value is about $\exp(2/\log X \log \log X)$. Thus $X$ and $Y$ anyway? The number $X$ is an estimate for the typical auxiliary number the algorithm produces. In the continued-fraction method, $X$ can be taken as $2 \sqrt{n}$. With Kraitchik’s polynomial, $X$ is a little larger: it is $n^{1/2+\epsilon}$. And the number $Y$ is an estimate for $p_B$, the largest prime in the factor base.

Thus factoring $n$, either via the Lehmer-Powers continued fraction or via the Kraitchik polynomial, should take about $\exp(\sqrt{2 \log n \log \log n})$ steps. This is not a theorem; it is a conjecture. The conjecture is supported by the above heuristic argument which assumes that the auxiliary numbers generated by the continued fraction of $\sqrt{n}$ or by Kraitchik’s quadratic polynomial are “random” as far as the property of being $Y$-smooth goes. This has not been proved. In addition, getting many auxiliary numbers that are $Y$-smooth may not be sufficient for factoring $n$, since each time we use linear algebra over $\mathbb{F}_2$ to assemble the congruent squares we may be very unlucky and only come up with uninteresting solutions which do not help in the factorization. Again assuming randomness, we do not expect inordinately long strings of bad luck, and this heuristic again supports the conjecture.

As mentioned, this complexity argument was first made by Richard Schroeppel in unpublished work in the late 1970s. (He assumed the result mentioned above from [4], even though at that time it was not a theorem or even really a conjecture.) Armed with the tools to study complexity, he used them during this time to come up with a new method that came to be known as the linear sieve. It was the forerunner of the quadratic sieve and also its inspiration.

Using Complexity to Come Up With a Better Algorithm: The Quadratic Sieve

The above complexity sketch shows a place where we might gain some improvement. It is the time we are taking to recognize auxiliary numbers that factor completely with the primes up to $Y = p_B$, that is, the $Y$-smooth numbers. In the argument we assumed this is about $\pi(Y)$ steps, where $\pi(Y)$ is the number of primes up to $Y$. The probability that a number is $Y$-smooth is, according to the notation above, $\psi(X, Y)/|X|$. As you might expect and as is easily checked in practice, when $Y$ is a reasonable size and $X$ is very large, this probability is very, very small. So one after the other, the auxiliary numbers pop up, and we have to invest all this time in each one, only to find out almost always that the number is not $Y$-smooth and is thus a number that we will discard.

It occurred to me early in 1981 that one might use something akin to the sieve of Eratosthenes to quickly recognize the smooth values of Kraitchik’s quadratic polynomial $Q(x) = x^2 - n$. The sieve of Eratosthenes is the well-known device for finding all the primes in an initial interval of the natural numbers. One circles the first prime 2 and then crosses off every second number, namely, 4, 6, 8, etc. The next unmarked number is 3. It is circled, and we then cross off every third number. And so on. After reaching the square root of the upper limit of the sieve, one can stop the procedure and circle every remaining unmarked number. The circled numbers are the primes; the crossed-off numbers the composites.

It should be noted that the sieve of Eratosthenes does more than find primes. Some crossed-off numbers are crossed off many times. For example, 30 is crossed off three times, as is 42, since these numbers have three prime factors. Thus we can quickly scan the array looking for numbers that are crossed off a lot and so quickly find the numbers which have many

1Actually, this is a question that has perplexed many a student in elementary algebra, not to mention many a philosopher of mathematics.
prime factors. And clearly there is a correlation between having many prime factors and having all small prime factors.

But we can do better than have a correlation. By dividing by the prime, instead of crossing off, numbers like 30 and 42 get transformed to the number 1 at the end of the sieve, since they are completely factored by the primes used in the sieve. So instead of sieving with the primes up to the square root of the upper bound of the sieve, say we only sieve with the primes up to $Y$. And instead of crossing a number off, we divide it by the prime. At the end of the sieve any number that has been changed to the number 1 is $Y$-smooth. But not every $Y$-smooth is caught in this sieve. For example, 60 gets divided by its prime factors and is changed to the number 2. The problem is higher powers of the primes up to $Y$. We can rectify this by also sieving by these higher powers and dividing hits by the underlying prime. Then the residual 1's at the end correspond exactly to the $Y$-smooth numbers in the interval.

The time for doing this is unbelievably fast compared with trial dividing each candidate number to see if it is $Y$-smooth. If the length of the interval is $N$, the number of steps is only about $N \log \log Y$, or about $\log \log Y$ steps on average per candidate.

So we can quickly recognize $Y$-smooth numbers in an initial interval. But can we use this idea to recognize $Y$-smooth values of the quadratic polynomial $Q(x) = x^2 - n$? What it takes for a sieve to work is that for each modulus $m$ in the sieve, the multiples of the number $m$ appear in regular places in the array. So take a prime $p$, for example, and ask, For which values of $x$ do we have $Q(x)$ divisible by $p$? This is not a difficult problem. If $n$ (the number being factored) is a nonzero square modulo $p$, then there are two residue classes $a$ and $b$ modulo $p$ such that $Q(x) \equiv 0 \mod p$ if and only if $x \equiv a$ or $b$ modulo $p$. If $n$ is not a square modulo $p$, then $Q(x)$ is never divisible by $p$ and no further computations with $p$ need be done.

So essentially the same idea can be used, and we can recognize the $Y$-smooth values of $Q(x)$ in about $\log \log Y$ steps per candidate value.

What does the complexity argument give us? The time to factor $n$ is now about $\exp(\sqrt{\log n \log \log n})$; namely, the factor $\sqrt{2}$ in the exponent is missing. Is this a big deal? You bet. This lower complexity and other friendly features of the method allowed a twofold increase in the length of the numbers that could be factored (compared with the continued-fraction method discussed above). And so was born the quadratic sieve method as a complexity argument and with no numerical experiments.

**Implementations and Enhancements**

In fact, I was very lucky that the quadratic sieve turned out to be a competitive algorithm. More often than not, when one invents algorithms solely via complexity arguments and thought experiments, the result is likely to be too awkward to be a competitive method. In addition, even if the basic idea is sound, there well could be important enhancements waiting to be discovered by the people who actually try the thing out. This in fact happened with the quadratic sieve.

The first person to try out the quadratic sieve method on a big number was Joseph Gerver (see [9]). Using the task as an opportunity to learn programming, he successfully factored a 47-digit number from the Cunningham project. This project, begun early in this century by Lt.-Col. Allan J. Cunningham and H. J. Woodall, consists of factoring into primes the numbers $b^n \pm 1$ for $b$ up to 12 (and not a power) and $n$ up to high numbers (see [3]). Gerver's number was a factor of $3^{225} - 1$.

Actually I had a hard time getting people to try out the quadratic sieve. Many Cunningham project factorers seemed satisfied with the continued-fraction method, and they thought that the larger values of Kraitchik's polynomial $Q(x)$, compared with the numbers $Q_1$ in the continued-fraction method, was too great a handicap for the fledgling quadratic sieve method. But at a conference in Winnipeg in the fall of 1982, I convinced Gus Simmons and Tony Warnock of Sandia Laboratories to give it a try on their Cray computer.

Jim Davis and Diane Holdridge were assigned the task of coding up the quadratic sieve on the Sandia Cray. Not only did they succeed, but they quickly began setting records. And Davis found an important enhancement that mitigated the handicap mentioned above. He found a way of switching to other quadratic polynomials after values of the first one, $Q(x) = x^2 - n$, grew uncomfortably large. Though this idea did not substantially change the complexity estimate, it made the method much more practical. Their success not only made the cover of the *Mathematical Intelligencer* (the volume 6, number 3 cover in 1984 had on it a Cray computer and the factorization of the number consisting of 71 ones), but there was even a short article in *Time* magazine, complete with a photo of Simmons.

It was ironic that shortly before the Sandia team began this project, another Sandia team had designed and manufactured an RSA chip for public key cryptography, whose security was based on our inability to factor numbers of about 100 digits. Clearly this was not safe enough, and the chip had to be scrapped.
Around this time Peter Montgomery independently came up with another, slightly better way of changing polynomials, and we now use his method rather than that of Davis.

One great advantage of the quadratic sieve method over the continued-fraction method is that with the quadratic sieve it is especially easy to distribute the task of factoring to many computers. For example, using multiple polynomials, each computer can be given its own set of quadratic polynomials to sieve. At first, the greatest successes of the quadratic sieve came from supercomputers, such as the Cray XMP at Sandia Laboratories. But with the proliferation of low-cost workstations and PCs and the natural way that the quadratic sieve can be distributed, the records passed on to those who organized distributed attacks on target numbers.

Robert Silverman was the first to factor a number using many computers. Later, Red Alford and I used over 100 very primitive, nonnetworked PCs to factor a couple of 100-digit numbers (see [2]). But we did not set a record, because while we were toiling up, Arjen Lenstra and Mark Manasse [12] took the ultimate step in distributing the problem. They put the quadratic sieve on the Internet, soliciting computer time from people all over the world. It was via such a shared effort that the 129-digit RSA challenge number was eventually factored in 1994. This project, led by Derek Atkins, Michael Graff, Paul Leyland, and Lenstra, took about eight months of real time and involved over $10^{17}$ elementary steps.

The quadratic sieve is ultimately a very simple algorithm, and this is one of its strengths. Due to its simplicity one might think that it could be possible to design a special-purpose computer solely dedicated to factoring big numbers. Jeff Smith and Sam Wagstaff at the University of Georgia had built a special-purpose processor to implement the continued-fraction method. Dubbed the "Georgia Cracker", it had some limited success but was overshadowed by quadratic sieve factorizations on conventional computers. Smith, Randy Tuler, and I (see [21]) thought we might build a special-purpose quadratic sieve processor. "Quasimodo", for Quadratic Sieve Motor, was built but never functioned properly. The point later became moot due to the exponential spread of low-cost, high-quality computers.

The Dawn of the Number Field Sieve

Taking his inspiration from a discrete logarithm algorithm of Don Coppersmith, Andrew Odlyzko, and Richard Schroeppel [6] that used quadratic number fields, John Pollard in 1988 circulated a letter to several people outlining an idea of his for factoring certain big numbers via algebraic number fields. His original idea was not for any large composite, but for certain "pretty" composites that had the property that they were close to powers and had certain other nice properties as well. He illustrated the idea with a factorization of the number $2^{67} + 1$, the seventh Fermat number. It is interesting that this number was the first major success of the continued-fraction factoring method, almost twenty years earlier.

I must admit that at first I was not too keen on Pollard's method, since it seemed to be applicable to only a few numbers. However, some people were taking it seriously, one being Hendrik Lenstra. He improved some details in the algorithm and, along with his brother Arjen and Mark Manasse, set about using the method to factor several large numbers from the Cunningham project. After a few successes (most notably a 138-digit number) and after Brian LaMacchia and Andrew Odlyzko had made some inroads in dealing with the large, sparse matrices that come up in the method, the Lenstras and Manasse set their eyes on a real prize, $2^{23} + 1$, the ninth Fermat number. Clearly it was beyond the range of the quadratic sieve. Hendrik Lenstra's own elliptic curve method, which he discovered early

\[2 \text{This number had already been suggested in Pollard's original note as a worthy goal. It was known to be composite—} \]
\[\text{in fact, we already knew a 7-digit prime factor—but the remaining 148-digit cofactor was still composite, with no factor known.} \]
in 1985 and which is especially good at splitting numbers which have a relatively small prime factor (say, "only" 30 or so digits) had so far not been of help in factoring it. The Lenstras and Manasse succeeded in getting the prime factorization of $2^{25} + 1$ in the spring of 1990. This sensational achievement announced to the world that Pollard’s number field sieve had arrived.

But what of general numbers? In the summer of 1989 I was to give a talk at the meeting of the Canadian Number Theory Association in Vancouver. It was to be a survey talk on factoring, and I figured it would be a good idea to mention Pollard’s new method. On the plane on the way to the meeting I did a complexity analysis of the method as to how it would work for general numbers, assuming myriad technical difficulties did not exist and that it was possible to run it for general numbers. I was astounded. The numbers, assuming myriad technical difficulties did not exist and that it was possible to run it for general numbers, I was astounded. The complexity for this algorithm—that-did-not-yet-exist was of the shape $\exp(c \log n)^{1/3}$ $(\log \log n)^{2/3})$. The key difference over the complexity of the quadratic sieve was that the most important quantity in the exponent, the power of $\log n$, had its exponent reduced from 1/2 to 1/3. If reducing the constant in the exponent had such a profound impact in passing from the continued-fraction method to the quadratic sieve, think what reducing the exponent in the exponent might accomplish. Clearly this method deserves some serious thought!

I do not wish to give the impression that with this complexity analysis I had single-handedly found a way to apply the number field sieve to general composites. Far from it. I merely had a shrouded glimpse of exciting possibilities for the future. That these possibilities were ever realized was mostly due to Joe Buhler, Hendrik Lenstra, and others. In addition, some months earlier Lenstra had done a complexity analysis for Pollard’s method applied to special numbers, and he too arrived at the expression $\exp(c \log n)^{1/3}$ $(\log \log n)^{2/3})$. My own analysis was based on some optimistic algebraic assumptions and on arguments about what might be expected to hold, via averaging arguments, for a general number.

The starting point of Pollard’s method to factor $n$ is to come up with a monic polynomial $f(x)$ over the integers that is irreducible and an integer $m$ such that $f(m) \equiv 0 \mod n$. The polynomial should have “moderate” degree $d$, meaning that if $n$ has between 100 and 200 digits, then $d$ should be 5 or 6. For a number such as the ninth Fermat number, $n = 2^{2^5} + 1$, it is easy to come up with such a polynomial. Note that $8n = 2^{15} + 8$. So let $f(x) = x^5 + 8$, and let $m = 2^{100}$.

Of what possible use could such a polynomial be? Let $a$ be a complex root of $f(x)$, and consider the ring $\mathbb{Z}[\alpha]$ consisting of all polynomial expressions in $\alpha$ with integer coefficients. Since $f(\alpha) = 0$ and $f(m) \equiv 0 \mod n$, by substituting the residue $m \mod n$ for each occurrence of $\alpha$ we have a natural map $\phi$ from $\mathbb{Z}[\alpha]$ to $\mathbb{Z}/(n\mathbb{Z})$. Our conditions on $f$, $\alpha$, and $m$ ensure that $\phi$ is well defined. And not only this, $\phi$ is a ring homomorphism.

Suppose now that $S$ is a finite set of coprime integer pairs $(a,b)$ with two properties. The first is that the product of the algebraic integers $a - \alpha b$ for all pairs $(a,b)$ in $S$ is a square in $\mathbb{Z}[\alpha]$, say, $y^2$. The second property for $S$ is that the product of all the numbers $a - \beta b$ for pairs $(a,b)$ in $S$ is a square in $\mathbb{Z}$, say, $v^2$. Since $\alpha$ may be written as a polynomial expression in $\alpha$, we may replace each occurrence of $\alpha$ with the integer $m$, coming up with an integer $u$ with $\phi(y) \equiv u \mod n$. Then

$$u^2 \equiv \phi(y)^2 = \phi(y^2) = \phi \left( \prod_{(a,b) \in S} (a - \alpha b) \right) = \prod_{(a,b) \in S} \phi(a - \alpha b) \equiv \prod_{(a,b) \in S} (a - \beta b) \equiv v^2 \mod n.$$ 

And we know what to do with $u$ and $v$. Just as Kraitchik showed us seventy years ago, we hope that we have an interesting congruence, that is, $u \equiv \pm v \mod n$, and if so, we take the greatest common divisor $(u - v, n)$ to get a nontrivial factor of $n$.

Where is the set $S$ of pairs $(a,b)$ supposed to come from? For at least the second property $S$ is supposed to have, namely, that the product of the numbers $a - \beta b$ is a square, it is clear we might again use exponent vectors and a sieve. Here there are two variables $a$ and $b$ instead of just the one variable in $Q(x)$ in the quadratic sieve. So we view this as a parametrized family of linear polynomials. We can fix $b$ and let $a$ run over an interval, then change to the next $b$ and repeat.

But $S$ is to have a second property too: for the same pairs $(a,b)$, the product of $a - \alpha b$ is a square in $\mathbb{Z}[\alpha]$. It was Pollard’s thought that if we were in the nice situation that $\mathbb{Z}[\alpha]$ is the full ring of algebraic integers in $Q(\alpha)$, if the ring is a unique factorization domain, and if we know a basis for the units, then we could equally well create exponent vectors for the algebraic integers $a - \alpha b$ and essentially repeat the same algorithm. To arrange for both properties of $S$ to hold simultaneously, well, this would just involve longer exponent vectors having coordinates for all the small prime numbers, for the sign of $a - \alpha b$, for all the “small” primes in $\mathbb{Z}[\alpha]$, and for each unit in the unit basis.

But how are we supposed to do this for a general number $n$? In fact, how do we even
achieve the first step of finding the polynomial \( f(x) \) and the integer \( m \) with \( f(m) \equiv 0 \mod n \). And if we could find it, why should we expect that \( \mathbb{Z}[\alpha] \) has all of the nice properties to make Pollard's plan work?

The Number Field Sieve Evolves

There is at least a very simple device to get started, that is, to find \( f(x) \) and \( m \). The trick is to find \( f(x) \) last. First, one decides on the degree \( d \) of \( f \). Next, one lets \( m \) be the integer part of \( n^{1/d} \). Now write \( n \) in the base \( m \), so that \( n = m^{d} + c_{d-1}m^{d-1} + \cdots + c_{0} \), where the base \( m \) "digits" \( c_{i} \) satisfy \( 0 \leq c_{i} < m \). (If \( n > (2d)^{d} \), then the leading "digit" \( c_{d} \) is 1.) The polynomial \( f(x) \) is now staring us in the face; it is \( x^{d} + c_{d-1}x^{d-1} + \cdots + c_{0} \). So we have a monic polynomial \( f(x) \), but is it irreducible?

There are many strategies for factoring primitive polynomials over \( \mathbb{Z} \) into irreducible factors. In fact, we have the celebrated polynomial-time algorithm of Arjen Lenstra, Hendrik Lenstra, and László Lovász for factoring primitive polynomials in \( \mathbb{Z}[x] \) (the running time is bounded by a fixed power of the sum of the degree and the number of digits in the coefficients). So suppose we are unlucky and the above procedure leads to a reducible polynomial \( f(x) \), say, \( f(x) = g(x)h(x) \). Then \( f = f(m) = g(m)h(m) \), and from a result of John Brillhart, Michael Filaseta, and Andrew Odlyzko this factorization of \( n \) is nontrivial. Our goal is to find a nontrivial factorization of \( n \), so this is hardly unlucky at all! Since almost all polynomials are irreducible, it is much more likely that the construction will let us get started with the number field sieve, and we will not be able to factor \( n \) immediately.

There was still the main problem of how one might get around the fact that there is no reason to expect the ring \( \mathbb{Z}[\alpha] \) to have any nice properties at all. By 1990 Joe Buhler, Hendrik Lenstra, and I had worked out the remaining difficulties and, incorporating a very practical idea of Len Adleman \([1]\), which simplified some of our constructions,\(^3\) published a description of the general number field sieve in \([11]\).

Here is a brief summary of what we did. The norm \( N(a - \alpha b) \) (over \( \mathbb{Q} \)) of \( a - \alpha b \) is easily worked out to be \( b^{d}f(a/b) \). This is the homogenized version of \( f \). We define \( a - \alpha b \) to be \( Y \)-smooth if \( N(a - \alpha b) \) is \( Y \)-smooth. Since the norm is multiplicative, it follows that if the product of various algebraic integers \( a - \alpha b \) is a square of an algebraic integer, then so too is the corresponding product of norms a square of an integer. Note too that we know how to find a set of pairs \( (a, b) \) with the product of \( N(a - \alpha b) \) a square. This could be done by using a sieve to discover \( Y \)-smooth values of \( N(a - \alpha b) \) and then combine them via exponent vector algebra over \( \mathbb{F}_{2} \).

But having the product of the numbers \( N(a - \alpha b) \) be a square, while a necessary condition for the product of the \( a - \alpha b \) to be a square, is far from sufficient. The principal reason for this is that the norm map takes various prime ideals to the same thing in \( \mathbb{Z} \), and so the norm can easily be a square without the argument being a square. For example, the two degree one primes in \( \mathbb{Z}[i] \), \( 2 + i \) and \( 2 - i \), have norm 5. Their product is 5, which has norm \( 25 = 5^{2} \), but \( (2+i)(2-i) = 5 \) is squarefree. (Note that if we are working in the ring of all algebraic integers in \( \mathbb{Q}[\alpha] \), then all of the prime ideal factors of \( a - \alpha b \) for coprime integers \( a \) and \( b \) are degree one; namely, their norms are rational primes.) For each prime \( p \) let \( R_{p} \) be the set of solutions to \( f(x) \equiv 0 \mod p \). When we come across a pair \( (a, b) \) with \( p \) dividing \( N(a - \alpha b) \), then some prime ideal above \( p \) divides \( a - \alpha b \).

And we can tell which one, since \( a/b \) will be congruent modulo \( p \) to one of the members of \( R_{p} \), and this will serve to distinguish the various prime ideals above \( p \). Thus we can arrange for our exponent vectors to have \#\( R_{p} \) coordinates for each prime \( p \) and so keep track of the prime ideal factorization of \( a - \alpha b \). Note that \( \#R_{p} \leq d \), the degree of \( f(x) \).

So we have gotten over the principal hurdle, but there are still many obstructions. We are supposed to be working in the ring \( \mathbb{Z}[\alpha] \), and this may not be the full ring of algebraic integers. In fact, this ring may not be a Dedekind domain, so we may not even have factorization into prime ideals. And even if we have factorization into prime ideals, the above paragraph merely assures us that the principal ideal generated by the product of the algebraic integers \( a - \alpha b \) is the square of some ideal, not necessarily the square of a principal ideal. And even if it is the square of a principal ideal, it may not be a square of an algebraic integer, because of units. (For example, the ideal generated by \(-9\) is the square of an ideal in \( \mathbb{Z} \), but \(-9\) is not a square.) And even if the product of the numbers \( a - \alpha b \) is a square.

\(^3\) Though Adleman's ideas did not change our theoretical complexity estimates for the running time, the simplicities they introduced removed most remaining obstacles to making the method competitive in practice with the quadratic sieve. It is interesting that Adleman himself, like most others around 1990, continued to think of the general number field sieve as purely a speculative method.

\(^4\) It is a theorem that if \( f \) is a monic irreducible polynomial over \( \mathbb{Z} \) with a complex root \( \alpha \) and if \( y \) is in the ring of integers of \( \mathbb{Q}(\alpha) \), then \( f'(\alpha)y \) is in \( \mathbb{Z}[\alpha] \). So if \( y^{2} \) is a square in the ring of integers of \( \mathbb{Q}(\alpha) \), then \( f'(\alpha)y^{2} \) is a square in \( \mathbb{Z}[\alpha] \).
of an algebraic integer, how do we know it is the square of an element of \( \mathbb{Z}[\alpha] \)?

The last obstruction is rather easily handled by using \( f'(\alpha)^2 \) as a multiplier, but the other obstructions seem difficult. However, there is a simple and ingenious idea of Len Adleman [1] that in one fell swoop overcomes them all. The point is that even though we are being faced with some nasty obstructions, they form, modulo squares, an \( \mathbb{F}_2 \)-vector space of fairly small dimension. So the first thought just might be to ignore the problem. But the dimension is not that small. Adleman suggested randomly choosing some quadratic characters and using their values at the numbers \( a - \alpha b \) to augment the exponent vectors. (There is one fixed choice of the random quadratic characters made at the start.)

So we are arranging for a product of numbers \( a - \alpha b \) to not only be a square up to the “obstruction space” but also highly likely actually to be a square. For example, consider the above problem with \(-9\) not being a square. If somehow we cannot “see” the problem with the sign but it sure looks like a square to us because we know that for each prime \( p \) the exponent on \( p \) in the prime factorization of \(-9\) is even, we might still detect the problem. Here is how: Consider a quadratic character evaluated at \(-9\), in this case the Legendre symbol \((-9/p)\), which is 1 if \(-9\) is a square mod \( p \) and \(-1\) if \(-9\) is not a square mod \( p \). Say we try this with \( p = 7 \). It is easy to compute this symbol, and it turns out to be \(-1\). So \(-9\) is not a square mod 7, and so it cannot be a square in \( \mathbb{Z} \). If \(-9\) is a square mod some prime \( p \), however, this does not guarantee it is a square in \( \mathbb{Z} \). For example, if we had tried this with 5 instead of 7, then \(-9\) would still be looking like a square. Adleman’s idea is to evaluate smooth values of \( a - \alpha b \) at the quadratic characters that were chosen and use the linear algebra to create an element with two properties: its (unaugmented) exponent vector has all even entries, and its value at each character is 1. This algebraic integer is highly likely, in a heuristic sense, to be a square. If it is not a square, we can continue to use linear algebra over \( \mathbb{F}_2 \) to create another candidate.

To be sure, there are still difficulties. One of these is the “square root problem”. If you have the prime factorizations of various rational integers and their product is a square, you can easily find the square root of the square via its prime factorization. But in \( \mathbb{Z}[\alpha] \) the problem does not seem so transparent. Nevertheless, there are devices for solving this too, though it still remains as a computationally interesting step in the algorithm. The interested reader should consult [15].

Perhaps it is not clear why the number field sieve is a good factoring algorithm. A key quantity in a factorization method such as the quadratic sieve or the number field sieve is what I was calling “\( X \)” earlier. It is an estimate for the size of the auxiliary numbers that we are hoping to combine into a square. Knowing \( X \) gives you the complexity; it is about \( \exp(c(\log X)^{2/3}(\log \log X)) \). In the quadratic sieve we have \( X \approx n^{1/2 + \epsilon} \). But in the number field sieve, we may choose the polynomial \( f(x) \) and the integer \( m \) in such a way that \((a - mb)^N(a - \alpha b)\) (the numbers that we hope to find smooth) is bounded by a value of \( X \) of the form \( \exp(2^{1/3}(\log \log X)) \). Thus the number of digits of the auxiliary numbers that we sieve over for smooth values is about the \( 2/3 \) power of the number of digits of \( n \), as opposed to the quadratic sieve where the auxiliary numbers have more than half the number of digits of \( n \). That is why the number field sieve is asymptotically so fast in comparison.

I mentioned earlier that the heuristic running time for the number field sieve to factor \( n \) is of the form \( \exp(c(\log n)^{2/3}(\log \log n)^{2/3}) \), but I did not reveal what \( c \) is. There are actually three values of \( c \) depending on which version of the number field sieve is used. The “special” number field sieve, more akin to Pollard’s original method and well suited to factoring numbers like \( 2^{29} + 1 \) which are near high powers, has \( c = (32/9)^{1/3} \approx 1.523 \). The “general” number field sieve is the method I sketched in this paper and is for use on any odd composite number that is not a power. It has \( c = (64/9)^{1/3} \approx 1.923 \). Finally, Don Coppersmith [5] proposed a version of the general number field sieve in which many polynomials are used. The value of “\( c \)” for this method is \( 1/(92 + 26\sqrt{13})^{1/3} \approx 1.902 \). This stands as the champion worst-case factoring method asymptotically. It had been thought that Coppersmith’s idea is completely impractical, but [8] considers whether the idea of using several polynomials may have some practical merit.

The State of the Art

In April 1996 a large team (see [7]) finished the factorization of a 130-digit RSA challenge number using the general number field sieve. Thus the gauntlet has finally been passed from the quadratic sieve, which had enjoyed champion status since 1983 for the largest “hard” number factored. Though the real time was about the same as with the quadratic sieve factorization of the 129-digit challenge number two years earlier, it was estimated that the new factorization took only about 15% of the computer time. This discrepancy was due to fewer computers being used on the project and some “down time” while code for the final stages of the algorithm was being written.
The First Twenty Fermat Numbers

\[
m \quad \text{known factorization of } F_m = 2^{2^m} + 1 \\
0 \quad 3 \\
1 \quad 5 \\
2 \quad 17 \\
3 \quad 257 \\
4 \quad 65537 \\
5 \quad 641 \cdot P_7 \\
6 \quad 274177 \cdot P_{14} \\
7 \quad 59649589127497217 \cdot P_{22} \\
8 \quad 123926361552897 \cdot P_{92} \\
9 \quad 2424833 \cdot 745560282564784208337395736200454918783366342657 \cdot P_{99} \\
10 \quad 45592577 \cdot 6487031809 \cdot 4659775785220018543264560743076778192897 \cdot P_{252} \\
11 \quad 319489 \cdot 974849 \cdot 167988556341760475137 \cdot 3560841906445833920513 \cdot P_{554} \\
12 \quad 114689 \cdot 26017793 \cdot 6376529 \cdot 190274191361 \cdot 1256132134125569 \cdot C_{1187} \\
13 \quad 2710954639361 \cdot 2663848877152141313 \cdot 3603109844542291969 \cdot 319546020820551643220672513 \cdot C_{2391} \\
14 \quad C_{4933} \\
15 \quad 1214251009 \cdot 232704250386417 \cdot C_{3944} \\
16 \quad 825753601 \cdot C_{19720} \\
17 \quad 31065037602817 \cdot C_{3944} \\
18 \quad 13631489 \cdot C_{78004} \\
19 \quad 70525124609 \cdot 646730219521 \cdot C_{157804} \\
\]

In the table, the notation \( P_k \) means a prime number of \( k \) decimal digits, while the notation \( C_k \) means a composite number of \( k \) decimal digits for which we know no nontrivial factorization.

The history of the factorization of Fermat numbers is a microcosm of the history of factoring. Fermat himself knew about \( F_0 \) through \( F_4 \), and he conjectured that all of the remaining numbers in the sequence \( 2^{2^m} + 1 \) are prime. However, Euler found the factorization of \( F_5 \). It is not too hard to find this factorization, if one uses the result, essentially due to Fermat, that for \( p \) to be a prime factor of \( F_m \) it is necessary that \( p \equiv 1 \mod 2^{m+2} \), when \( m \) is at least 2. Thus the prime factors of \( F_5 \) are all 1 mod 128, and the first such prime, which is not a smaller Fermat number, is 641. It is via this idea that \( F_5 \) was factored (by Landry in 1880) and that "small" prime factors of many other Fermat numbers have been found, including more than 80 beyond this table.

The Fermat number \( F_7 \) was the first success of the Brillhart-Morrison continued fraction factoring method. Brent and Pollard used an adaptation of Pollard’s "rho" method to factor \( F_7 \). As discussed in the main article, \( F_7 \) was factored by the number field sieve. The Fermat numbers \( F_{10} \) and \( F_{11} \) were factored by Brent using Lenstra’s elliptic curve method.

We know that \( F_{14} \), \( F_{20} \) and \( F_{22} \) are composite, but we do not know any prime factors of these numbers. That they are composite was discovered via Pepin’s criterion: \( F_m \) is prime if and only if \( 3^{(F_m-1)/2} \equiv -1 \mod F_m \). The smallest Fermat number for which we do not know if it is prime or composite is \( F_{24} \). It is now thought by many number theorists that every Fermat number after \( F_3 \) is composite.

Fermat numbers are connected with an ancient problem of Euclid: for which \( n \) is it possible to construct a regular \( n \)-gon with straightedge and compass? Gauss showed that a regular \( n \)-gon is constructible if and only if \( n \) is a product of distinct, prime Fermat numbers. Gauss’s theorem, discovered at the age of 19, followed him to his death: a regular 17-gon is etched on his gravestone.

So where is the crossover between the quadratic sieve and the number field sieve? The answer to this depends somewhat on whom you talk to. One thing everyone agrees on: for smaller numbers—say, less than 100 digits—the quadratic sieve is better, and for larger numbers—say, more than 130 digits—the number field sieve is better. One reason a question like this does not have an easy answer is that the issue is highly dependent on fine points in the programming and on the kind of computers used. For example, as reported in [7], the performance of the number field sieve is sensitive to how much memory a computer has. The quadratic sieve is as well, but not to such a large degree.

There is much that was not said in this brief survey. An important omission is a discussion of the algorithms and complexity of the linear algebra part of the quadratic sieve and the number field sieve. At the beginning we used Gaussian elimination, as Brillhart and Morrison did with the continued-fraction method. But the size of the problem has kept increasing. Nowadays a factor base of size one million is in the ballpark for record factorizations. Clearly, a linear algebra problem that is one million by one million is not a trifling matter. There is interesting new work.
on this that involves adapting iterative methods for dealing with sparse matrices over the real numbers to sparse matrices over \( \mathbb{F}_2 \). For a recent reference, see [14].

Several variations on the basic idea of the number field sieve show some promise. One can replace the linear expression \( a - mb \) used in the number field sieve with \( b^k g(a/b) \), where \( g(x) \) is an irreducible polynomial over \( \mathbb{Z} \) of degree \( k \) with \( g(m) \equiv 0 \mod n \). That is, we use two polynomials \( f(x) \), \( g(x) \) with a common root \( m \mod n \) (the original scenario has us take \( g(x) = x - m \)). It is a subject of current research to come up with good strategies for choosing polynomials. Another variation on the usual number field sieve is to replace the polynomial \( f(x) \) with a family of polynomials along the lines suggested by Coppersmith. For a description of the number field sieve incorporating both of these ideas, see [8].

The discrete logarithm problem (given a cyclic group with generator \( g \) and an element \( h \) in the group, find an integer \( x \) with \( g^x = h \)) is also of keen interest in cryptography. As mentioned, Pollard's original idea for the number field sieve was born out of a discrete logarithm algorithm. We have come full circle, since Dan Gordon, Oliver Schirokauer, and Len Adleman have all given variations of the number field sieve that can be used to compute discrete logarithms in multiplicative groups of finite fields. For a recent survey, see [22].

I have said nothing on the subject of primality testing. It is generally much easier to recognize that a number is composite than to factor it. When we use complicated and time-consuming factorization methods on a number, we already know from other tests that it is an odd composite and it is not a power.

I have given scant mention of Hendrik Lenstra's elliptic curve factorization method. This algorithm is much superior to both the quadratic sieve and the number field sieve for all but a thin set of composites, the so-called "hard" numbers, for which we reserve the sieve methods.

There is also a rigorous side to factoring, where researchers try to dispense with heuristics and prove theorems about factorization algorithms. So far we have had much more success proving theorems about probabilistic methods than deterministic methods. We do not seem close to proving that various practical methods, such as the quadratic sieve and the number field sieve, actually work as advertised. It is fortunate that the numbers we are trying to factor have not been informed of this lack of proof!

For further reading I suggest several of the references already mentioned and also [10, 13, 17, 18, 19, 20]. In addition, I am currently writing a book with Richard Crandall, PRIMES: A computational perspective, that should be out sometime in 1997.

I hope I have been able to communicate some of the ideas and excitement behind the development of the quadratic sieve and the number field sieve. This development saw an interplay between theoretical complexity estimates and good programming intuition. And neither could have gotten us to where we are now without the other.

Acknowledgments

This article is based on a lecture of the same title given as part of the Pitcher Lecture Series at Lehigh University, April 30–May 2, 1996. I gratefully acknowledge their support and encouragement for the writing of this article. I also thank the Notices editorial staff, especially Susan Landau, for their encouragement. I am grateful to the following individuals for their critical comments: Joe Buhler, Scott Contini, Richard Crandall, Bruce Dodson, Andrew Granville, Hendrik Lenstra, Kevin McCurley, Andrew Odlyzko, David Pomerance, Richard Schroeppel, John Selfridge, and Hugh Williams.

References

When I was asked to speak tonight, I could not refuse. This is a truly celebratory occasion, and I feel that as Julia's sister I should be here. Yet I find myself in a very difficult position. Here I am to speak about Julia, and being spoken about is the last thing Julia would want. As a mathematician, as was done by Carol Wood on Monday morning, yes. But as a person, no.

So I decided my subject would be simply "Being Julia Robinson's Sister". That is the one subject connected with Julia that I can talk freely about, because it's my life, not Julia's. But in the course of the evening, talking about our sisterhood—from not so much a personal point of view as from what one might call "a point of view pertaining somewhat to mathematics"—I can tell you something about Julia that will not violate her desire for personal privacy and something also about the feelings that she expressed to me on the subject of her other sisters—all the women here and the others who are mathematicians.

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This article is an adaptation of a banquet talk given by Constance Reid at the AWM's Julia Robinson Celebration of Women in Mathematics at MSRI, July 1-3, 1996.
number theory, and at RAND she had solved an important problem in game theory. She had also begun to work on Hilbert's Tenth Problem.

I knew practically nothing about these mathematical achievements or interests. Once, a year or two before, when Julia came home to San Diego for a visit, she had tried to explain to me what she had done in her thesis. I did not have the faintest idea what she was talking about or why it was significant, but I remember feeling a little sorry for her because she could not explain something important that she had done even to her sister. Oddly enough, I did not feel sorry for myself for not being able to understand.

Later in the time I am talking about, when not only I but our entire family had migrated from San Diego to the Bay Area, Julia and I saw a lot of each other. We met for lunch in San Francisco and shopped furniture stores and talked endlessly both in person and on the phone. We had many common interests. She was a housewife who did mathematics, and I was a housewife who wrote. There was also politics—this was the era of Joseph McCarthy and the infamous Loyalty Oath at Berkeley.

When we got together as a family, which we frequently did, Raphael liked to make conversation with me by telling me things about mathematics. He was a remarkable expositor, as some of you know, and he told me about Gödel's work, and Turing machines, and the theory of sets, and the pearls of number theory, and $n$-dimensional geometry, and knot theory—maybe even about Hilbert's problems. I was somewhat used to such "teaching", because during a brief period in college when Julia and I shared a room she used to tell me about things she had read in *Men of Mathematics*, which had just appeared at that time.

Well, all this effort on the part of both Robinsons was to bear fruit one morning in 1951 when Julia, in the course of a telephone conversation, reported to me the success of a program of Raphael's for testing the primality of very large Mersenne numbers on one of the new giant computers—this one was SWAC (the Bureau of Standards Western Automatic Computer). These computers, which were popularly called "giant brains", had been invented during the Second World War and had been known to the public for only about five years. Julia also explained to me the connection between Mersenne numbers and "perfect" numbers. This achievement of Raphael's interested me; it struck me as something I could write about that would interest other people too.

Julia promptly encouraged me, in a very practical way, by inviting me to lunch with Dick Lehmer, the mathematician in charge of SWAC, so that I could find out from him what SWAC looked like and how it was operated. At that time neither Raphael nor Julia had ever actually seen one of the new computers, and it is still remarkable, even to experts, that Raphael had successfully programmed SWAC simply by studying the manual. Well, Dick was helpful, and his wife, Emma, was helpful, too; it was she who suggested that I send my article to *Scientific American*. To make a long story short, *Scientific American* published it, a publisher read it and wrote to ask if I, Constance Reid, who had left mathematics for Latin in her sophomore year in high school, would be interested in writing a little book on numbers for him.

Now what still amazes me is that Julia did not try to talk me out of this project but actually encouraged me. Raphael did not encourage me, but he was not negative either. The publisher was thinking about a book on numbers to go with a book he had published on the alphabet. This suggested to me a book about the digits, since the *Scientific American* article had been in a way a story about "6" as the first perfect number. I thought I would just treat the other digits in a similar way.

Constance Reid, left, and her sister Julia Robinson in 1979.
fashion: a mixture of number theory, history, and what you might call numerology. Julia and Raphael seemed to think that I could do that. Later, though, when I got to the chapter on 9, which was to be about "casting out 9s" and other such checks, Raphael insisted that there should be some real mathematics in the book, so he explained congruences to me and the Law of Quadratic Reciprocity.

Well, that first book, From Zero to Infinity, was something of a success; it has been in print now for forty-some years. One book led to another and another, and these I wrote more and more on my own, although Julia and Raphael always read the finished manuscripts.

While I was writing these books, handling the financial side of my husband's law practice, raising my children, and working to improve the San Francisco public schools, Julia had become so absorbed in politics that she had virtually given up mathematics.

You know that Julia was a solver of mathematical problems, but do you know that she put her mind to all sorts of other problems—relatively small problems like how Marina Ratner's little daughter could learn English quickly and enjoyably (Julia's solution was to give her stories about Nancy Drew) and larger problems of the University of California (and it had plenty of problems during those years), the Democratic Party, the United States, the world.

I can give you an example of Julia's non-mathematical problem solving on a major scale. In 1952, when Adlai Stevenson was badly defeated by Eisenhower and the Democratic Party was in what can best be described as disarray, Julia was concerned about the fact that the intellectual grassroots support for Stevenson was separating itself from the Democratic Party and from party politics. She decided that her sister Constance should convey her ideas in a letter to the editor of the New Republic, since in her view I could write and she could not. Well, this past Sunday I went down to the library and looked up that letter. There it was: a column and a third at the beginning of the Letters to the Editor column in the New Republic of January 26, 1953. It was odd to read it. The words were Constance Reid's, but the political passion was Julia Robinson's! The letter appeared just before an important meeting of Democratic Party leaders at Asilomar, to which interested citizens were also invited. At Julia's urging my husband and I went with her and Raphael. We found to our amazement that all the bigwigs at the meeting were talking about my letter and were asking, "Who is this Constance Reid?" I know people have sometimes suspected that Constance Reid was really Julia Robinson, and on this occasion it was so. I do not remember exactly what happened, but the end result was that Julia involved herself during the following half dozen years in the nitty-gritty of Democratic Party politics: she registered voters, stuffed envelopes, and rang doorbells in neighborhoods where people expected to be paid for their vote. She even served as Alan Cranston's campaign manager for Contra Costa County when he successfully ran for state controller, his first political office.

This political period of Julia's life ended about 1960 when, her physical condition having become much worse, she underwent major heart surgery. The surgery greatly improved her general health, although she still lacked the stamina of a normal person; and when she taught a single class at Berkeley, as she frequently did, everything else had to be put on hold.

At this time, after writing three books explaining mathematics to laymen, I felt that I had exhausted not mathematics, but the mathematics that I was capable of explaining. So I was rather at loose ends in my writing. I wanted to do something different. Well, after three popular books about mathematics Julia had begun to think of me, not only as a writing asset, but as an asset to mathematics. One day she came across an obituary of some mathematician who had recently died. She read it with interest and, remembering what E. T. Bell's Men of Mathematics had meant to her when she was a college student, she decided it would be good for students to be able to read about more modern mathematicians than those in Bell, mathematicians whose names were also attached to theorems in their textbooks.

Constance should update E. T. Bell.

To set this proposed project in the context of Julia's mathematical career, I should say that she and Martin Davis and Hilary Putnam had just published their joint paper, "The decision problem for exponential Diophantine equations", but Julia was becoming somewhat discouraged about her ideas on the subject. To set this proposed project in the context of Julia's political career, I should say that she and Martin Davis and Hilary Putnam had just published their joint paper, "The decision problem for exponential Diophantine equations", but Julia was becoming somewhat discouraged about her ideas on the subject. A year or so before, again at Asilomar, she had explained the Tenth Problem to me. By this time I had a little more understanding than I had had when she explained her thesis. She had said to me then—which had impressed me greatly—that she did not care whether she solved the problem herself, she just had to know the answer; she would not want to die without knowing.

It was during this period that she came up with the idea of my writing a collection of short biographies of modern mathematicians, and she spent a great many hours with me going through Math Reviews and making out three-by-five cards for all the obituaries, memoirs, autobiographies, and biographies of mathematicians that we could find between the first issue in 1940 and the most recent one in 1964. I should mention that
in 1964, although there were lots of obituaries, there were no full-length biographies. There were two autobiographies, Norbert Wiener's *Ex-pupdigy* and G. H. Hardy's *A Mathematician's Apology*, which was somewhat autobiographical. That was all. This situation has changed dramatically in the interim, as you know—if not in numbers, at least in percentages.

Well, Julia was very persistent, and I became interested if not excited, so we decided to go to Europe, where I could absorb local color and interview some relatives of the mathematicians on our list, all of whom had been born after the First World War and had died.

It happened that, at the time, Julia was auditing a class of Alfred Tarski's in which the person who always arranged to sit next to her was a young Ph.D. from Gottingen, a probabilist then, named Volker Strassen. She told him that her sister was planning to write a book about men and women of modern mathematics, and Volker said that of course then we must come to Gottingen and when we came he would show us around.

It was on that trip that I first realized the respect in which Julia was held by other mathematicians.

Volker's Ph.D. adviser, Konrad Jakobs, was eager to entertain us—rather, to entertain Julia. It was clear that Volker had scored a coup with his "Doktorvater" by bringing her to Gottingen. (Incidentally, Julia told me later that it was her paper on game theory, the only paper she ever wrote on that subject, which so interested Jakobs.) Volker himself, whose wife was momentarily expecting their second child, told us that the baby was a girl—in those days people did not know before the event—he was going to name her Julia. The baby was born while we were still in Gottingen but turned out to be a boy, so Volker named him Tyko after Tycho Brahe, which showed me the class Julia was in as far as Volker was concerned.

The result of our visit to Gottingen, however, was that I abandoned the project of updating E. T. Bell and decided that I, who knew almost nothing about mathematics but what Julia and Raphael had explained to me, would write a life of David Hilbert.

I should say here that Julia had not suggested that I write about Hilbert. I came to him on my own; Hilbert simply enchanted me as he had enchanted all the young mathematicians and physicists who had flocked to study with him in Gottingen. But if you think Julia tried to discourage her mathematically untrained sister from writing the life of the greatest mathematician of the first half of the twentieth century, you did not know Julia.

For my birthday she gave me the three volumes of Hilbert's collected works, and when her mathematical friends inquired about my qualifications for writing the life of Hilbert, she told them with a perfectly straight face that I was reading all his papers.

(Incidentally, I did read *all the words* in Hilbert's collected works—mathematicians of those days wrote more in words than they write today—and Hilbert's were quite enlightening in regard to his ideas and feelings about mathematics.)

Julia then suggested that I interview mathematicians in the area who had actually known Hilbert: Lewy, Pólya, Szegö, even Siegel, who was passing through Palo Alto on his way back to Germany. But I was hesitant about talking to real mathematicians about writing about Hilbert—Julia and Raphael, OK; they were family, but Carl Ludwig Siegel? I remember Julia's saying slyly, "You're afraid they will find out that you're a hoax, Constance"—which, of course, I was.

Now, even a quarter of century after the publication of *Hilbert* and the other biographies that have followed, I still do not really understand why Julia encouraged me as she did when I might have disgraced, certainly embarrassed, both her and Raphael.

I think that perhaps at least part of the explanation lies in something Julia said to Olga Taussky after *Hilbert* was published and was an unexpected success among mathematicians. Olga was complaining that there were other important things that she would have told me about her mathematical relationship to Hilbert if she had known "that EVERYBODY was going to read the book," but many people had come in the past to talk to her about her days in Göttingen and then nothing had ever happened, so she had thought it would be the same with me.

"Olga," Julia said, "you should have known that the Bowman girls always finish what they start."

At that time Julia had not been a Bowman for thirty years, and I had not been a Bowman for twenty; but I think that the strong sense our parents conveyed to us that being a Bowman was something special, although in actuality the Bowmans were quite ordinary people, was at the foundation of Julia's sense of herself, and of course she knew it had rubbed off on me too. I might write as Constance Reid, but at bottom I was Constance Bowman.

Well, after *Hilbert* I wrote a life of Richard Courant at the suggestion of K. O. Friedrichs, who became my mathematical collaborator in that project. I can not say that Julia and Raphael were exactly "miffed" to see me going off on my own, but they did feel a little out of it, although both of them read the manuscript.
Naturally, after I had written *Hilbert* and *Courant*, and Julia had become famous, and Saunders Mac Lane had proposed her for membership in the National Academy of Sciences, and Alfred Tarski and Jerzy Neyman, who were old and not well and who didn't much care for each other, had both made the trip back to Washington, DC, just so that they would be present to help explain the importance of Julia's work, people began to make what they always thought was an original suggestion: why don't you write a life of your sister?

The truth of the matter is that I never considered doing so.

I knew Julia and I knew myself, and neither of us would want our biographies written by anyone. I did think, however, that Julia should let herself be interviewed for *More Mathematical People*, which I was helping to edit, because—and this was a telling point—she had objected in regard to the earlier book, *Mathematical People*, that it had contained interviews with three women—me, Mina Rees, and Olga Taussky Todd—people, not mathematicians, being the operative word in the title—but only one of the three was a research mathematician.

"Julia," I said, "how can you object when you yourself refused to be interviewed?"

She of course had no answer to that.

Well, after her election to the National Academy of Sciences in 1976—you have all heard, I am sure, the story about Julia's being identified as "Professor Robinson's wife" when the university press office called the mathematics department to find out just who Julia Robinson was—Berkeley started to think how it could get this new academician into its stable. There was the problem that Julia because of her health, although it was much improved, did not want and could not handle the rigors of a full professorship.

(Incidentally, Julia once told Cathleen Morawetz—this must have been in the early 1970s when she and Raphael began to talk about his retiring early so he could devote more of his time to mathematics—that what she would really like was to share a job with him, but I am sure she had never suggested this to anybody in the Berkeley department. Certainly I had never heard anything about it nor, according to Raphael, had he, but it is a kind of "Julia solution" to a problem.)

Well, to go back, after she was elected to the Academy, the Berkeley mathematics department came up with the idea of offering her a full professorship with the duty of teaching just one-fourth time, which was just about exactly what she had been doing for a number of years. The department seemed to have been a little concerned about the appropriateness of such an offer, because the chairman consulted Saunders Mac Lane, who recently sent me a copy of his response:

"In my opinion it would be eminently appropriate that Dr. Robinson receive a professorial appointment, under such part-time arrangement as may be mutually agreeable," Mac Lane wrote. "Her accomplishments in mathematical logic and related topics are, in my considered opinion, outstanding and would justify her appointment as a Distinguished Service Professor, or its equivalent, at any leading American university, but most appropriately at the University of California at Berkeley."

As you know, Julia accepted Berkeley's offer. But that was not the end. She was showered with more and more honors. I can still hear her, telephoning me about some new award, saying, almost in despair—anyway in mock despair—"Constance, what next?"

This may in fact have been when she was asked if she was willing to have her name put up as the unopposed candidate for president of the American Mathematical Society. Raphael did not think that she should accept but should save her energy for mathematics, as he would have done. He did not try to impose his view on her; he simply stated his opinion. But when she consulted me, I said that I felt there was no way she could not accept, and she agreed, not because it was my opinion, but because it was the same as her own. It might be a long time before another woman mathematician was offered the position. In fact, of course, it was almost ten years.

I should tell you, however, that Raphael accepted Julia's decision with grace, cooking and taking care of himself during her many absences.

So here my sister was, famous for her mathematical work and famous for her "firsts", steadfastly refusing to be written about. "Dear So and So," she wrote to someone who wanted to include her in a book about women scientists, "I am of course very flattered to be considered for your
book, but I must ask you not to write about me. I am appalled at the prospect of details of my life and beliefs appearing in print. (I don't even want to be written about after I'm dead but that is difficult to manage.) This has nothing to do with your abilities and qualifications, as I will continue in the future to discourage any account of my life.

In her view a mathematician was his or her work; personality/personal details could do nothing to illuminate that and so were of no importance. She detested what she saw as the cult of personality: the prying into every aspect of what was private that was and still is prevalent in biographical—and, for that matter, autobiographical—writing.

Although I felt very much the same, I thought that her position in relation to any writing about her life and views was logically untenable. She, however, stubbornly maintained that position until it was clear to her and to me that she was going to die.

Then I brought forth my most telling argument. Given her achievements, somebody was bound to write a biography of her. How much better if her sister wrote it and she herself had the opportunity to approve it! She finally agreed.

On June 30, 1985—as it turned out, just thirty days before she died—we had an interview about what she recalled as significant about her life. She was lying on the couch in her living room and Raphael was present, although he never said a word or even made a sound, except to agree with a chuckle that Julia was indeed very stubborn.

Almost immediately I got the idea of writing her life, in imitation of Gertrude Stein, as "The Autobiography of Julia Robinson". I think this was because Julia had told me at this time how struck she had been by something Kay Boyle had written to the effect that the only reason for writing a book that could be placed in the hands, not only of a mathematician, but of mathematicians, was to give credit where credit was due. There were people to whom Julia very much wanted to give credit. Beyond our parents and others from her early days, these were all men. A young assistant professor at San Diego State College who, in opposition to the head of his department, told her to go and to go to Berkeley. Her husband, Raphael Robinson, of whom she said that she did not think she would have become a mathematician if he had not been for him. Alfred Tarski, her thesis adviser, whose mathematics was so completely right for Julia that it is hard to imagine her career if he had not come to Berkeley when he did. Jerzy Neyman, who by providing financial support made it possible for her to continue graduate study at Berkeley after she got her A.B. Yuri Matijasevich, who provided the last thing that was needed to prove that the solution of the Tenth Problem is indeed negative and whose friendship and collaboration over the barriers of age, sex, geography, and the cold war were so satisfying to her during the last years of her life.

I worked very hard on the "autobiography", knowing I was working against time, and each day read what I had written to Julia, who was back in the hospital. She listened attentively, making suggestions or deletions. Today when I reread the "autobiography", I feel that I am reading something that Julia herself wrote. It is an eerie sensation.

"The Autobiography of Julia Robinson" was published in the College Mathematics Journal in 1986 and reprinted in More Mathematical People in 1990. I felt that I had done all that was needed. Then, at the beginning of 1995, Raphael Robinson died, and I became the executor of his estate. Since he had not disposed of Julia's papers, photographs, and memorabilia when she died ten years earlier, I became her executor as well. This was the last service I was called upon to perform for my sister, a sort of closure of our "somewhat mathematical" relationship.

I knew very well Julia's feelings about privacy, and I tried to observe them in making decisions. I gave her mathematical letters to the Bancroft Library with the proviso that nothing personal was to be quoted without my permission. I cooperated with the American Mathematical Society in its wish to publish her collected papers along with the very fine memoir Solomon Feferman had written for the National Academy of Sciences. But after I had disposed of the mathematical correspondence and the mathematical papers, there were still many photographs and much memorabilia. I could not help wishing that I had had these to illustrate the "autobiography", particularly those that were relevant, although not technically mathematical, to Julia's mathematical career. It seemed that something more about Julia was wanted: a book that could be placed in the hands, not only of professional mathematicians, but of mathematics teachers and students and even non-mathematicians. My first thought was perhaps the "autobiography" should be reprinted in a little book of its own and expanded with some of the illustrative material that I had found among Julia's things, yet never going beyond the content of the "autobiography", which was all she had wanted to leave as a record of her life. But then I felt that the book should include as well something about Julia's mathematical work that gave a sense of the character of her thought and the personal warmth that she brought to collaboration. So I asked Lisl Gaal, Martin Davis, and Yuri Matijasevich for permission to reprint articles they had written earlier that had been published in widely separated places. The result of
This publication is an indispensable source of information for students seeking support for graduate study in the mathematical sciences. Providing data from a broad range of academic institutions, it is also a valuable resource for mathematical sciences departments and faculty.

Assistantships and Graduate Fellowships brings together a wealth of information about resources available for graduate study in mathematical sciences departments in the U.S. and Canada. Information on the number of faculty, graduate students, and degrees awarded (bachelor's, master's, and doctoral) is listed for each department when provided. Stipend amounts and the number of awards available are given, as well as information about foreign language requirements. Numerous display advertisements from mathematical sciences departments throughout the country provide additional information.

Listed are sources of support for graduate study and travel, and summer internships in the U.S. for foreign nationals. Finally, a list of reference publications for fellowship information makes Assistantships and Graduate Fellowships a centralized and comprehensive resource.

1996; 126 pages; Softcover; ISBN 0-8218-0189-9; List $20; Individual member $12; Order code ASST/96NA

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our "collaboration", the book Julia, a life in mathematics, is being published by the Mathematical Association of America.

I do not feel that I want to profit from these books about Julia, so I am donating my share of the royalties from the collected works and all the royalties from Julia to the San Diego High School Foundation to fund a Julia Bowman Robinson Prize at the high school where, after the sophomore year, she was the only girl taking mathematics. The prize is not gender-designated. It is simply to go to the best mathematics student in the graduating class. Last year it happened that it went to a young man and this year to a young woman; and I understand from their teacher, a remarkable and dedicated woman, that the ratio of females to males in the advanced mathematics class is now 50:50.

Julia firmly believed that there is no reason that women cannot be mathematicians, and she just as firmly believed that there should be affirmative action to bring women onto mathematical faculties at colleges and universities. "If we do not change anything," she said to me in that last interview, "then nothing will change." She did not expect the ratio to be 50:50, but she felt that affirmative action should continue until male mathematicians no longer considered the presence of female mathematicians to be unusual.

Julia thought of mathematicians—these were her words once to a group of young people—"as forming a nation of our own without distinctions of geographical origins, race, creed, sex, age, or even time (the mathematicians of the past and you of the future are our colleagues too)—all dedicated to the most beautiful of the arts and sciences."

As the nonmathematical sister of the mathematician Julia Robinson, I would like to close with that thought.
Report on the 1996 Survey of New Doctoral Recipients

John D. Fulton

This report presents a statistical profile of recipients of doctoral degrees awarded by departments in the mathematical sciences at universities in the United States during the period July 1, 1995, through June 30, 1996. It includes an analysis of the employment market for 1995-1996 doctoral recipients and a demographic profile summarizing characteristics of citizenship status, gender, and racial/ethnic group. Table 1 provides the response rates for the 1996 Survey of New Doctoral Recipients. Please see pages 1501-1502 for a description of the Groups, newly defined for the 1996 Survey.

Table 1: Response Rates

<table>
<thead>
<tr>
<th>Group</th>
<th>Response Rate</th>
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<tr>
<td>I</td>
<td>47 of 48</td>
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<tr>
<td>II</td>
<td>54 of 56 including 3 with 0 degrees</td>
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<tr>
<td>III</td>
<td>63 of 72 including 17 with 0 degrees</td>
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<tr>
<td>IV</td>
<td>54 of 80 including 4 with 0 degrees</td>
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<tr>
<td>Va</td>
<td>16 of 19</td>
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<tr>
<td>Vb</td>
<td>13 of 33 including 2 with 0 degrees</td>
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</table>

Doctoral Degrees Granted
The number of new doctoral recipients reported in 1995-1996 by U.S. mathematical sciences departments is 1,153. Table 2A gives the fall and spring counts for the past four Annual Surveys together with the current fall count. This year's fall count will be updated in the Second Report of the 1996 Survey, to appear in a spring 1997 issue of Notices.

Table 2A: U.S. New Doctoral Recipients, Fall and Spring Counts

<table>
<thead>
<tr>
<th>Year</th>
<th>Fall</th>
<th>Spring</th>
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<tr>
<td>1991-1992</td>
<td>1050</td>
<td>1062</td>
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<td>1992-1993</td>
<td>1202</td>
<td>1214</td>
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<td>1993-1994</td>
<td>1059</td>
<td>1076</td>
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<td>1994-1995</td>
<td>1226</td>
<td>1237</td>
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<tr>
<td>1995-1996</td>
<td>1153</td>
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</table>

The fall count of the total number of new doctoral recipients represents a decrease of 6.0 percent from the fall all-time high count of 1,226 in the 1995 Survey. This year's fall count still represents an increase, of 57.5 percent, over the 1984-1985 fall count of 732 new doctoral recipients from U.S. institutions, one of the lowest counts within the last twenty years.

Table 2B records the annual number of new doctoral recipients in the mathematical sciences in the U.S. from the year 1991-1992, exclusive of Group Vb. The response rate for Group Vb, which includes some departments in engineering and management science, is the lowest of all groups.

Table 2B: New Doctoral Degrees Awarded by Groups I-Va, Fall Count

<table>
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<tr>
<th>Year</th>
<th>91-92</th>
<th>92-93</th>
<th>93-94</th>
<th>94-95</th>
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<tr>
<td>I-Va</td>
<td>998</td>
<td>1104</td>
<td>1025</td>
<td>1148</td>
<td>1098</td>
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The columns in Table 3B indicate how the count of 1,153 new doctoral recipients was spread over the mathematical sciences departments in Groups I-V. For mathematics departments (Groups I, II, and III combined), there was a decrease of 4.3 percent in the fall count of new doctoral recipients. Because of the new groupings of mathematics departments, it would not be meaningful to make comparisons involving Groups I, II, or III individually with the counts of 1994-1995 or previous years.


The Annual Survey of New Doctoral Recipients provides a view of the employment market for new Ph.D.s in the mathematical sciences from the perspective of job applicants. Additional information about recruitment by four-year colleges and universities is reported in the Second Report of the Annual Survey; see the 1995 Second Report, Notices, August 1996, pages 848-858, for data on the numbers of positions departments attempted to fill and characteristics of the people hired.

Table 3A shows the employment status, by type of employer and field of degree, of the 1,153 recipients of doctoral degrees conferred by mathematical sciences departments in the U.S. between July 1, 1995, and June 30, 1996. The names of the individuals will be listed with their thesis titles in a later issue of Notices. The employment information was obtained initially from the departments granting the degrees and subsequently from data provided by the degree recipients themselves.

Most new doctoral recipients seek and accept academic positions. Of the 732 new doctoral recipients employed in the U.S., a total of 506 (69.1 percent) hold jobs in academia. For compari-
### Table 3A: Employment Status of 1995–1996 U.S. New Doctoral Recipients in the Mathematical Sciences

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<tr>
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</table>

*Non-U.S. citizens who return to their country of citizenship and whose status is reported as "unknown" or "still seeking employment".

### Table 3B: Employment Status of 1995–1996 U.S. New Doctoral Recipients by Type of Granting Department

<table>
<thead>
<tr>
<th>TYPE OF EMPLOYER</th>
<th>TYPE OF DOCTORAL DEGREE-GANTING DEPARTMENT</th>
<th>GROUP I (PUBLIC)</th>
<th>GROUP I (PRIVATE)</th>
<th>GROUP II</th>
<th>GROUP III</th>
<th>GROUP IV</th>
<th>GROUP V</th>
<th>ROW TOTAL</th>
<th>ROW SUBTOTAL</th>
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<td>Math</td>
<td>Math</td>
<td>Math</td>
<td>Statistics</td>
<td>Applied Math/OR</td>
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<td>Two-Year Colleges</td>
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<td>Other Academic Depts.</td>
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<td>Research Institutes</td>
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<td>7</td>
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</tr>
<tr>
<td>Business and Industry</td>
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<tr>
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<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not seeking employment</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Still seeking employment</td>
<td>23 14 34 12 6 5 94</td>
<td>70</td>
<td>24</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unknown (U.S.)</td>
<td>23 14 10 5 6 13 71</td>
<td>54</td>
<td>17</td>
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<td></td>
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<tr>
<td>Unknown (non-U.S.)*</td>
<td>21 11 16 13 12 12 85</td>
<td>67</td>
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<td>Column Total</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Column Male</td>
<td>263 137 181 89 126 108 904</td>
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<tr>
<td>Subtotals Female</td>
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<td>249</td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

*Non-U.S. citizens who return to their country of citizenship and whose status is reported as "unknown" or "still seeking employment".

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son, last year’s First Report showed 724 new doctoral recipients employed in the U.S., including 534 (73.8 percent) in academic positions. Thus total U.S. employment of new doctoral recipients increased for the second year in a row but the rate of increase this year, 1.1 percent, was slight. The percentage of positions in academia decreased by 5.2 percent. Concomitantly, the number of nonacademic positions in the U.S. taken by new doctoral recipients increased by 18.9 percent to 226.

The 506 U.S. academic positions this year include a total of 239 in U.S. doctoral degree-granting departments (Groups I-V). This number is 3.9 percent higher than last year (230 positions in Groups I-V). The number of new doctoral recipients employed by master’s and bachelor’s degree-granting colleges and universities (Groups M and B) decreased by 35 (17.4 percent) from the number reported last year. While the numbers of new doctoral recipients hired by government remained constant and new doctoral recipients hired by research institutes increased slightly from those reported last year (by 5.9 percent), hiring by business and industry increased markedly (by 18.1 percent). Employment of the new doctoral recipients by business and industry constitutes 26.8 percent of all U.S. employment of these new doctoral recipients. Last year, 22.9 percent were hired by business and industry.

Though the number of positions into which new doctoral recipients have been hired has decreased (by 2.5 percent), the job market for 1995–1996 new doctoral recipients has been somewhat better than the corresponding markets for 1991-1992, 1992-1993, 1993-1994, and 1994-1995. Table 3A shows that among those whose employment status is known, 9.4 percent are unemployed. (The corresponding rate of unemployment for 1994–1995 doctoral recipients from U.S. institutions, reported in fall 1995, was 14.7 percent). The 1996 unemployment level ranks as the lowest since the fall 1990 rate of 5.7 percent. Last year's unemployment rate of 14.7 percent ranked as the highest ever observed since 1971, when employment information about new doctoral recipients was first reported in the current format.

The data in Table 3A were obtained in many instances early in the summer of 1996 and do not reflect subsequent hiring. Nonetheless, the year-to-year comparisons are all based on data acquired over the same time period of each year, and they reliably reflect the relative state of this year’s market. An update of Table 3A will appear in the 1996 Second Report. Table 3C shows the trend in the unemployment figures reported in the respective Annual Survey Reports for the 1989–1990 through 1994–1995 cohorts of new doctoral recipients.

Beyond the unemployment statistics that are explicitly reported in Tables 3A and 3C, the 1996 Survey reveals other indicators of a somewhat improved job market. For example, 32 (2.8 percent) new doctoral recipients are reported to hold part-time positions, and 69 (6.9 percent) new doctoral recipients hold employment at the same institution that awarded their degree, although not necessarily in the same department in which the degree was earned. To compare with the corresponding statistics in 1995, out of 230 jobs held by 1994–1995 doctoral recipients in doctoral degree-granting departments, 45 (4.2 percent) were part-time and 78 (7.2 percent) were held by doctoral recipients in the same institutions where they earned their doctoral degrees.

<table>
<thead>
<tr>
<th>Year</th>
<th>Fall</th>
<th>Spring</th>
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</thead>
<tbody>
<tr>
<td>1989-1990</td>
<td>5.7</td>
<td>2.2</td>
</tr>
<tr>
<td>1990-1991</td>
<td>12.4</td>
<td>5.0</td>
</tr>
<tr>
<td>1991-1992</td>
<td>12.7</td>
<td>6.7</td>
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<tr>
<td>1992-1993</td>
<td>12.4</td>
<td>8.9</td>
</tr>
<tr>
<td>1993-1994</td>
<td>14.2</td>
<td>10.7</td>
</tr>
<tr>
<td>1994-1995</td>
<td>14.7</td>
<td>10.7</td>
</tr>
<tr>
<td>1995-1996</td>
<td>9.4</td>
<td></td>
</tr>
</tbody>
</table>

percentage of noncitizens in the same category (24.1 percent of citizens versus 21.6 percent of noncitizens). The percentage of U.S. citizens holding positions in U.S. doctoral degree-granting departments (23.4 percent) is slightly lower than the percentage for non-U.S. citizens (24.8 percent). U.S. citizens hold positions in non-doctoral-degree granting U.S. departments in substantially higher proportion than do noncitizens (37.7 percent of citizens compared to 13.6 percent of noncitizens). All percentages exclude new doctoral recipients whose job status is unknown.

If complete information about the visa status of the non-U.S. citizens were known, then it would be more natural and common to group those holding permanent-resident status with the U.S. citizens for the comparison of employment patterns. However, the visa status is unknown for many of the non-U.S. citizens simply because this is a detail of their immigration status which is not always known to departmental staff; visa status is not known for 24.8 percent of the non-U.S. citizens.

Nonetheless, the distribution of job categories was gathered for 123 non-U.S. citizens new doctoral recipients who are known to be permanent U.S. residents. Of those whose employment status is known, 23.6 percent are employed by a doctoral degree-granting department in the U.S., 17.9 percent are employed by a non-doctoral degree-granting department in the U.S., and 16.3 percent are unemployed.

**Gender, Ethnicity, and Citizenship of U.S. New Doctoral Recipients, 1995-1996**

Table 4 presents a breakdown according to gender, ethnic group, and citizenship of the new doctoral recipients. The information reported in this table was obtained in summary form from the departments granting the degrees and in a few cases from the recipients themselves.

The citizenship status is known for 1,150 of the 1,153 new doctoral recipients, including 493 U.S. citizens. (Because different survey forms are used to compile the summary of gender, ethnicity, and citizenship than are used to learn the country of citizenship of each individual, and the unknown or missing items from the two survey forms may not coincide, this count of known citizenship status and of U.S. citizens differs from the count shown in Table 3D). The number of U.S. citizen new doctoral recipients is 13.1 percent less than the 1994-1995 figure of 567, which had been the highest reported since 1980-1981. Table 5 shows the changes from year to year in the numbers and proportions of U.S. citizens.

The percentage of U.S. citizens among the new doctoral recipients is 42.9 percent, a significant decrease from last year’s percentage of 47.0 percent, and very close to the all-time low of 42.3 percent in 1991-1992. A total of 657 noncitizens were awarded doctoral degrees by U.S. institutions in 1995-1996. This represents an increase of 17 individuals (2.7 percent) from last year's count. The 1995-1996 count is 99 percent greater than the number awarded by U.S. institutions ten years ago (330 in 1984-1985).

Among the U.S. citizens receiving doctoral degrees in the mathematical sciences, 9 are black (7 men and 2 women) and 9 are Mexican American, Puerto Rican, or other Hispanic (8 men and 1 woman). The former is up 3 from last year, while the latter remained the same.

Women account for 23.5 percent of the U.S. citizens receiving doctoral degrees in the mathematical sciences from U.S. universities. This is the fourth highest percentage ever reported but down from the record high percentage (28 percent) reported in 1993 and also down from the percentage (24.9 percent) reported last year. The total number of U.S. citizen women who were 1995-1996 doctoral recipients (116) decreased by 17.7 percent from last year’s reported 141, and is 29 less than the highest number, reported in 1992-1993 (see Table 6).

---

**Table 4: Gender, Ethnicity, and Citizenship of 1995-1996 U.S. New Doctoral Recipients**

<table>
<thead>
<tr>
<th>RACIAL/ETHNIC GROUP</th>
<th>MEN</th>
<th>WOMEN</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>U.S.</td>
<td>Other</td>
<td>Not Known</td>
</tr>
<tr>
<td>Asian, Pacific Islander</td>
<td>13</td>
<td>303</td>
<td>2</td>
</tr>
<tr>
<td>Black</td>
<td>7</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>American Indian, Eskimo, Aleut</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Mexican American, Puerto Rican, or other Hispanic</td>
<td>8</td>
<td>28</td>
<td>36</td>
</tr>
<tr>
<td>White (non-Hispanic)</td>
<td>347</td>
<td>179</td>
<td>1</td>
</tr>
<tr>
<td>Unknown</td>
<td>1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>377</td>
<td>523</td>
<td>3</td>
</tr>
</tbody>
</table>
sitions filled. To date, 256 individual responses have been received from new doctoral recipients by academic institutions. Sixty-four percent of these respondents report that their positions are not tenure-eligible and the remaining 34.5 percent report that their positions are tenured or tenure-track positions (1.5 percent are unknown). Out of the 164 nontenure-eligible respondents, 24.4 percent can hold their current positions for a maximum of one year, and 53.7 percent can hold their positions for up to two years. Thus, the incumbents of many of the nontenure-eligible positions will again be seeking jobs during the current year.

The proportion of the jobs filled which are tenured or tenure-eligible varies significantly between the survey Groups. Among the 256 individual respondents holding jobs in academic institutions, 101 have positions in a doctoral degree-granting department, and 85 have positions in a bachelor's or master's degree-granting department. In the doctoral degree-granting departments 84.2 percent of the positions held by new doctoral recipients are not tenure-eligible, while 37.6 percent of the positions in bachelor's and master's degree-granting departments are not tenure-eligible.

Table 3B reveals the dependence of employment patterns on the type of department from which the doctoral degree is received. The patterns of compartmentalization and stratification of the job market for new doctoral recipients are similar to the patterns seen in the 1995 Survey. For example, Table 3B shows that new doctoral recipients hired for positions in doctoral degree-granting mathematics departments (Groups I, II, III) are drawn predominantly from mathematics degree recipients: 93.3 percent of the positions filled in Groups I, II, and III are held by those who received their degrees from Group I, II, or III departments. Similarly, 86.7 percent of the Group IV jobs held by new doctoral recipients went to Group IV degree recipients. These percentages compare with 86 percent and 90 percent, respectively, from the 1995 Survey.

Women represent 21.6 percent of the population of new doctoral recipients, down from 22.9 percent in 1994-1995, but the proportion is not uniform across different types of departments. For example, 20.7 percent of the new doctoral recipients in mathematics (Groups I+II+III) are women (down from 22.2 percent last year), and 26.1 percent of the new doctoral recipients from statistics departments are women (up from 24.1 percent last year). The proportion of women among new doctoral recipients hired by doctoral degree-granting mathematics departments (20.6 percent) is slightly less than their proportion among mathematics doctoral recipients. The rate of unemployment for the female new doctoral recipients (11.2 percent) is greater than the rate for the male new doctoral recipients (8.9 percent).

Table 3B shows different rates of unemployment for doctoral recipients from the five Groups. The percentages unemployed, among those whose employment status is known, are Group I (Public)-8.2 percent, Group I (Private)-9.4 percent, Group II-17.3 percent, Group III-11.3 percent, Group IV-3.9 percent, and Group V-4.5 percent.

Table 3D shows the pattern of employment within broad job categories broken down by the citizenship status of the new doctoral recipients (from U.S. institutions). The citizenship status is known for 1,144 of the 1,153 new doctoral recipients. For those whose job status is known, the rate of unemployment for non-U.S. citizens is nearly 3 percentage points higher than that for U.S. citizens (10.8 percent noncitizens and 8.0 percent citizens). The unemployment rate for U.S. citizens is 5.6 percentage points below the level reported in the 1995 First Report for 1994-1995 new doctoral recipients. The percentage of U.S. citizens in U.S. nonacademic jobs is higher than the per-

Table 3D: Employment Status of 1995-1996 U.S. New Doctoral Recipients by Citizenship Status*

<table>
<thead>
<tr>
<th>TYPE OF EMPLOYER</th>
<th>TYPE OF CITIZENSHIP</th>
<th>TOTAL DOCTORAL RECIPIENTS WHOSE CITIZENSHIP IS KNOWN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>U.S. Citizens</td>
<td>Non-U.S. Citizens</td>
</tr>
<tr>
<td></td>
<td>Number   Percent</td>
<td>Number   Percent</td>
</tr>
<tr>
<td>U.S. Academic, Ph.D. Department</td>
<td>108       22</td>
<td>131       20</td>
</tr>
<tr>
<td>U.S. Academic, non-Ph.D. Department</td>
<td>174       35</td>
<td>72        11</td>
</tr>
<tr>
<td>U.S. Research Institute</td>
<td>5         1</td>
<td>13        2</td>
</tr>
<tr>
<td>U.S. Nonacademic</td>
<td>111       22</td>
<td>114       18</td>
</tr>
<tr>
<td>Foreign Academic</td>
<td>18        4</td>
<td>116       18</td>
</tr>
<tr>
<td>Foreign Nonacademic</td>
<td>0         0</td>
<td>10        2</td>
</tr>
<tr>
<td>Not seeking employment</td>
<td>8         2</td>
<td>15        2</td>
</tr>
<tr>
<td>Still seeking employment</td>
<td>37        7</td>
<td>57        9</td>
</tr>
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<td>41        8</td>
<td>29        5</td>
</tr>
<tr>
<td>Unknown status (foreign address)</td>
<td>0         0</td>
<td>85        13</td>
</tr>
<tr>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
</tbody>
</table>

**The adjusted total varies from that in Table 5 because the data are gathered on different surveys.

**Column percents are rounded to the nearest whole percent.
Table 5: U.S. Citizen Doctoral Recipients

<table>
<thead>
<tr>
<th>Year</th>
<th>Adjusted Total* of Degrees Granted by U.S. Institutions</th>
<th>Total of U.S. Citizen Doctoral Recipients</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>75-76</td>
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<td>722</td>
<td>75</td>
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<tr>
<td>76-77</td>
<td>901</td>
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<td>76</td>
</tr>
<tr>
<td>77-78</td>
<td>868</td>
<td>634</td>
<td>73</td>
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<td>78-79</td>
<td>806</td>
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<td>79-80</td>
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<td>578</td>
<td>73</td>
</tr>
<tr>
<td>80-81</td>
<td>839</td>
<td>567</td>
<td>68</td>
</tr>
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<td>81-82</td>
<td>798</td>
<td>519</td>
<td>65</td>
</tr>
<tr>
<td>82-83</td>
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</tr>
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<td>83-84</td>
<td>738</td>
<td>433</td>
<td>59</td>
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<td>84-85</td>
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<td>55</td>
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<tr>
<td>85-86</td>
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<tr>
<td>86-87</td>
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<td>362</td>
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<td>87-88</td>
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<td>43</td>
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<tr>
<td>95-96</td>
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<td>493</td>
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</tr>
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</table>

*Number of doctorates whose citizenship is known. Total may vary from that on Table 3D because the data are gathered on different surveys.

Graph for Table 5: U.S. Citizen Doctoral Recipients

Table 6: U.S. Citizen Doctoral Recipients, Male and Female

<table>
<thead>
<tr>
<th>Year</th>
<th>Total of U.S. Citizen Doctoral Recipients</th>
<th>Male</th>
<th>Female</th>
<th>%</th>
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<td>95-96</td>
<td>493</td>
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</table>
Note that in Table 5 and Table 6 all years prior to 1982–1983 include doctoral recipients from computer science departments.

Acknowledgments
The Annual AMS-IMS-MAA Survey attempts to provide an accurate appraisal and analysis of various aspects of the academic mathematical sciences scene for the use and benefit of the community and for filling the information needs of the professional organizations. Every year, college and university departments in the United States are invited to respond. The Annual Survey relies heavily on the conscientious efforts of the dedicated staff members of these departments for the quality of its information. On behalf of the AMS-IMS-MAA Data Committee and the Annual Survey staff, I thank the many secretarial and administrative staff members in the mathematical sciences departments for their cooperation and assistance in responding to the survey questionnaires.

Several people have made essential contributions to the preparation of the reports on the 1996 Annual AMS-IMS-MAA Survey. Kinda Remick has provided indispensable support and taken many initiatives to facilitate the Data Committee’s work. Kinda Remick and Jim Maxwell share credit for the companion articles on starting salaries of new doctoral recipients and on faculty salaries.

Bibliography
———, Selected data on graduate students and post-doctorates in science and engineering, Fall 1991, NSF 92-335; Selected Pamphlet No. 11: Institutional Listings, NSF 90–324–11; Selected Pamphlet No. 12: Postdoctorates and Other Nonfaculty Research Staff, NSF 90–324–12; Washington, DC, 1990.
Reclassification of Departments

As has been the case for a number of years, much of the data in these reports is presented for departments divided into groups according to several characteristics, the principal one being the highest degree offered in the mathematical sciences. Doctorate-granting departments of mathematics are further subdivided according to their ranking of "scholarly quality of program faculty" as reported in the 1995 publication Research-Doctorate Programs in the United States: Continuity and Change. These rankings update those reported in a previous study published in 1982. Consequently, the departments that now comprise Groups I, II, and III differ significantly from those used in prior surveys. The reader should keep this in mind when attempting to make comparisons by group with previous Annual Survey reports. A list of the departments in each of these groupings appears below.

The subdivision of the Group I institutions into Group I Public and Group I Private is new with the 1996 Annual Survey. With the increase in number of the Group I departments from 39 to 48, the AMS-IMS-MAA Data Committee judged that a further subdivision along the lines of public and private would provide more meaningful reporting of the data for these departments.

Brief descriptions of the groupings used for reporting purposes are as follows:

Group I is composed of 48 departments with scores in the 3.00–5.00 range.

Group I Public and Group I Private are Group I departments at public institutions and private institutions, respectively.

Group II is composed of 56 departments with scores in the 2.00–2.99 range.

Group III contains the remaining U.S. departments reporting a doctoral program, including a number of departments not included in the 1995 ranking program faculty.

Group IV contains U.S. departments (or programs) of statistics, biostatistics, and biometrics reporting a doctoral program.

Group V contains U.S. departments (or programs) in applied mathematics/applied science, operations research, and management science which report a doctoral program.

Group Va is applied mathematics/applied science; Group Vb is operations research and management science.

Group M contains U.S. departments granting a master's degree as the highest graduate degree.

Group B contains U.S. departments granting a baccalaureate degree only.

---

**GROUP I Public**
(Scores between 3.00 and 5.00)  
25 Total  
(Mathematics Departments)

CUNY, Graduate School and University Center  
Georgia Institute of Technology  
Indiana University at Bloomington  
Michigan State University  
Ohio State University, Columbus  
Pennsylvania State University, University Park  
Purdue University  
Rutgers University  
SUNY at Stony Brook  
University of California, Berkeley  
University of California, Los Angeles  
University of California, San Diego  
University of California, Santa Barbara  
University of Illinois at Chicago  
University of Illinois at Urbana-Champaign  
University of Maryland, College Park  
University of Michigan  
University of Minnesota, Minneapolis  
University of North Carolina at Chapel Hill  
University of Oregon  
University of Texas at Austin  
University of Utah  
University of Virginia  
University of Washington  
University of Wisconsin, Madison

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**GROUP I Private**
(Scores between 3.00 and 5.00)  
23 Total  
(Mathematics Departments)

Boston University  
Brandeis University  
Brown University  
California Institute of Technology  
Carnegie Mellon University  
Columbia University  
Cornell University  
Duke University  
Harvard University  
Johns Hopkins University  
Massachusetts Institute of Technology  
New York University, Courant Institute  
Northwestern University

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2. These findings were published in An assessment of research-doctorate programs in the United States: Mathematical and physical sciences, edited by Lyle V. Jones, Gardner Lindzey, and Porter E. Coggeshall; National Academy Press, Washington, D.C., 1982. The information on mathematics, statistics, and computer science was presented in digest form in the April 1983 issue of the Notices, pages 257–267, and an analysis of the classifications was given in the June 1983 Notices, pages 392–393.
| University of Arizona     | University of California, Davis | University of California, Irvine |
| University of California, Riverside | University of California, Santa Cruz | University of Cincinnati |
| University of Colorado, Boulder | University of Connecticut, Storrs | University of Delaware |
| University of Florida | University of Georgia | Ohio University |
| University of Hawaii | University of Houston | Oklahoma State University |
| University of Iowa | University of Kentucky | University of Alabama, Tuscaloosa |
| University of Massachusetts, Amherst | University of Miami | University of Alaska, Fairbanks |
| University of Michigan | University of Rochester | University of Arkansas at Fayetteville |
| University of South Carolina, Columbia | University of Tennessee | University of Central Florida |
| University of Texas at Arlington | Vanderbilt University | University of Colorado, Denver |
| Virginia Polytechnic Institute & State University | Washington State University | University of Denver |
| Wayne State University | Wesleyan University | University of Idaho |
| University of Hawaii | University of Houston | University of Kansas |
| University of Iowa | University of Kentucky | University of Maryland Baltimore County |
| University of Massachusetts, Amherst | University of Miami | University of Memphis |
| University of Michigan | University of Rochester | University of Mississippi |
| University of South Carolina, Columbia | University of Tennessee | University of Missouri, Kansas City |
| University of Texas at Arlington | Vanderbilt University | University of Missouri, Rolla |
| Virginia Polytechnic Institute & State University | Washington State University | University of Montana |
| Wayne State University | Wesleyan University | University of New Hampshire |
| University of New Mexico | University of Northern Colorado | University of Rhode Island |
| University of South Florida | University of Southern Mississippi | University of Southwestern Louisiana |
| University of Texas at Dallas | University of Toledo | University of Vermont |
| University of Tulsa | University of Wisconsin, Milwaukee | University of Wyoming |
| University of Wyoming | Utah State University | West Virginia University |
| Western Michigan University | Wichita State University | Worcester Polytechnic Institute |

The figures for 1996 were compiled from questionnaires sent to individuals who received doctoral degrees in the mathematical sciences during the 1995–1996 academic year from universities in the United States.

Questionnaires requesting information on salaries and professional experience were distributed to 922 recipients of degrees using addresses provided by the departments granting the degrees; 364 individuals returned forms between late June and mid-September. Responses with insufficient data or from individuals who indicated they had part-time employment, were not yet employed, or were not seeking employment, were considered unusable. Numbers of usable responses for each salary category are reported in the following tables.

Readers should be warned that the data in this report are obtained from a self-selected sample, and inferences from them may not be representative of the population.

Key to Tables. Salaries are listed in hundreds of dollars. Nine-month salaries are based on 9–10 months teaching and/or research, not adding extra stipends for summer grants or summer teaching or the equivalent. Years listed refer to the academic year in which the doctorate was received. *M* and *F* are Male and Female, respectively. One year or less experience means that the persons had experience limited to one year or less in the same position or a position similar to the one reported; some persons receiving a doctoral degree had been employed in their present position for several years. Quartile figures are given only in cases where the number of responses is large enough to make them meaningful.

Graphs. The graphs show variants of standard box plots summarizing salary distribution information. The horizontal line shows the 1995 median salary in hundreds of dollars. Values plotted for other years are converted to 1995 dollars using the implicit price deflator prepared annually by the Bureau of Economic Analysis, U.S. Department of Commerce. The 1996 salary data are not shown on the graphs because the deflator is not yet available for this year.

For a given year, the box shows the first and third quartiles and the median salary. (Prior to 1975, the quartiles are not available, and only the median is depicted by the horizontal stroke.) The "whiskers" give additional information about the spread of the data, extending to points that are 1.5 interquartile distances from the median. Minimum and maximum salaries are depicted by asterisks or dots outside the whiskers; dots are used to distinguish extreme outliers, i.e., values that are more than 3 interquartile distances from the median.

Note that salaries for teaching or teaching and research have yet to return to their high point of 1970, although considerable progress has been made since 1980.
### Research Nine-Month Salaries

(2 men + 1 woman)

<table>
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<th>Ph.D. Year</th>
<th>Min</th>
<th>Q₁</th>
<th>Median</th>
<th>Q₃</th>
<th>Max</th>
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</table>

#### 1993M
1993F

#### 1994M
1994F

#### 1995M
1995F

#### 1996M
1996F

One year or less experience (2 men + 1 woman)

<table>
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<tr>
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<th>Q₁</th>
<th>Median</th>
<th>Q₃</th>
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### Teaching or Teaching and Research Twelve-Month Salaries

(20 men + 7 women)

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</table>

#### 1993M
1993F

#### 1994M
1994F

#### 1995M
1995F

#### 1996M
1996F

One year or less experience (13 men + 6 women)

<table>
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### Research

**Twelve-Month Salaries**

(23 men + 8 women)

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**Ph.D. Median in 1995 $**

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</table>

One year or less experience (18 men + 5 women)

<table>
<thead>
<tr>
<th>Year</th>
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<th>Median</th>
<th>Q3</th>
<th>Max</th>
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### Government

**Twelve-Month Salaries**

(11 men + 3 women)

<table>
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<th>Median</th>
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</table>

**Ph.D. Median in 1995 $**

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One year or less experience (10 men + 1 woman)

<table>
<thead>
<tr>
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<th>Median</th>
<th>Q3</th>
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### Business and Industry

**Twelve-Month Salaries**

(42 men + 4 women)

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<tr>
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<th>Median</th>
<th>Q₃</th>
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<td>1996</td>
<td>250</td>
<td>510</td>
<td>580</td>
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<table>
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<th>Q₁</th>
<th>Median</th>
<th>Q₃</th>
<th>Max</th>
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</table>

One year or less experience (28 men + 3 women)

<table>
<thead>
<tr>
<th>Year</th>
<th>Min</th>
<th>Q₁</th>
<th>Median</th>
<th>Q₃</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996M</td>
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<td>481</td>
<td>580</td>
<td>615</td>
<td>950</td>
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<tr>
<td>1996F</td>
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<td>----</td>
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</table>
Salary Survey 1995–1996 for Faculty

The charts on the following pages display faculty salary data for Groups I Public, I Private, II, III, IV, V, M, and B: faculty salary distribution by rank, mean salaries by rank, information on quartiles by rank, and the number of usable returns for the group. Since groupings used for the mathematics departments in this year's report differ from prior years, comparisons are not possible. Departments were asked to report the number of faculty whose 1995–1996 academic-year salaries fell within given salary intervals. Reporting salary data in this fashion eliminates some of the concerns about confidentiality but does not permit determination of actual quartiles. What can be determined is the salary interval in which the quartiles occur; the salary intervals containing the quartiles are denoted by \( <n, n+5> \).

<table>
<thead>
<tr>
<th>Faculty Salaries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I Public—Doctoral degree-granting departments of mathematics (25)</td>
</tr>
<tr>
<td>23 usable responses (92%)</td>
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</table>

<table>
<thead>
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<th>Median</th>
<th>Q3</th>
<th>Mean</th>
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</thead>
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<td>&lt;40,45&gt;</td>
<td></td>
<td>&lt;45,50&gt;</td>
<td>46,771</td>
</tr>
<tr>
<td>Associate Professor</td>
<td>187</td>
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<td>&lt;50,55&gt;</td>
<td>&lt;55,60&gt;</td>
<td>53,052</td>
</tr>
<tr>
<td>Full Professor</td>
<td>879</td>
<td>&lt;65,70&gt;</td>
<td>&lt;75,80&gt;</td>
<td>&lt;85,90&gt;</td>
<td>78,586</td>
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</table>

1995–1996 Academic Year Salary

\( \text{No.} \)
Faculty Salaries
Group I Private—Doctoral degree-granting departments of mathematics (23)
15 usable responses (65%)

<table>
<thead>
<tr>
<th>Rank</th>
<th>No. Reported</th>
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<th>Median</th>
<th>Q3</th>
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<tr>
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<tr>
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Faculty Salaries
Group II—Doctoral degree-granting departments of mathematics (56)
45 usable responses (80%)

<table>
<thead>
<tr>
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<th>Q3</th>
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<tr>
<td>Assistant Prof.</td>
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<td>&lt;45,50&gt;</td>
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<td>467</td>
<td>&lt;40,45&gt;</td>
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<td>&lt;50,55&gt;</td>
<td>48,892</td>
</tr>
<tr>
<td>Full Prof.</td>
<td>876</td>
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<td>&lt;65,70&gt;</td>
<td>&lt;75,80&gt;</td>
<td>69,551</td>
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Faculty Salaries
Group III—Doctoral degree-granting departments of mathematics (72)
58 usable responses (81%)

<table>
<thead>
<tr>
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<th>Q3</th>
<th>Mean</th>
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<tr>
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<tr>
<td>Full Prof.</td>
<td>572</td>
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Faculty Salaries
Group IV—Doctoral degree-granting departments of mathematics (80)
50 usable responses (63%)

<table>
<thead>
<tr>
<th>Rank</th>
<th>No. Reported</th>
<th>Q1</th>
<th>Q3</th>
<th>Mean</th>
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</thead>
<tbody>
<tr>
<td>Assistant Prof.</td>
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<td>&lt;40,45</td>
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<td>110</td>
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<tr>
<td>Full Prof.</td>
<td>364</td>
<td>&lt;60,65</td>
<td>&lt;90,95</td>
<td>79,469</td>
<td>78,326</td>
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**Faculty Salaries**

Group V—Doctoral degree-granting departments of mathematics (33)

<table>
<thead>
<tr>
<th>Rank</th>
<th>No. Reported</th>
<th>Q&lt;sub&gt;1&lt;/sub&gt;</th>
<th>Median</th>
<th>Q&lt;sub&gt;3&lt;/sub&gt;</th>
<th>Mean</th>
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<tr>
<td>Assistant Professor</td>
<td>27</td>
<td>$&lt;30,55&gt;$</td>
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<td>$&lt;60,65&gt;$</td>
<td>$59,133$</td>
<td>60,344</td>
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<tr>
<td>Full Professor</td>
<td>89</td>
<td>$&lt;70,75&gt;$</td>
<td>$&lt;100,105&gt;$</td>
<td>$87,205$</td>
<td>87,189</td>
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</table>

Group M—Doctoral degree-granting departments of mathematics (255)

<table>
<thead>
<tr>
<th>Rank</th>
<th>No. Reported</th>
<th>Q&lt;sub&gt;1&lt;/sub&gt;</th>
<th>Median</th>
<th>Q&lt;sub&gt;3&lt;/sub&gt;</th>
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</thead>
<tbody>
<tr>
<td>Assistant Professor</td>
<td>609</td>
<td>$&lt;35,40&gt;$</td>
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<tr>
<td>Associate Professor</td>
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<td>$&lt;50,55&gt;$</td>
<td>$48,275$</td>
<td>47,492</td>
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<td>1107</td>
<td>$&lt;55,60&gt;$</td>
<td>$&lt;85,70&gt;$</td>
<td>$81,594$</td>
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</table>

1995-1996 Academic Year Salary
### Faculty Salaries

**Group B—Doctoral degree-granting departments of mathematics (884)**
394 usable responses (45%)

<table>
<thead>
<tr>
<th>Rank</th>
<th>No. Reported</th>
<th>Q1 Median</th>
<th>Q2 Median</th>
<th>Mean Mean</th>
</tr>
</thead>
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<td>$&lt;35,40&gt;$</td>
<td>$&lt;40,45&gt;$</td>
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<tr>
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<td>$&lt;40,45&gt;$</td>
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<td>Full Professor</td>
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<td>$&lt;45,50&gt;$</td>
<td>$&lt;55,60&gt;$</td>
<td>$&lt;60,65&gt;$</td>
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**1995-1996 Academic Year Salary**
The mathematical sciences community today faces some of the toughest problems it has seen in decades. The combination of tight research funds, shrinking higher-education budgets, a dismal job market, and questions about the adequacy of graduate education has hit hard. And despite surprising discoveries of links between branches of mathematics once thought to be quite separate, the increasing specialization required to do research has often isolated the branches from one another. In this climate traditional divisions within the mathematical sciences—between, for example, pure and applied areas, or elite and nonelite schools—could harden. However, the presidents of the three major societies concerned with mathematical sciences research—the AMS, the Institute of Mathematical Statistics, and the Society for Industrial and Applied Mathematics—are optimistic about the community’s ability to work together to solve these problems. The Notices presents below the presidents’ responses to five questions about important issues facing the community today.

—Allyn Jackson

JAMES BERGER, past-president, Institute of Mathematical Statistics, and NANCY REID, president, Institute of Mathematical Statistics

Question 1: How has the increasing breadth of research in the mathematical sciences affected relations among researchers in different areas?

First, we need to make a few comments to clarify where we are coming from. The Institute of Mathematical Statistics represents, by and large, academic statisticians and probabilists with the closest ties to mathematics; statisticians who are mainly involved in applications in other subject areas would typically turn to one of the more applied statistical societies. As the IMS is at the mathematical end of statistics, we find ourselves in the curious position of looking very applied from the viewpoint of most mathematicians and yet looking very theoretical from the viewpoint of most statisticians. So one day we argue for the benefits of theory and the next for the benefits of interacting with applications.

We also should point out that the IMS represents both statisticians and probabilists. We happen to be statisticians, and our comments will thus naturally be more reflective of the statistical viewpoint; probabilists tend to relate more directly to the pure and applied mathematical communities than do statisticians.

But back to the original question.

Statistical research has always covered a broad range, from mathematics to economics and psychology through to medical applications, and so on. So we are accustomed to debates on the relative importance of various subareas. The increasing breadth of research in the mathematical sciences (or perhaps what is more relevant is the increasing depth of research) has changed the nature of the interactions between mathematics and statistics and within statistics. Statisticians, even mathematical statisticians, are less conversant with current work in probability and pure mathematics than they were even twenty years ago and vice versa. And, even within statistics, it is increasingly difficult to simultaneously work in several areas. We thus know less today about the work of the statistician in the...
office next door, let alone the work of the mathematician in the next building. Luckily, the reaction to this seems to be one of increasing tolerance. As we know less about the details of the work of others, we tend to interact and appreciate each other more on the basis of our common view of the centrality of the mathematical sciences.

The increasing breadth of research in the mathematical sciences has probably helped the relationship between statistics and mathematics. Statistics derives its motivation from application to practical problems. This is not to say that research in statistical theory is not important, but theoretical investigations are often performed with at least a long-range eye towards practical needs. This practical orientation of statistics was not always appreciated by the mathematical community. Today, however, the increasing breadth of mathematics seems to have greatly elevated the status of work concerned with potential applications, and this has eased strains between the mathematical and statistical communities.

Question 2: What are the major issues in graduate education?

As in other areas of the mathematical sciences, there is a tension between breadth of knowledge and specialization, and it is difficult to find the right compromise for graduate education. As the result of various pressures, statistics graduate students are now spending more time learning to do applied work and less time studying mathematics or mathematical statistics.

There is also a trend, as in many areas of science, to increasing emphasis on interdisciplinary work, and a graduating student with a subject area specialty is very employable. But to ask students to have a graduate-level education in, for example, statistics and sociology or statistics and geology further increases the tension between specialization and breadth. This tension will probably also be increasingly felt in other areas of the mathematical sciences; not only is interdisciplinary work a current "fashion", but with the job market for academic researchers shrinking, we need to educate our students to be conversant in more than one specialty. Of course, this means a major change from the way we've always done things, and we are all struggling to find the right course. It is interesting that the statistics community seems to have agreed upon the necessity of this change, even if it does not yet know how to go about it.

Question 3: Has the difficult job market produced strains?

We have started to feel the strain in the past few years; until recently the job market for academic statisticians was very strong, and we are only now facing problems that have long been familiar to mathematicians. For example, as recently as five years ago it was relatively unusual for students to do a postdoc before their first tenure-track appointment, but it is now becoming quite usual.

We are in the fortunate position of having many nonacademic employment opportunities for our students, although increasingly these jobs are requiring specialization in particular application areas of statistics, leaving even less time for general mathematical training. Interestingly, most statistics departments seem to be adapting to this situation without too much stress, eliminating courses on theory and replacing them with more applied or specialized courses. One, of course, continuously hears the "theory-versus-application" educational arguments, but the trend is clear. Perhaps since statistics has always been intimately connected with applications, we are rather amenable to shifting our educational programs in response to the perceived outside needs.

Question 4: How do the pure and applied mathematical communities relate to each other?

It makes more sense for us to answer a different question, namely, "How do the statistics and mathematics communities relate to each other?" The community represented by the IMS is, by and large, rather closer to mathematics than is the average statistician; most of our members are academic, many are working in mathematics departments, and most of the members began their academic training as mathematicians. Even so, the answers of our members to this question would vary enormously. Many would say that they have little to do with the mathematics community these days, while others would attest to frequent collaboration with mathematicians. The amount of such collaboration has probably declined over the years, but this could simply be due to the problem raised in Question 1.

There is a fairly widespread feeling among statisticians that their approach to scientific problems is not well appreciated by either pure or applied mathematicians, since statistical modelling requires the development of insights that cannot be reduced to mathematics alone. Conversely, because our research tends to be more directly driven by applications than is mathematics, we tend to be skeptical of the notion that research in the mathematical sciences can usefully proceed in isolation from the world.

On the whole, however, we feel that the statistical and mathematical communities are sympathetic to each other. We approach the world from a similar perspective and have similar long-range goals. And, if anything, statisticians have
Question 1: How has the increasing breadth of research in the mathematical sciences affected relations among researchers in different areas?

The mathematical sciences are broader, and core areas are going deeper in their explorations. There have been many major breakthroughs. Mathematicians concentrating on research have to take a narrow view because one needs a lot of specialized knowledge to do research, so in this sense there is not so much breadth. But in the last fifteen years there have been many interactions between different parts of pure mathematics that never interacted before. Core mathematicians are very proud of this fact.

Certainly there are strains in all sciences between their individual branches; it's part of what keeps it going. I think in other sciences it's less spelled out, but it's there. On the other hand, progress depends not only on cooperation but also the natural competition that drives people forward. But in fact there are fewer strains in the mathematical sciences today than there were in the past and a much stronger sense of working together. I would like to add that I don't like either expression, "core" or "pure", but for lack of a better alternative, I have to use them.

Question 2: What are the major issues in graduate education?

One deep problem is the length of graduate education. A person embarks on a project of five years and at the end can't get a job. There ought to be more places to go if, say, after two years you want to change your direction. On the other hand, if you stay the course and are destined to be a researcher, there ought to be more places for postdoctoral training, so that if you take a broader program for your Ph.D., you can really specialize afterwards.

I believe in the long run there will be a need for people with the kind of skills a mathematical sciences education gives. But right now we're floundering because the era of technology has not yet called on the mathematical sciences community. We have a lot that is needed, and we must convey it in understandable terms. At the same time, it's always been the case that a number of new Ph.D.s go into industry or government labs, and their mathematical sciences training gives them a way of thinking, of attacking problems. That ability is extremely useful and much appreciated.

Another point of strain is the growing awareness that we can't "brain drain" the rest of the world forever. The fact that we can attract mathematicians from other countries has led us to neglect developing our own. In particular we need to bring more women and minorities into the mainstream of the mathematical sciences. It's a question of the future of the science. I take seriously the projections of what the character of the population will be in the future. At the present time we take the best from all the other countries. If some other country is richer and can provide more for them, then they won't come here, and we will not have produced our own. We will have lost on all counts. We have to insure that mathematics education is broad enough that it catches everyone in its net and is at the same time deep enough to prepare future mathematicians.

Question 3: Has the difficult job market produced strains?

Certainly, because we're producing more students than there are jobs for them. People in strongly applied areas like statistics or operations research are having much less trouble. And people from places outside the top tier are also having fewer problems because their advisors and departments have more connections for teaching jobs, especially in local community colleges. At the top schools the best students are getting good jobs, but the second- to third-best students are having a lot of trouble, in part because they have fewer connections to jobs involving mostly teaching and not so much re-
search. This strain cuts the community in a different way from the research strains.

This is just a painful situation, and I don’t see how we can remedy it. I think dramatic efforts to cure that situation might lead to overkill. In the 1970s, when the job situation was bad, though not as bad as it is now, there was a tremendous decline in the number of Ph.D.s produced and then a great shortage. So there’s a cycle here, and it’s a question of how to dampen the cycle.

Question 4: How do the pure and applied mathematical communities relate to each other?

There is no question that, in the U.S. fifty or sixty years ago, despite the fact that there had been very prominent Americans who did a great deal of applied mathematics—like Hill, or Gibbs, or Birkhoff—there was a historic reluctance toward applied mathematics. It was much less so in Europe. During the Second World War, with the refugees coming and the war needs, there was an enormous growth in applied mathematics. After the war there was a sense among many of them that they weren’t being recognized. So it’s a history of “on-again, off-again” relations between the two communities. I for one see it as a great loss when, for example, a mathematics department separates into two departments of pure and applied mathematics. But as I said before, I think that today there is much more unity than in the past. This can be seen in the trend toward having unified departments with both pure and applied mathematicians.

People in pure mathematics feel they are at the very basis of structure of a science. And they’re building that structure, putting the pieces together, linking them, and many of them are not particularly anxious about the fruit of their labor entering into some practical problem. But in the end mathematics history shows that those things eventually percolate into applications or get applied. On the other hand, in digging in the structure of mathematics, it often turns out that input from the physical world gives some new insight. They feed on each other.

Question 5: What signs do you see that the mathematical sciences community is coming together to try to tackle some of these difficult problems?

Although there is naturally a tendency to grow apart, I can assure you that strong efforts are going on to counteract that tendency. Historically, the MAA split from the AMS; SIAM grew out of the alienation of applied mathematicians. I don’t know the history of the IMS. So trying to draw our societies together is an old challenge that we are beginning to meet. We do a lot with MAA through joint meetings and joint committees. SIAM and AMS are jointly funded by the Sloan Foundation to work on employment opportunities. The Joint Policy Board for Mathematics is our triple front on government policy. In the area of public awareness of the role of and the need for mathematics, we are all working and working together. Among our joint committees with the IMS are two especially active ones, the Data Committee and the Committee on Joint Summer Research Conferences.

I would like to see us also do a lot more with the IMS, and these committees provide a place to start from.

MARGARET WRIGHT, president, Society for Industrial and Applied Mathematics

Question 1: How has the increasing breadth of research in the mathematical sciences affected relations among researchers in different areas?

Let me mention two opposite effects of the increasing breadth of research.

First, the growing volume of new results in individual subject areas means that it is more and more difficult to keep up to date. Since expertise and depth are needed to survive as a credible researcher, some mathematicians may focus mostly on their specialty, go to conferences only in that area, read mainly papers in that area, and so on. When this happens, these researchers talk less often to mathematicians in other fields, and the overall mathematical sciences community becomes more fragmented.

There is, however, a second, countervailing trend: that once-separate topics have spread out so far that they have started to blend together. In several fields, intellectual structures and techniques from what was once “outside” are now securely in the mainstream. This phenomenon means that mathematicians need to understand what is going on in multiple areas, even those apparently far from their special interests, and thus formerly disparate areas are naturally brought together.

On balance, I like to think that increasing breadth in research will help the mathematical sciences to recognize our essential unity.

Question 2: What are the major issues in graduate education?

U.S. graduate education has been the subject of several recent reports—for example, from the National Research Council (NRC) and the National Science Foundation (NSF)—suggesting changes. It’s impossible to summarize these in a few words, so let me make some remarks about only one aspect, the growing interest in interdisciplinary work.

Interdisciplinary research as a way of doing science is here to stay. Having said that, I absolutely do not think that it is necessary for
mathematicians to look outside their own field for inspiration and nourishment. Nonetheless, I know that mathematicians can learn about problems that are extraordinarily rich mathematically by interacting with other disciplines. I tend to regard it as a sign of a good mathematician that he or she can find something mathematically interesting in essentially any problem. If we accept that future Ph.D.s will be engaged in interdisciplinary work for at least part of their careers, this argues for broadening exposure to other sciences as part of graduate education. It also suggests that training in written and oral communication to nonspecialists would be helpful. In addition, computation is fundamental in all of science today; therefore, I believe that someone with a Ph.D. in mathematics needs to have a substantive understanding of the intellectual issues in computation, even if that person never subsequently goes near a computer.

The prospect of changing graduate education naturally arouses concern, especially when the impetus comes from outside forces. In my view the suggestions made so far are not meant to change what is working, but rather to offer mechanisms that provide graduate students with more professional options and flexibility along with qualities (like good writing and speaking) that are useful in any context.

Question 3: Has the difficult job market produced strains?

This issue is closely tied with those mentioned in the answer to Question 2. The academic job market is extremely difficult, which means that many Ph.D.s are thinking, in some cases reluctantly, about nonacademic jobs. SIAM has many members who work in industry (including me), and of course we believe that nonacademic jobs can be extremely rewarding, but that’s a different subject! SIAM’s 1995 “Mathematics in Industry” (MIF) report indicates that mathematicians are highly valued in nonacademic settings and that graduate education provides excellent preparation in perceiving, formulating, and analyzing the structure of complex problems. However, current graduate education in the mathematical sciences does less well in other domains, such as providing some breadth of scientific interests, an understanding of computation, and skills in communication. In fact, these skills are important for mathematicians regardless of where they end up working, so that including them in a graduate program does not, in my opinion, compromise quality or integrity. The MIF report recommends that graduate departments consider ways to provide these qualities and makes numerous suggestions for how to do this.

Question 4: How do the pure and applied mathematical communities relate to each other?

The wording of this question touches on a point of great concern to me. In speaking about the mathematical sciences at a policy level, I try never to draw distinctions between pure and applied mathematics, or between “core” mathematics and the rest of mathematics (whatever the noncore is called). First, I am not aware of an unambiguous definition of these terms—and precise definitions are something we are supposed to be good at! For example, most people would assert that number theory is pure mathematics, but of course number theory is applied in a big way in cryptography. And many people working in fields usually called “applied mathematics”, such as partial differential equations, develop mathematical structure and prove theorems that are completely divorced from any application. So we can’t label fields as pure and applied, or even draw a clear distinction between research and applications. Some define by intent—that pure mathematics happens when the mathematician doing it has no interest in practical consequences—but this definition seems like theology, not mathematics.

Even more important than the lack of a precise definition is that dividing up mathematics into pure and applied, or core and noncore, seems to me to be unproductive. Mathematicians are not a homogeneous group, and no one wants them to be. But rather than stressing what divides us from each other, I hope that we can think about mathematics as a discipline that is unified, with common themes (such as rigor, formalism, analysis of underlying structure and patterns, etc.) that apply to all areas of mathematics. Our main priority should be to clarify why mathematics is important as a way of thinking. I would like to think that we can move forward together, that we can appreciate each other’s work, and that the only distinction that really counts is between good and bad work.

Question 5: What signs do you see that the mathematical sciences community is coming together to try to tackle some of these difficult problems?

My perception is that many mathematicians recognize that we need to work together on all of these problems. Let me cite a few instances of this.

For several years the Joint Policy Board for Mathematics (JPBM) has been one means for the AMS, SIAM, and the Mathematical Association of America (MAA) to present a unified case for the mathematical sciences. For example, last year Arthur Jaffe testified for support for the NSF budget, and Bob Plemmons of Wake Forest Uni-
versity testified to two separate committees in support of Department of Defense funding for basic research.

There are four mathematicians on the Advisory Committee for the NSF Directorate of Mathematical and Physical Sciences (I am one of them). We are there not only to represent the mathematical sciences but also to participate in the broader issues that face science policy and funding within the NSF.

Cathleen and I have made an explicit effort during our terms as AMS and SIAM presidents for the two societies to work together whenever possible. For example, in February we met with NSF director Neal Lane and spoke strongly about the centrality and unity of the mathematical sciences. The AMS and SIAM are continuing a joint activity, funded by the Sloan Foundation, to provide information and resources about nonacademic careers.

Let me conclude by saying that the mathematical sciences have such a good story to tell—it's real, not hype—and we alone are responsible for making our case. No one else is going to do it for us. Try to picture yourself in a room filled with physicists, chemists, biologists, and so on—each of them can argue, correctly, that his or her individual area is important. But mathematics is uniquely fundamental and pervasive; we need to say so, both often and together.
It seems that most of the letters to the editor and some of the other communications in these Notices over the last few years have been on the subject of mathematics education. By way of contrast, I would like to express a view on a subject related to what is presumably the Society's primary mission, namely, that of promoting and facilitating mathematical research.

As the century draws to a close, some sort of stocktaking would seem appropriate. It is natural to ask the obvious question, What has been achieved during these years? Well, to me it is overwhelmingly clear that the second half of this century has been a golden age for mathematics, far and away more productive than any similar period in history, and I am moved to write about this because I have a strong sense that very few people aside from the comparatively small community of research mathematicians are aware of what has been going on. By way of illustration, most people who keep up with science would probably know about the great revolution in physics that occurred during the first half of the century, but these same people would probably be surprised to learn that what the first fifty years were for physics the second fifty have been for mathematics. (The other subject that has made giant strides during this same period is, of course, biology.) Indeed, even in the mathematical community itself, I get the feeling that many people do not sufficiently appreciate what has been happening around them.

To be sure, there is a trivial sense in which mathematical "productivity" gets bigger every year, since the number of research mathematicians keeps growing with each new crop of mathematics Ph.D.s. Just looking at the content of current issues of Mathematical Reviews, I would estimate that something like ten thousand new mathematical results are added to the literature every month, but this purely quantitative phenomenon obviously does not in itself constitute "progress".

The notion of progress is, of course, rather subjective and is to some extent in the eye of the beholder. Nevertheless, I do expect many mathematicians would agree that the past fifty years have been quite exceptional. No doubt future historians of the subject will be able to pinpoint the development quite specifically. I would speculate, though, that the mathematical explosion began right at mid-century with Serre's thesis, followed some years later by Milnor's discovery of exotic differential structures. Each of us has our own ideas of which were the most significant landmarks, but there is no question that they were many. Indeed, in some ways these years have had an almost storybook quality, culminating in true fairytale fashion in a climactic moment—the spectacular achievement of Andrew Wiles in solving the Fermat problem. As I said, I expect many, perhaps most, research mathematicians are aware of all this, but I have never seen it stated explicitly in print, and it seems to me very worthwhile to say it loud and

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clear, especially since apparently even among mathematicians I am not sure there is a full awareness of what has been happening. In fact, sometimes when I express these views to other mathematicians, there are challenges. If this has been such a great period, they will say, who are its giants? Where are the Hilberts, Lebesgues, Minkowskis, Poincarés, Godels, Kolmogorovs, and Cartans? Perhaps we are too close to the era to see who our own giants are, but another possibility is that, to continue the fairytale metaphor, the age of giants may have passed. The subject of mathematics has become so large and has spread in so many directions that there simply cannot be dominating figures like those of the past. They, the forefathers, were the ones who laid the foundations. Their discoveries and insights are what we now use daily and perhaps even take for granted, but it was those insights which bore fruit in the extraordinary takeoff that occurred with the coming to maturity of the first postwar generation of mathematicians. (Some people have said that they believe the great surge may have peaked and things are now starting to slacken off. In any case, even if this is true, it was quite something while it lasted.)

Everything that has been said so far applies to the international mathematical community, but there is also a special sense in which the achievements are relevant for the AMS. Note that there are no Americans in my list above (though perhaps one could have included Birkhoff and Wiener). In the postwar mathematics boom the situation has been quite different. It is perhaps better to let the reader fill in the names at this point, but any history of the progress of mathematics over the past fifty years will have to include, for example, the already-mentioned results in differential topology, the proofs of the Poincaré conjecture in dimensions four and greater, the solution of a celebrated Hilbert Problem, the independence of the continuum hypotheses, the classification of the finite simple groups. In all of these areas Americans played the leading role. Whether the mathematicians of the future will consider them giants or merely geniuses does not really make much difference.

Concluding Remarks: We of the mathematical community are often told that we do a poor job of communicating to the public what it is we do and why what we do is important. When I have tried to tell nonmathematicians this golden age story, they are always surprised and even skeptical. If this is so, they wonder, why haven't we heard about it? Unfortunately, it is difficult for us to make headlines. The trouble is we have no double helices or charmed quarks to expound upon, and it is hard to make the front page with solitons or gauge fields or strange attractors or Mandelbrot sets, even though these things have been among the many breakthroughs of the past decades. I suppose we could all go around shouting from the rooftops about the glories and achievements of our discipline, but it is not clear that anyone would listen. It is also unsatisfactory to tell people that this is all great stuff, but you'll just have to take our word for it. Perhaps the only answer is to face the daunting task of providing expository materials which will make some of these things as comprehensible as possible to the general public without getting into the technicalities that are necessary for full understanding. Well, it seems I have ended up talking about education after all.

Addendum: I am grateful to several colleagues for opinions on the foregoing remarks; the most frequently heard comment was, how can you write about the state of contemporary mathematics without even mentioning the impact of computers? Good point. My excuse is that I am limiting my observations to what might be called mainstream mathematics or, more appropriately, the mathematics we inherited (from the masters of the past). Equally impressive, however, are the brand-new branches of mathematics that have been created during this same period, and of course this is where computers come in; e.g., they have been the inspiration for complexity theory, automata theory, etc. Indeed, "I'm glad you asked that question," because it only reinforces my main point by providing yet more examples of the remarkable originality and creativity that have characterized the mathematics of the past fifty years.

As the century draws to a close...It is natural to ask the obvious question, What has been achieved during these years?
A Tour of the Calculus

Paul Zorn

The book lives up to its name—it is indeed a tour of the subject. But there are tours and tours: package tours of Europe, walking tours of Spain, treks in Nepal, Caribbean cruises, a prospective college student's campus visit, a junior year abroad, Disney World, a time-shared condo in Cancun.

Berlinski's tour is none of these. The cover art—a lonely road in arid landscape—is misleading. What Berlinski's tour most resembles in the tour catalog is an air-conditioned "study cruise" up the Amazon River, with on-board naturalist, historian, and ethnographer—all of them chatty and slightly manic, willing to invent a bit when certain knowledge runs out. There is an occasional short, sweaty walk into the jungle, or even a run through the rapids. But qualified medical personnel are standing by, and there is good Chilean chardonnay chilling back on board.

Understood this way, Berlinski's Tour is a good value and an entertaining read. In about 300 pages, Berlinski visits—briefly—most of the "standard" destinations, from basics of the real number system through limits, continuity, and the mean value theorem to the fundamental theorem of calculus. More remarkable for mathematically versed readers, however, may be the variety and number of side trips and optional excursions. Among the attractions: Dedekind cuts; Zeno's paradoxes; historical interludes, partly invented, featuring Newton, Leibniz, Euler, Cauchy, Rolle, Gauss, Riemann, and others; the author's Eastern European travel memoirs and classroom misadventures; frequent encouraging words for mathematical novices; proofs of such results as the irrationality of $\sqrt{2}$ (proved in Socratic-style dialogue—with a taxi driver), the mean value theorem, and the fundamental theorem of calculus; and some quite sharp and perceptive musings on the culture and nature of mathematical science.

The prose style is distinctive, to say the least. Here, for instance, is Berlinski setting the stage for Galileo's law of falling bodies (page 96):

Now imagine a gorgeous tower, its parapet encrusted, the dreamy Perugian hills in the background, lacy clouds above. And on this tower an Italian dandy, dressed in silks puffed at the wrists and at his thighs, is fin­
gering a large and lavish rose and ruf­

ouso stone, a fabulous ruby or garnet, something luscious and lustrous. He
dangles an elegant forearm over the
draped hand, holding the ruby in his upturned palm, and then slowly and
with vast sensuous deliberation rotates
his wrist so that the precious stone,
its cut facets catching the golden Tus-
can light, slides from his polished palm and winking colored fire slips off into space.

This style may be too rich for some tastes, like cruise-ship food. But here Berlinski has a good point to make: Galileo's law (and, by extension, the calculus) is universal; it applies regardless of the Tuscan light, the puffed silks, the cut facets, and every other accident. But a little of this vivid, charged writing goes a long way. Here and there the style gets out of hand: the adjective burden can be taxing and the breathless tone annoying. About polynomials, for instance, we read (page 80, italics in original):

The polynomial functions constitute an archipelago, and like the islands in an archipelago they are close to one another, the pale blue ocean waters bright, but not deep. The transcendental functions, by way of contrast, are not algebraic; they go beyond—they transcend—the algebraic operations .... They rise as isolated and volcanic atolls out in the open ocean where the waters are dark blue and where an object that is dropped would travel for years before hitting the ocean's sandy bottom.

By the time this tour ends, some passengers will welcome the respite from metaphor overload. Sometimes Berlinski's imagery overpowers the mathematics. Distinguishing between lines and curves, for instance, Berlinski writes (page 178, italics in original):

...But curvature at a point would seem to tremble on the same margin of incoherence as speed at an instant. The moving finger meanders over the rounded shoulder and stops, creating a pressure dimple in the molded flesh, but the hand having stopped, the sense of curvature conveyed by the caress disappears as well, the indented point being simply what it is, a way station along a sensuous arc; it is the whole of that shoulder that conveys to the voluptuary the conviction that he is getting anywhere at all.

...The lesson of love is not to linger too long at a point, the same lesson, curiously enough, taught by the calculus.

What were we talking about again? This time, even the author appears distracted by the metaphor—in the next few pages he seems to conflate slope with curvature.

Such technical slips are unusual, however. Berlinski's mathematics is generally sound and clearly explained and sometimes goes surprisingly deep. For example, there is more here on the subtleties of completeness (not so-named, by the way) than in most college calculus texts; many a math major could learn something from the discussion. Here is a sample (page 96, italics in original):

The line is in some sense richer than the numbers that are used to represent it, and this is an old, an inconvenient fact; but Dedekind's diagnosis goes beyond a revisiting of such facts in order to display the long-hidden source of the discrepancy between line and number. Every rational number produces a cut among the numbers; but some cuts answer to no rational number and in this respect—this alone, no other—the numbers and the line are different. Dedekind's calm but profound investigation succeeds as an act of intellectual liberation because it connects a particular fact—that some distances cannot be measured by any rational number—with the much larger, the more general, fact that some cuts cannot be made at any rational number.

For readers who want a tour itinerary similar to Berlinski's, but with a much more Spartan feel and a different balance between describing and doing, there still seems to me nothing that quite dethrones W. W. Sawyer's 1961 should-be-classic, What Is Calculus About?, which describes many of the same mathematical ideas in spare, crystalline prose. Sawyer's final chapter, which glances at some topics of "higher" mathematics, is still fresh after thirty-five years.

In the end, readers who do not already know calculus will not learn much here about actually doing calculus. (That is not a criticism—Berlinski's guidebook has different aims.) But even mathematically sophisticated tourists will learn something about calculus and about the author's view of its nature, development, and uses. Indeed, Berlinski's luxury cruise might well lure some tourists back, perhaps on foot, for another, longer, closer look.
What goes on in the precollege classroom has great repercussions for the college classroom, yet it is fair to say that most research mathematicians are oblivious of the instruction that goes on in those classrooms. I believe that the majority of research mathematicians have not been in a high school classroom in years; in fact, many have not been in a high school classroom in this country at all, given the number of foreign mathematicians on our faculties. Yet it is our responsibility as university faculty to continue the mathematical education of these students. But the word "continue" seems out of place here, since this word implies some continuity in this educational process. How can there be continuity if we are uninformed as to the methods of instruction of our colleagues in the K-12 community? That question is the rationale for this article.

I am fortunate to be on the National Advisory Committee for the EQUITY 2000 program of the College Board. The goal of this program is to have every high school student complete algebra by ninth grade and geometry by the tenth grade.

In 1993, as a member of this Advisory Committee, I visited an Equity 2000 middle school in Prince George's County, Maryland, a suburb of Washington, DC. When I entered the classroom, the students were discussing quadratic equations. On the overhead projector, an overhead display was placed for the graphing calculator. The teacher put up a quadratic equation on the board. With almost no coaxing, a student went over to the overhead and produced a graph of the quadratic equation. From the graph one could see that it had two roots. Next the teacher asked for the exact values of the roots. A student went over to the board and applied the quadratic formula to obtain the roots. The teacher then asked for the approximate value of the roots. Without doing any numerical calculations, the students produced a very rough estimate of the radical by producing an integer whose square was close to the value of the radicand. The students now did the arithmetic and produced the approximate decimal values of the roots. The teacher then asked how this computation tied into the graph that was displayed. One of the students "zoomed in" on one of the roots, producing a number that was close to their arithmetic calculations. I was impressed.

Actually two things struck me about this visit. First, I would be thrilled if first-year college students could have done all of this. Second, I was struck by the vitality that was displayed in that classroom. I wondered how these students would feel coming from this setting and having to sit
in our college classrooms to listen to a lecture and being forced to take a passive role in their education.

The more I work with the K-12 educational system, the more I am struck by the breadth of educational reform that is ongoing, by the audacity and courage that is shown by the K-12 faculty as they struggle to find better ways to reach their students.

The EQUITY 2000 district-wide program is coordinated by the College Board under the direction of Dr. Vinetta Jones. The starting point for this program comes from a very simple observation. Algebra and geometry are the gatekeepers to college. Research has shown that students who do not complete these two courses have a 1-in-60 chance of going on to college. In place of algebra, students take watered-down curricula that serve as dead-end courses. One of the principal outcomes that results when a school system adopts the EQUITY 2000 program is that these dead-end courses are eliminated and replaced by a solid first-year course in algebra. The aim is to have 100 percent of high school students complete algebra by their first year and geometry by their second year.

The EQUITY 2000 program began its operations in 1990. Eventually this program ran at six pilot sites—Fort Worth, TX; Nashville, TN; Milwaukee, WI; San Jose, CA (a consortium of nine school districts); Providence, RI; and Prince George’s County, MD—where a total of fourteen school districts were involved and approximately 700 schools, 2,800 mathematics teachers, and 500 guidance counselors participated. To date over 500,000 K-12 students have been affected by the program. Having learned from the experiences at these pilot sites, the EQUITY 2000 program has now reached its dissemination stage and as of July 1996 has been made available to school districts nationwide.

The principal reasons for the success of this program are that it is district-wide and the commitment to excellence in instruction is long-range. EQUITY 2000 recognizes that the entire school system must become integrally involved in the process of change, from the school superintendent to the principals and teachers, guidance counselors, and parents. Based on its experience with the pilot sites, EQUITY 2000 has formulated its dissemination and institutionalization program. The EQUITY 2000 team will work with the school district in the following areas by providing technical assistance in:

1. Designing the curriculum and structure for summer institutes for teachers, counselors, and principals,
2. designing student-enrichment programs, which include Saturday academies for students,
3. assisting districts in the development of parent and community outreach programs,
4. assisting districts as they seek to create data-collection systems that will provide disaggregated student enrollment and achievement data to drive decisions and monitor the reform.

These points clearly indicate that EQUITY 2000 has formulated a program that encompasses the entire school system. Further, this program has already had a very positive impact at the pilot sites. There are more students now passing algebra at the sites than there were students enrolled in algebra before the program was institutionalized. There has also been a marked increase in the number of students taking advanced placement examinations in mathematics.

It is in the best interest of our profession and of our students that we be informed of these programs and that we find a way of taking an active role in some of these initiatives. If you would like to have more detailed information about the EQUITY 2000 program, please contact Dr. Vinetta Jones, College Board, 45 Columbus Avenue, New York, NY 10023-6992; phone 212-713-8268; fax: 212-713-8293.
Karp and Smale Receive National Medals of Science

In June of this year President Clinton announced the recipients of the National Medal of Science, the nation’s highest honor in science and technology. Among the eight recipients are mathematician STEPHEN SMALE and theoretical computer scientist RICHARD KARP. Five National Medals of Technology were also awarded.

The National Medal of Science, established by Congress and administered by the National Science Foundation, honors individuals for contributions to the present state of knowledge in one of the following fields: physical, biological, mathematical, engineering, or social and behavioral sciences. The medal has now been awarded to 344 distinguished scientists and engineers.

Richard M. Karp

Richard M. Karp was awarded the National Medal of Science for “linking advances in theoretical computer science to real-world problems.” Karp was born January 3, 1935, in Boston, Massachusetts. He received his bachelor’s degree (1955), his master’s degree (1956), and his Ph.D. in applied mathematics (1959) from Harvard University. He was a member of the research staff at the IBM T. J. Watson Research Center from 1959 until 1968, and he was on the faculty of industrial and management engineering at Columbia University during 1967–68. In 1968 he took a position as professor of computer science and operations research at the University of California, Berkeley, and starting in 1980 he also held a joint position in the department of mathematics. He also held a position as research scientist at the International Computer Science Institute in Berkeley. In 1995 he moved to the University of Washington in Seattle to take positions as professor of computer science and engineering and adjunct professor of molecular biotechnology.

The Contributions of Richard M. Karp to Computer Science

David B. Shmoys

Richard M. Karp has made fundamental contributions to the foundations of computer science and over the past four decades has dramatically extended our understanding of the nature of efficient computation. He has made seminal contributions to a wide variety of areas within the field of theoretical computer science and has had a profound influence on the directions in which this rapidly growing field has moved over this period, giving it both mathematical depth and practical relevance.

Karp’s most significant contribution, presented in his landmark 1972 paper entitled “Reducibility among Combinatorial Problems”, showed that twenty-one combinatorially defined computational problems are all $\mathcal{NP}$-complete. This provided concrete evidence that a plethora of well-studied optimization problems, such as the traveling salesman problem and the graph coloring problem, were hard to solve. This work focused attention on the $\mathcal{P} = \mathcal{NP}$? question as the central open problem in our under-

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standing of efficient computation. For any set $L$, the membership problem for $L$ is to decide, given an input $x$, whether $x \in L$. For some sets, it is trivial to decide if a given $x$ is in $L$, whereas for others no efficient algorithm is known. The set $L$ is in the complexity class $P$ if there exists an algorithm that solves the membership problem for $L$ and runs in time bounded by a polynomial in the length of the input; this is the leading theoretical characterization of an efficient algorithm, and $P$ is the set of all efficiently solvable computational problems. The class $NP$ is the set of problems $L$ for which there exists $L' \in P$ such that $x \in L$ if and only if there exists a polynomial-length $y$ such that $(x, y) \in L'$; intuitively, $NP$ is the class of problems $L$ with the property that each $x \in L$ has a succinct, efficiently verifiable proof $y$ of its membership.

In 1971 Cook obtained a pivotal result: he showed that the satisfiability problem, i.e., deciding whether a given Boolean formula (in conjunctive normal form) has an assignment that makes the formula "true", is complete for $NP$, in the sense that any problem in $NP$ could be solved by a polynomial number of calls to a subroutine for the satisfiability problem; furthermore, he showed that this result might have implications for other combinatorial problems by showing, in essence, that the clique problem in graphs was also $NP$-complete. Karp's paper refined this approach and showed that many of the most notoriously intractable computational problems were all $NP$-complete. As Karp noted at the time, this suggests "that these problems, as well as many others, will remain intractable perpetually." The theory of $NP$-completeness, as developed by Cook and Karp, and independently by Levin, has had an impact well beyond computer science, since $NP$-complete computational problems arise in virtually every discipline of engineering and the physical and social sciences.

Karp also made important contributions to the design of efficient algorithms for a number of combinatorial problems. In particular, his work with Edmonds gave polynomial-time algorithms for the maximum flow and minimum-cost flow problems, two of the most fundamental network optimization problems and a subject of intense investigation in operations research since the mid-50s. These algorithms introduced basic techniques, such as data scaling, that were later used by others in a wide variety of settings. Furthermore, if one considers the work that has followed in the design of algorithms for network problems, there is scarcely a paper that does not build on this work in some substantial way. These results also highlighted what would become a central issue in this area: the difference between polynomial and strongly polynomial algorithms, where in the latter case the running-time bound is a function of the size of the underlying combinatorial structure, but not the magnitude of the numbers that are part of the input. In joint work with Hopcroft, Karp gave the most efficient algorithm known for another basic problem in combinatorial optimization, the bipartite matching problem; the algorithm is quite natural, and their running-time analysis provides deep insight into the structure of this well-studied problem.

The traveling salesman problem, another central problem in operations research, was a recurring subject of Karp's investigations; in this problem the aim is to find a shortest tour that visits a collection of points, given the distances between points. In 1962, in joint work with Held, he gave an elegant dynamic programming algorithm for the traveling salesman problem. Although this algorithm takes exponential time, it was the most efficient approach known then to solve this problem. Nearly ten years later, in two further papers with Held, he gave an important way to quickly compute a lower bound on the length of the optimal tour. The Held-Karp lower bound remains one of the most effective ways of efficiently estimating the optimal tour length; years of testing have led to the general belief that it typically produces bounds within 1–2 percent of optimal. Even more importantly, the bound is based on a "Lagrangian relaxation" technique; due to its success in this context, this approach was immediately applied to a wide range of combinatorial problems. For well more than a decade, Lagrangian relaxation was the method of choice...

Richard M. Karp
for obtaining strong lower bounds for optimization problems.

The traveling salesman problem was also the starting point for Karp’s investigation into algorithms that work well with respect to inputs drawn from specified probability distributions. Suppose that the input to the traveling salesman problem consists of points that are selected independently and uniformly at random in the unit square $[0,1]^2$ and the distance between them is measured in the $\ell_2$ metric. Karp proposed a natural divide-and-conquer strategy which partitions the points into clusters of nearby points, solves the induced problem for each cluster (using dynamic programming), and then patches these subtours together. He then showed that this algorithm produces a tour that asymptotically tends to the optimum with probability approaching 1. Many results on the probabilistic analysis of heuristics for $NP$-hard problems followed, and this continues to be a thriving area of research. Karp made many significant contributions to this area, giving ingenious analyses of algorithms for such problems as linear programming, bin-packing, and set partitioning.

A recurring theme in Karp’s research in the past two decades is the use of randomization in the design of algorithms. In this setting an algorithm is allowed to “toss coins” as one of its basic operations. Unlike the results on probabilistic analysis mentioned above, in this setting one still takes a worst-case view: one wishes to show that for any input, the algorithm’s output, which is a random variable, has the desired property, e.g., is optimal with high probability. In many settings, a problem can be solved using a randomized algorithm and yet no deterministic analogue is known. In joint work with Aleliunas, Lipton, Lovász, and Rackoff in 1979, he gave an algorithm to determine if two given vertices are in the same connected component of an undirected graph that, surprisingly, uses space bounded by a logarithm of the size of the graph. Roughly speaking, such an algorithm is limited to auxiliary storage consisting of a constant number of node labels, and it is widely believed, but still unproven, that no deterministic analogue exists. The randomized linear-time pattern-matching algorithm of Karp and Rabin is one of the most appealing results of the area: it combines mathematical elegance with practical efficiency and generality. Luby and Karp considered the problem of computing the reliability of planar networks, which is $P$-complete, and hence believed to be substantially harder than even the $NP$-complete problems discussed above. They gave a randomized approximation scheme for this problem, which was the first known for any $P$-complete problem; once again, the subsequent study of randomized approximation schemes for $#P$-complete problems has blossomed into one of the most exciting areas of algorithm design for combinatorial problems.

In the mid-80s Karp turned his attention to the design of parallel algorithms. This is another setting in which randomization has turned out to be an important tool for algorithm design. One theoretical notion of efficiency for parallel computation is the class $NC$; this is the set of problems solvable with a polynomial number of processors in time bounded by a polynomial in the logarithm of the input size, with a shared memory for interprocessor communication. In a quite surprising result, Karp and Wigderson showed that the maximal independent set problem is in $NC$; prior to their work, this problem had been widely suspected to be one for which parallelism could not be used effectively. Their algorithm was based on first designing a randomized algorithm and then “derandomizing” it by showing that the randomization could be restricted to uniform sampling from a polynomial-size sample space and then making parallel runs, one for each sample. This subsequently became one of the most useful paradigms of parallel algorithm design. His $RNC$ algorithm for the matching problem, obtained jointly with Upfal and Wigderson, was another breakthrough result; this has prompted interesting research on techniques that might lead to a deterministic $NC$ algorithm, but no such matching algorithm is currently known.

Among the issues prevalent in his research in the past decade, Karp has made leading contributions to the study of online algorithms and has worked towards bridging the gap between theoretical models of parallel computation and the realities of parallel machines. Most recently, Karp has focused on computational issues in molecular biology. Although the motivation for these problems is different from those that he studied previously, this research nonetheless is a natural extension of his investigations into efficient algorithm design for combinatorial problems.

Karp has been awarded virtually every major prize in computer science and operations research, including the ACM Turing Award, the ORSA/TIMS von Neumann Theory Prize, the Lancaster Prize, and the Fulkerson Prize; he is a member of the National Academy of Sciences and the National Academy of Engineering. In addition to his gifts as a researcher, Karp has a phenomenal talent for teaching. Having spent most of his career at the University of California, Berkeley, and now at the University of Washington, he has inspired several generations of students with his lectures of laser-sharp clarity. He has the uncanny ability to take the most
opaque just-proven result, to understand its essence, and then to present it in a perfectly transparent way.

Throughout his career, Dick Karp has repeatedly initiated an important path of research, obtained elegant and significant results to start the area, and stimulated the research community to continue in his footsteps. It is difficult to imagine any individual having a more profound impact on any field.

**Stephen Smale**

Stephen Smale received the National Medal of Science for "four decades of pioneering work on basic research questions which have led to major advances in pure and applied mathematics." Smale was born on July 15, 1930, in Flint, Michigan. He received his bachelor's degree (1952), his master's degree (1953), and his Ph.D. in mathematics (1956) from the University of Michigan, Ann Arbor. He was an instructor at the University of Chicago from 1956 until 1958, when he became a member of the Institute for Advanced Study. In 1961 he went to Columbia University, and in 1964 to the University of California, Berkeley. He retired from Berkeley in 1995 and is currently a professor of mathematics at the City University of Hong Kong. His many honors include the Fields Medal, awarded in 1966.

The Mathematical Work of Stephen Smale

Steve Batterson

Steve Smale has made profoundly original contributions to a stunning array of mathematical specialities. In 1990 the Smalefest conference celebrated Steve's sixtieth birthday with a program entitled "From Topology to Computation: Unity and Diversity in the Mathematical Sciences". The proceedings of this conference (edited by M. W. Hirsch et al., Springer-Verlag, 1993) include individual survey articles on Smale's work in differential topology, economic theory, dynamical systems, computation, nonlinear analysis, and mechanics. See this volume for a more substantive review of the remarkable depth and breadth of Smale's mathematics.

Smale completed his Ph.D. thesis in 1956 under the direction of Raoul Bott at the University of Michigan. Two curves are regularly homotopic provided that there exists a homotopy through regular curves for which the tangent vector varies continuously as a function of the curve and homotopy parameters. The 1937 Whitney-Graustein Theorem classified regular closed curves in the plane, up to regular homotopy, by their winding numbers. In his thesis Smale generalized the result to regular closed curves living on an n-manifold. The classification is provided by a bijection to the fundamental group of the unit tangent bundle to the manifold. To establish the link, Smale skillfully employed algebraic topology, analysis, and especially the theory of fiber spaces. The thesis did not attract a great deal of attention.

A few months into his postdoctoral career at the University of Chicago, Smale obtained his first famous result. He succeeded in pushing the fiber space techniques to immersions of spheres. Smale classified $C^2$ immersions of $S^2$ into $R^n$, up to regular homotopy, by the second homotopy group of the Stiefel manifold, $V_{n,2}$. Since $\pi_2(V_{3,2})$ is trivial, an immediate corollary is the regular homotopy equivalence of all immersions of $S^2$ into $R^3$. In particular, there exists a regular homotopy of the inclusion to the antipodal immersion, in effect turning the sphere inside out. The result was counter to the prevailing intuition that placed these immersions in different classes. The fact that Smale's proof offered little insight into a comprehensible realization of the homotopy added to its mystique.

In the summer of 1958 Mauricio Peixoto introduced Steve to the Andronov-Pontryagin concept of structurally stable vector fields (the trajectory dynamics are preserved under small perturbations to the vector field). Peixoto sought a characterization of structural stability that extended beyond the surface setting. Smale quickly saw the relevance of transversality and topology to the higher-dimensional situation. He conje-
tured that a class of vector fields, now known as Morse-Smale, were exactly the structurally stable ones. Additionally, he asked if the Morse-Smale systems were dense in the $C^1$ topology. This was the first approximation in Smale’s bold vision for dynamical systems, a qualitative study of differential equations that transcended the algebraic form of the equation.

Smale began a two-year National Science Foundation Postdoctoral Fellowship in 1958. Following 1-1/2 years at the Institute for Advanced Study, Steve moved to Rio de Janeiro to complete the final six months at the Instituto de Matematica Pura e Aplicada. During this period in early 1960 he obtained two sensational results. Shortly after his arrival in Brazil, Smale received a letter from Norman Levinson asserting that there were structurally stable systems that were not Morse-Smale. This led to Smale’s construction of the horseshoe map and his early study of chaotic phenomena.

Next, Steve resumed his work on the Poincaré Conjecture. The problem, a compact $n$-manifold with the algebraic topology of the $n$-sphere is homeomorphic to the $n$-sphere, had attracted Smale since his graduate student days. The situations $n = 3$ and $n \geq 3$ are known respectively as the Poincaré Conjecture and Generalized Poincaré Conjecture. At the time there was an overwhelming conventional wisdom that difficulty increased with dimension. The three-dimensional problem was so daunting that larger $n$ appeared out of reach, at least until dimension three was resolved. Undeterred, Smale conceived a Morse Theory approach to the Generalized Poincaré Conjecture. As he developed these ideas, an extraordinary element emerged. His proof was valid for all dimensions $n \geq 5$, but failed in dimensions three and four. Smale had proved the Higher Dimensional Poincaré Conjecture. In the eighties Michael Freedman established the four-dimensional theorem, but $n = 3$ remains unsolved.

In 1961 Smale proved the h-Cobordism Theorem. This seminal result provides algebraic topological criteria for establishing that higher-dimensional manifolds are diffeomorphic. Having set a new agenda for differential topology, Smale then abruptly shifted his attention back to dynamical systems. Steve was renewing his quest for a generic structurally stable collection of dynamical systems. His original Morse-Smale candidate had been disqualified by the horseshoe. As Smale sought a second approximation he unearthed other essential elements of his developing program for dynamical systems. The project was put on hold from 1962 to 1964 as Steve’s interests detoured into infinite-dimensional analysis. There he, independently with Richard Palais, extended Morse Theory to those nonlinear maps on infinite-dimensional manifolds that satisfy what is now known as the Palais-Smale condition. Next he obtained an infinite-dimensional generalization of the Morse-Sard theorem.

Smale returned to dynamical systems in 1965, showing that structural stability was not dense. Smale’s original vision for dynamical systems could not be realized, but his approximations were converging to something exciting. In his landmark 1967 Bulletin survey article, Smale presented his program for hyperbolic systems and stability, complete with a superb collection of problems. The major theorem of the paper was the $\Omega$-Stability Theorem, whose proof was a tour de force in the new methods.

By the late sixties Smale had moved into applications. He modeled physical processes by dynamical systems, opening new lines of inquiry. The n-body problem and electric circuit theory were among the applications that Smale framed in the language of dynamical systems. For much of the seventies Steve focused on economics, injecting topology and dynamics into the study of general economic equilibria. Having established the nature of the equilibria, Smale began to think about algorithms for their computation. While traditional approaches to the convergence theory of algorithms were local, Smale introduced a global perspective to the problems. Was the algorithm reasonably reliable, and how many iterations were to be expected? Newton’s method and the simplex algorithm gained new meaning from this perspective.

In recent years Smale, in collaboration with Lenore Blum and Mike Shub, has sought to unify the fields of theoretical computer science and numerical analysis. Practical numerical algorithms involve the computation of real numbers, while the classical Turing machines manipulate discrete sets. The Blum-Shub-Smale model for computation operates on a ring, thus encompassing the 0-1 world of Turing machines and the real-complex number setting required for numerical analysis. The result is a generalization of the classical theory that provides a theoretical foundation for numerical analysis.

So many brilliant threads pervade Smale’s mathematics that providing a summary is partly a matter of personal taste. Throughout his career Smale has approached mathematical problems with the scholarship to learn from others, the audacity to be unconstrained by conventional wisdom, and the power and vision to employ new methods and construct original frameworks. After the fact, a Smale development seems so natural, yet no one else thought of it.
The Mathematical Association of America (MAA) presented a number of awards at the Seattle Mathfest in August 1996.

Daniel J. Velleman, Gregory S. Call, and Judith V. Grabiner received the Carl B. Allendoerfer Award. Established in 1976, the Carl B. Allendoerfer Awards recognize excellent articles published in the Mathematics Magazine. Daniel J. Velleman, Amherst College, and Gregory S. Call, Amherst College, received the award for their article, "Permutations and Combination Locks" (Math. Mag. 68 (1995), 243-253). Judith V. Grabiner, Pitzer College, received the award for her article, "Descartes and Problem-Solving" (Math. Mag. 68 (1995), 83-97).


John H. Ewing and James G. Simmonds received the George Pólya Award on August 9, 1996, at the Summer Mathfest in Seattle. Established in 1976, the George Pólya Awards recognize excellent articles published in The College Mathematics Journal. John H. Ewing, American Mathematical Society, received the award for his article, "Can We See the Mandelbrot Set?" (College Math. J. 26 (1995), 90-99). James G. Simmonds, University of Virginia, received the award for his article, "A New Look at an Old Function, $e^{10}$" (College Math. J. 26 (1995), 6-10).

Joel Chan, Underwood Dudley, Joseph A. Gallian, and Alan C. Tucker received the Trevor Evans Award. Established in 1992, the Trevor Evans Awards recognize authors of exceptional articles that are accessible to undergraduates and published in Math Horizons. Joel Chan, University of Toronto, received the award for his article, "As Easy as Pi" (Math Horizons (Winter 1993), 18-19). Underwood Dudley, DePauw University, received the award for his article, "Why History?" (Math Horizons (Nov. 1994), 10-11). Joseph A. Gallian, University of Minnesota at Duluth, received the award for his article, "Weird Dice" (Math Horizons (Feb. 1995), 30-31). Alan C. Tucker, State University of New York at Stony Brook, received the award for his article, "The Parallel Climbers Puzzle" (Math Horizons (Nov. 1995), 22-24).
The 1996 AMS-MAA-SIAM Frank and Brennie Morgan Prize for Outstanding Research in Mathematics by an Undergraduate Student was presented to MANJUL BHARGAVA. The prize was presented during the Seattle Mathfest in August. LENHARD L. NG was named Honorable Mention. Both Bhargava and Ng were undergraduates at Harvard and finished their degrees there this year.

The Morgan Prize Committee consists of Kelly Black, Don Chakerian, Frank Morgan, Martha Siegel (chair), John Ryff, and Lee Zia. Their citation for Bhargava follows.

Manjul Bhargava was an undergraduate at Harvard University when he wrote the four papers that were submitted to the Morgan Prize Committee. His Senior Honors Thesis, written under the direction of Barry Mazur, was suggested to Bhargava by Joseph Gallian at a summer REU. Bhargava completely solved the problem posed in the summer of 1995 in his paper "Congruence preservation and polynomial functions from $\mathbb{Z}^n$ to $\mathbb{Z}^m$", which has been accepted for publication in *Discrete Mathematics*. This research ultimately led to his thesis, "On $P$-orderings and polynomial functions on arbitrary subsets of Dedekind-type rings", which unifies and generalizes the results of about twenty previous papers, many by well-known mathematicians. In addition, Bhargava has settled several long-standing conjectures in the theory of polynomial functions on various types of rings.

His paper "Generalizing the factorial functions: Sequence of ideals associated with a subset of an algebraic field", submitted to the *Journal of Number Theory*, contains a generalization of the factorial function and work on fixed divisors. Under the supervision of Gallian, Bhargava also has resolved a conjecture, gives significant new results, and unifies and generalizes all previous results in mistlings with rectangular tiles in his "Mistlings of the plane with rectangles", submitted recently to *Discrete Mathematics*.

The many letters the committee received from his mentors, as well as from other mathematicians whose work he has generalized, reinforced our judgment that Bhargava has done truly outstanding mathematical research, and we are pleased to award him the 1996 Morgan Prize.
The Mathematician and the Mathematics Education Reform

H. Wu

E. H. Moore's Retiring Address as AMS president took place in 1902. Moore had a firm commitment to both teaching and research, but the theme of his address centered on mathematics education. On the role of the AMS in education he said: "Do you not feel with me that the AMS, as the organic representative of the highest interests of mathematics in this country, should be directly related with the movement of [education] reform?" ([7], p. 671) With the current mathematics education reform movement in place for almost a decade, Moore's words of a century ago become all the more relevant now.

The "reform" referred to in this article will cover both the K-12 mathematics education reform and the calculus reform, since these two reforms share an almost identical outlook and ideology. (See, for example, [29].) Unbeknownst to most mathematicians, the AMS has already taken part in this reform: p. vi of the NCTM Standards[18] carries the following statement:

There are valid reasons why we as members of the AMS should, as Moore said, be "directly related with the reform." To the outside world the AMS has spoken for all of us by endorsing NCTM's "vision", and the reform is settling in, becoming codified in law in some states and being mandated on local and national levels. It is now incumbent on us to consider, even if a trifle too late, whether this vision is indeed the one that we could—or should—endorse personally. The purpose of this article is to present some facts to help the mathematical community make up its collective mind.

The dictionary definition of reform is "the improvement or amendment of what is wrong, corrupt, unsatisfactory". Does this reform then improve on what is unsatisfactory in the so-called

ENDORSERS


This document is available on WWW; please see the references.

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traditional curriculum? The answer is both yes and no: the reform presents not an unalloyed improvement but a set of uneasy tradeoffs. The succeeding paragraphs give some of the details. My comments on the reform are based on the following documents and texts: [1, 3, 4, 5, 6, 10, 11, 12-14, 15, 16, 22, 18-21, 24, 26, 27, 28, and 30]. (It may be added that most of these documents are either basic to the reform, such as [18-20] and [10]; or highly praised, such as [12] and [22]; or widely used either nationally or within a state, such as [6] and [4].) A discussion of the impact of the reform on school and university mathematics education together with specific suggestions of how mathematicians can help the cause of education will be given in a separate article [31].

First, a word of caution: I have referred to the reform and the traditional curriculum as if they were monolithic entities, but of course they are not. Insofar as they are in the social domain, general statements in this article must be understood to have some exceptions.

In the following, the traditional curriculum will refer to the generic school mathematics curriculum of the 80s. By the time the idea of the latest reform took hold in 1986—the year NCTM convened its first meeting to draft the NCTM Standards [18]—the concept of a "proof" in the traditional curriculum had either become nonexistent or degenerated into meaningless ritual. For those who went to school in the 40s or 50s, such a statement may come as a surprise, as not a few of us had been charmed by Euclidean geometry—the essence of proofs—into becoming mathematicians (cf. [23]). Yet Euclidean geometry is now perhaps the most vilified portion of school mathematics. What happened? The mathematics curriculum in the schools went through the New Math of the 60s and the Back-to-Basics Movement of the 70s and emerged oversimplified and dumbed down. Even synthetic Euclidean geometry has become corrupted by bad texts and bad teaching, so that a proof can often be mistaken for "one more thing to memorize" by the students.

Example: the first theorem in the popular geometry text [25] is: "If two angles are right angles, then they are congruent." This occurs on p. 24—up to that point there has been no attempt to build up students' geometric intuition—and the two-column proof consists of five steps. Without divulging the secret of how to stretch such a proof to so many steps, let me just mention that, according to the text, "a right angle is an angle whose measure is 90", and "congruent angles are angles with the same measure." In turn, "the measure of an angle is the amount of turning you would do if you were at the vertex, looking along one side, and then turned to look along the other side," but for the precise measure of "90 (degrees)", the text tells you to use a protractor (p. 9, line -9). To make matters worse, a teacher in this situation typically asks students to commit to memory the format of such a presentation for the purpose of exams (cf. [27], pp. 157-8). The whole point of having axioms and modus ponens in order to ascertain the truth of a statement has clearly fallen by the roadside in the intervening years.

The overriding characteristic of the traditional curriculum is its emphasis on learning algorithms by rote: mathematics becomes a set of algorithms to be memorized and regurgitated at exam time. For example, while some algebra texts of the 50s still gave proofs of the basic properties of polynomials, it would be difficult to find a standard algebra text of the 80s that takes the trouble to explain anything. Anyone who teaches freshman calculus regularly knows only too well the ill-effects of this kind of mathematics education. It does not add to our comfort to realize that many calculus courses in college also lend themselves to learning by rote, so that students often come out of such a course equating derivative with "the thing that changes x^n to nx^{n-1} and nothing more. The accusation against this traditional curriculum is that It is arid, boring, and irrelevant. Students lose interest. The abysmal test scores of the late 70s through the early 90s together with massive drop-outs in K-12 math classes testify to its failure.

From a mathematical point of view, the main problem with the traditional curriculum is that it deals with the how of mathematics, but not with the why. The basic questions of why something is true and why something is important are allowed to remain unanswered. What we need is a curriculum that provides answers to these questions.

Proofs
A reasonable response to the absence of proofs in the traditional curriculum would be to give precise proofs of a set of select basic theorems, with rigor appropriate to the grade level, and to offer heuristic arguments whenever possible for the rest. The crucial point here is to help develop students' critical faculty by making them aware of the distinction between the two: a proof and a heuristic argument. On the one hand, logical deduction—proof—is the backbone of mathematics. If we are serious about mathematics education, we should aspire to making every high school student learn what a proof is. On the other hand, it would be a grave mistake to insist that every statement in elementary mathematics, up to and including calculus, be given a proof. There is no reason to impose the kind
of training designed for future professional mathematicians on the average student. (In particular, e-δ proofs may be best reserved for honors calculus.) What is important, however, is to give students adequate training in making logical deductions. This can be done by using what may be called local axiomatics; i.e., before the proof of a theorem, make clear what statements are assumed to be true and proceed to show how to use them in the proof. This shows students how to demonstrate the truth of a statement on the basis of explicit hypotheses. A reasonable mathematics education should aim for at least this much.

We turn now to the reform's response to the absence of why. The overall strategy of the reform is to supply motivation and heuristic arguments, but only motivation and heuristic arguments. In mathematics, heuristic arguments are used as preludes to proofs, but in the recent reform documents they are used as substitutes for proofs.

This strategy presents a new set of problems of its own. For example, when a seductively phrased heuristic argument, in reality very far from a proof, is presented without further comments, it is perilously close to a deception. The argument offered for the Fundamental Theorem of Calculus on p. 171 of [10] is a good illustration: Given \( F \) defined on \([a, b]\), partition the latter into \( n \) equal subdivisions \( x_0 < x_1 < \cdots < x_n \) and let the length of each subdivision be \( \Delta t \). Then for \( n \) large, the change of \( F \) in \([t_i, t_{i+1}]\) is approximately \( \Delta F \approx \frac{F(b) - F(a)}{n} \Delta t \). But the total change in \( F = \sum \Delta F \approx \sum_{i=0}^{n-1} F'(t_i) \Delta t \). Thus the comment in [5] about the above heuristic argument for \( \frac{d}{dx} \sin x = \cos x \) is (p. 103):

\[
\text{How sweet it is. Math happens.}
\]

In other words, the students are explicitly asked to believe that, thanks to the computer, they have witnessed mathematics at work.

**Precision and Technical Skills**

Precision is a defining characteristic of our discipline. For ease of discussion, let us artificially separate precision into the following two categories: conceptual precision (definitions, theorems, and proofs) and formal precision (symbolic computations and algorithms). Since proofs have already been discussed, we now concentrate on formal precision.

The traditional curriculum is driven by algorithms-without-explanations. By overly simplifying mathematics in this fashion, this curriculum acquires several virtues: it has built-in precision, it brings computational skills to the forefront, it sets a clear goal for students (always strive to produce a correct answer), and finally, it lets teachers know unambiguously what to

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\(^{2}\text{We note for emphasis that in reality there is no such separation.}\)
teach. Its weaknesses are that, especially in unskilled hands, it can easily degenerate into mindless number crunching and symbol pushing, so that students end up not learning even the computational skills. These weaknesses are correctable: supply the motivation and reasoning behind the algorithms, and replace some of the routine drills with exercises that make a greater demand on students’ conceptual understanding.

The reform responds by promoting what it calls “process over product”. It stresses qualitative reasoning (hence heuristic arguments, as described above) and motivation. It also introduces the idea of looking at counterexamples or conjectures in connection with a new concept or theorem. These are welcome changes. Not welcome is the reform’s downplaying of symbolic computations, precise definitions, neat formulas, and precise answers.

The advisability of these decisions is debatable. Consider the following statement on p. 125 of the Standards [18]: “the 9-12 standards call for a shift in emphasis from a curriculum dominated by memorization of isolated facts and procedures to one that emphasizes conceptual understandings, multiple representations and connections, mathematical modeling, and mathematical problem solving.” In and of itself, this sentiment cannot be faulted—trying to lead students away from memorization towards understanding. Yet when there is no simultaneous emphasis on basic technical skills throughout the whole document, statements such as this in [18] open the door to texts and curricula which make believe that one can be technically deficient (not knowing precise definitions or not equipped with symbolic computational skill, say) and still achieve conceptual understandings, make multiple connections, and solve problems. How much can a student understand about second-degree polynomials without knowing the quadratic formula? Quite a bit for a history major, perhaps, but not nearly enough if one wants to do exact sciences or mathematics. The fact must be faced that, in mathematics, one cannot have understanding without technique. The two are intertwined.

An excellent illustration of the shortcomings of the “process over product” approach is in the treatment of arithmetic series and geometric series in the introductory algebra text [30]. It goes through the detailed method of summing these series for concrete cases but relegates the two well-known formulas to two exercises (pp. 191 and 399). All of a sudden, formulas seem to have fallen into disgrace. In the reform curriculum this is a severe case of throwing out the baby with the bath water. Similarly, we have the absence of any mention of convergence tests for infinite series in the calculus text [10], and of the binomial theorem in the precalculus text [22], and of the geometric series in [22] and [12].

Another aspect of “process over product” is the downgrading of the importance of getting a single correct answer. One way is to demonstrate that mathematics is not “a domain of single right answers”. To this end, the NCTM Teaching Standards have a teacher posing the following problem (p. 45 of [19]): if 30 points were scored in a basketball game without a single foul shot, how were the 30 points scored? (There are 2-point shots and 3-point shots in basketball.) From a mathematical standpoint, this problem is not correctly formulated: the teacher could have asked the students either “to list all the possible ways the 30 points were scored” (in which case there would be a unique answer), or to show “how such an imprecise question in daily life could be translated into a precise mathematical problem.” It is clear that this is where a firm mathematical direction from the teacher would help to clarify the situation. Instead, the discussion in [19] makes a point of not making such a clarification (cf. the marginal remarks on pp. 46-7). In the meantime, even some good teachers are led to believe that problems which have a unique correct answer are bad for students (p. 122 of [32]; one can find in [32] a more extended discussion as well as further examples of such problems).

The slighting of technical skills in calculus presents additional educational problems, however. For example, the text [10] is written to be accessible to students with weak algebraic background. To the question whether reform calculus was “passing students through calculus with at best a rudimentary knowledge of algebra,” a reformer’s reply was that “we were doing this long before calculus reform” [17]. Should the calculus reform not be interested in improving on this aspect of mathematics education instead of accepting the status quo? Educators have long recognized the unfortunate fact that the prestige of any K-12 mathematics curriculum hinges on its ability to prepare students to pass calculus. By sending out a signal that being weak in algebra is acceptable in calculus, the reform in effect sanctions the continued decline in school students’ symbolic manipulative skill, especially when this signal is reinforced by [10], at present a bestseller in calculus. The devastating impact this has on school mathematics education as a whole will be long lasting, because the students of today will be the teachers of tomorrow and weak teachers tend to produce even weaker students. This is not the kind of “improvement” expected of a reform.
Relevance

A curriculum of elementary mathematics should achieve a balance between theory and applications and, ultimately, a balance between the abstract and the concrete. A majority of students learn mathematics to be good citizens, not to become professional mathematicians. For this they need to learn both the cultural aspect of mathematics and its utility.

For many students, a major defect of the traditional curriculum is its seeming irrelevance. The result is substantial dropouts in mathematics classrooms across the nation.

Part of this feeling of irrelevance stems from the poor integration of theory and applications in the traditional curriculum. Word problems, too often mishandled in the classroom, lend themselves too easily to solutions-by-template. This then leads to the danger of learning by rote not only the theories but also their applications. A second difficulty is that the applications used have not caught up with the explosion of the more recent applications of mathematics (especially discrete mathematics) in everyday life.

A third difficulty is the paucity of “internal applications” within mathematics; e.g., how to use an algebraic technique in geometry or vice versa.

This perception of irrelevance was in fact one of the main targets of the reform from the beginning. “Mathematics has become a critical filter for employment and full participation in our society. We cannot afford to have the majority of our population mathematically illiterate: Equity has become an economic necessity” (p. 4 of [18]). The battle cry is “Mathematics for all!” To this end the reform promotes curricula which center around so-called real-world problems. Thus [10] states in the preface: “Formal definitions and procedures evolve from the investigation of practical problems” (p. vii). Also, one finds in [18]: “Problem solving must be central to schooling” (p. 4). The resulting more realistic alignment of the reform curricula with the real world is a definite improvement.

But again, improvement comes at a price. The literal insistence on using real-world problems as core brings in new and sometimes surprising pedagogical issues. For example, do the messy real-world details obscure the basic mathematics, thereby obstructing the very mathematical skills the students should be learning? Another is whether one person’s real-world experience may not be another’s drivel. Consider some of the applications in [22]: why short tennis players should use a spin serve, why it would be advantageous to have elevators go to certain floors but not all floors, locating a hot dog stand for student convenience, the number of barbers needed in a given town, how to relate the counter reading of a tape being wound in a cassette machine to the amount of time left on the tape, etc.

Perhaps the most serious issue faced by a problem-oriented curriculum is that of mathematical closure, or rather the absence thereof. The problems are only a means to an end — the vehicle to facilitate the learning of mathematics — but not the end itself. Therefore, the solutions of problems in such a curriculum need to be rounded off with a mathematical discussion of the underlying mathematics. If new tools are fashioned to solve a problem, then these tools have to be put in the proper mathematical perspective: their purely technical developments should be addressed and their place in the overall mathematical structure clarified. Otherwise, the curriculum lacks mathematical cohesion. Moreover, if care is given to the distillation of the key mathematical idea of a solution from its original (real-world) context and its subsequent applications to entirely different situations, students will become convinced of the need for precision and abstraction. Without appearing to minimize the difficulty of achieving this kind of mathematical closure in a problem-oriented setting, it must be said that none of the reform texts I have consulted for this article is entirely successful in this regard. In fact, many of the mathematical transgressions in these texts are directly traceable to this obsession with real-world applications at the expense of abstract considerations.

The NCTM Standards [18] do not ever mention mathematical closure. (See [31] for a more extended discussion of this fact.)

Is It an Improvement?

Is the current reform an improvement over the traditional curriculum? Looking over the facts, we see that almost every improvement brought about by the reform is accompanied by some pronounced liabilities and that the two curricula are flawed in complementary ways. The traditional curriculum teaches how but not why; the reform curriculum teaches a little bit of both, but at the end may succeed in teaching neither. However, education is not a purely intellectual enterprise. Are there perhaps other relevant social issues that need to be considered in evaluating the reform?

It has been suggested that given students' inability to master symbolic computations, as evinced by students' low mathematics achievements in K–12 and calculus, the reform should be given credit for doing the best job possible with the kind of students we have. What is left unsaid in this analysis is that a true reform needs to maximize curriculum, teacher qualification (especially in regard to knowledge of mathematics), and student effort at the same
time. Instead, this NCTM-centered reform has thus far kept the last two constant while varying the first somewhat randomly. This does not seem a good strategy for optimization.

It has also been suggested that the de-emphasis of the abstract in favor of the concrete, of symbolic computations in favor of technological supplements, and of precision in favor of qualitative reasoning are exactly what future users of mathematics (engineers, physicists, etc.) need. Evidently the feeling is that the few future mathematicians who need such training can get it in courses like elementary analysis. In the case of engineers, etc., good use of a tool is presumably not to be learned through forcing them to think abstractly and precisely.

Yet, again, there are good reasons for rejecting such an approach. One is that students who want to learn about mathematics per se, not only for its utility as a tool for science, should not be prevented from doing so. We should teach mathematics for what it is, unless and until we are willing to start labelling foundational mathematics courses as “minimal survival kits for the sciences”. In addition, the notion of what scientists need from mathematics is volatile. My own informal survey indicates that, while such opinions cover a wide spectrum, there is no disagreement on the need of versatility and flexibility in the use of mathematical tools. It is unlikely that such flexibility and versatility can be achieved in a curriculum without the kind of mathematical closure described above. Recently, the introduction of a textbook on mathematical physics [9] makes an eloquent plea for scientists to acquire such a rigorous training in mathematics:

One might argue that although mathematics provides a very important tool to the scientist and engineer, this is not a sufficient reason for the arduous training in mathematics. After all, it is possible to use tools without detailed knowledge of their mode of functioning; it is possible to drive a car without any idea of the working of the internal combustion engine. Indeed, problems of a very well defined nature and limited scope are solvable by computer programs into which one has only to plug the data. But the situation of most engineers and scientists is not like that of the driver of a car, but rather like that of a worker detonating blast charges. Unless he has a good acquaintance with the properties of explosives, he is likely to come to grief.

It is time for us to restore mathematical balance to problem-driven curricula. Let us not deny our students the opportunity to acquire this kind of arduous training.

**Summing Up**

To the extent that the traditional curriculum is so seriously flawed, reform is way overdue. But if the preceding marshalling of facts means anything, it is that if this particular reform curriculum instead of the traditional curriculum were already in wider use across the land, then its serious defects would also be signaling the need for yet another reform. We cannot afford to experiment with a whole generation of our children when the odds are stacked against the present reform’s long-term success.

While I have grave misgivings about other aspects of the reform, its pedagogical practices (cf. [31]), and its assessment strategies (cf. [2]), I have chosen not to discuss them here. This is due in part to considerations of space, but also because I believe (perhaps wrongly) that these are decisions that can more easily be reversed. What this article has presented then are aspects of the reform’s curricular decisions reflecting an educational philosophy gone awry. These will not go away simply by the flipping of a switch. Corrections can be achieved only if the reform is revamped from the ground up.

Let us ask ourselves defining questions: Are we after a Band-Aid solution to a troubled curriculum? Are we to allow the issue of accessibility to override the basic integrity of the subject? In designing a curriculum, should we include only topics that can be learned without real hard work? Can we compromise the issue of student entitlement to the availability of mathematical knowledge? And, the question best addressed by the membership of the AMS: What kind of mathematics do we want to teach our students?

At the beginning of this article it was pointed out that the AMS has endorsed the vision of this reform as set forth in the *NCTM Standards* [18]. The question is whether, as members of the AMS, we believe we have been properly represented in this endorsement. There is a lengthy discussion of the *NCTM Standards* in the companion article [31], but this book is required reading for every mathematician who thinks mathematics should have something to do with mathematics education reform. You must decide for yourself if this is really a vision that you can support. Perhaps you have a better educational vision?

**Acknowledgment**

The writing of this article was greatly helped in manifold ways by Dick Askey, Steven Krantz, Dick Stanley, and Ralph Raimi. Madge Goldman’s

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*The name compumatics has also been suggested in [8].*
detailed critique and corrections are responsible for great improvements in its readability. I was stimulated by an e-mail exchange with Lynn Steen, and also benefited from the suggestions of Al Cuoco, Ken Ross, Jack Roach, and Zal Usiskin. Hugo Rossi’s illuminating comments clarified several key points. Last but not least, the support and encouragement of Wolfgang Fuchs have been an inspiration. It is a pleasure for me to thank them all.

References

Croatian Mathematical Society Awards Prize

Ivan Slapničar from University of Split, Split, Croatia, was awarded the Croatian Mathematical Society Prize for his work in the theory of relative perturbations for eigenvalue problems. The prize was presented at the start of The First Croatian Mathematical Congress held July 18–20, 1996, at the University of Zagreb, in Zagreb, Croatia. This prize will be awarded every four years to a young Croatian mathematician under the age of 35 for an outstanding scientific contribution.

-from Croatian Mathematical Society Announcement

Juris Hartmanis Heads NSF Computer Directorate

Juris Hartmanis, an expert in the theory of computation and computational complexity, has been appointed assistant director of the National Science Foundation Directorate of Computer and Information Science and Engineering (CISE). This directorate has responsibility for NSF’s efforts with the Internet, supercomputers, robotics and intelligent systems, information processing systems, and computational research.

After receiving his doctorate in mathematics from the California Institute of Technology in 1955, Hartmanis taught at Cornell and Ohio State University before going to General Electric Research Laboratory. Since 1965 Hartmanis has been at Cornell University, where he helped create the computer science department and served as its first chair. He is a member of the National Academy of Engineering and in 1993 received the Turing Award, the highest award in computer science.

In 1992 he chaired a National Research Council study which resulted in the book *Computing the Future: A Broader Agenda for Computer Science and Engineering*. The two years’ work with the committee, he said, helped focus his interest on computer science policy.

-from NSF Announcement

Mathematics Competition Awards Announced

At the International Congress of Mathematics Education in Seville, Spain, this past summer, the World Federation of National Mathematics Competitions presented the David Hilbert International Award and the Paul Erdős Awards. These awards recognize mathematicians whose contributions have played a significant role in the development of mathematical challenges at the international and, respectively, the national levels.

The Hilbert award was presented to Andrew Chang-Fung Liu of the University of Alberta. He has worked on a wide range of mathematical competitions, including the USA Mathematical Olympiad (USAMO), the International Mathematical Olympiad (IMO), the Australian Mathematics Competition, and the International Mathematics Tournament of the Towns. He has been running a local mathematics club
since 1981 and has received a number of teaching awards from his university.

The 1994–1995 Erdős award goes to GEORGE BERZENYI and TONY GARDINER. Berzenyi, a professor of mathematics at the Rose–Hulman Institute of Technology, has worked on the USAMO and the American Invitational Mathematics Examination, as well as the Australian Mathematics Competition. He was instrumental in creating Larmor Mathematics Day and the Texas Mathematics Olympiad. Gardiner has taught in East Africa and lectured in Germany, Austria, Canada, the U.S., Australia, Norway, and Hungary. He is best known for three contributions: founding the UK Schools Mathematical Challenge in 1988 (which grew to 105,000 participants by 1993), organizing the Junior Math Olympiad of the British Mathematical Olympiad, and serving as national team leader for the British IMO team.

The 1995–1996 Erdős award goes to DEREK HOLTON of the University of Otago. Since arriving in New Zealand in 1985 Holton has transformed an isolated set of mathematics enrichment programs into a coordinated national program. His activities include running a regular problem-solving session for high school students, organizing and participating in mathematics camps for bright students, and conducting research on working with talented students. He also initiated the Tournament of the Towns and the International Mathematical Challenge in New Zealand.

—from World Federation of National Mathematics Competitions Announcement

Presidential Mentoring Awards Announced

In September the National Science Foundation (NSF) announced that sixteen organizations and individuals were selected to receive the Presidential Awards for Excellence in Science, Mathematics, and Engineering Mentoring. Established by the White House Office of Science and Technology Policy and administered by the NSF, these awards recognize individuals, educational institutions, and organizations most responsible for enhancing the participation of underrepresented groups in science, mathematics, and engineering. Each award includes a $10,000 grant and a Presidential commemorative certificate.

Ten awards went to individuals, and among these were two in the mathematical sciences: JOAQUIN BUSTOZ of Arizona State University and RICHARD A. TAPIA of Rice University. They are two of the twenty-seven Mexican-Americans in the U.S. who hold Ph.D.s in mathematics.

Bustoz has established mentoring programs for underrepresented minority precollege students living in urban areas and on Arizona reservations to encourage their study of mathematics. These programs now reach over 200 students, and over 1,000 students have gone through the program since 1985. These efforts have contributed to the attraction of mathematics at Arizona State University, where one-third of the mathematics majors are minorities. He also worked extensively on the Navajo and Pima Reservations, in an NSF-funded Young Scholars program. This program includes a component for teachers and an after-school program. He and Tapia work on the SUMMA project of the Mathematical Association of America (Strengthening Underrepresented Minorities’ Mathematics Achievement).

Tapia is the Noah Harding Professor of Mathematical Sciences at Rice. He also serves as the associate director of minority affairs in the Office of Graduate Studies and as the director of education and minority programs of the Center for Research in Parallel Computation (CRPC). In addition to overseeing the college careers of hundreds of minority students, Tapia has directed the advanced work of twenty-eight students, including seven minority students, in computational and applied mathematics. The programs he directs at CRPC have, in less than ten years, reached more than 750 students and 700 teachers, especially underrepresented minorities and women. Tapia, who has served as a consultant for major corporations and the government, was the first Mexican-American to be elected to the National Academy of Engineering.

—from NSF News Release

Visiting Mathematicians

(Supplementary List)

Mathematicians visiting other institutions during the 1996–97 academic year have been listed in recent issues of the Notices: July 1996, pp. 784–786; September 1996, p. 988; November 1996, p. 1371. The following is an update to those lists (home countries are listed in parentheses).

SHARAD AGNIHORTI (United Kingdom), University of Texas, Austin, Analysis, 9/96–8/97.

DRAGOS HRIMIUC (Romania), University of Alberta, Finsler Geometry, 4/96–4/97.

YOUNG YOON LEE (Korea), University of Alberta, Functional Analysis, 8/96–7/97.

ANDREA NAHMOD (Argentina), University of Texas, Austin, Harmonic Analysis, 9/96–8/97.

HON-KIT WAI (Hong Kong), University of Texas, Austin, Differential Geometry and Topology, 9/96–8/97.

XIAO-QIANG ZHAO (China), University of Alberta, Differential Equations, Dynamical Systems, 5/96–12/96.

JOHN ZWECK (Australia), University of Texas, Austin, Geometry, 9/96–8/97.
NRC-Ford Foundation Fellowships for Minorities

The National Research Council plans to award approximately twenty Ford Foundation Postdoctoral Fellowships for Minorities. The program provides a year of continued study and research for Native American Indians, Alaskan Natives (Eskimo or Aleut), Black/African-Americans, Mexican-Americans/Chicanos, Native Pacific Islanders (Micronesians or Polynesians), and Puerto Ricans. The competition is open to citizens of the U.S. who are members of the designated minority groups, who are engaged in a teaching or research career or are planning such a career, and who have held the Ph.D. or Sc.D. degree for not more than seven years.

Awards will be made in all areas of science and in mathematics. Each fellow selects an appropriate nonprofit institution of higher education or research to serve as host for the year of postdoctoral research.

The deadline for submission of applications is January 3, 1997. Inquiries should be directed to: Fellowship Office, TJ 2039, National Research Council, 2101 Constitution Avenue, NW, Washington, DC 20418. Further information is also available at the Web site http://www.fellowships.nas.edu/index.html.

— from NRC Announcement

Call for Proposals: MAA Programs for Women and Girls

The Mathematical Association of America (MAA) offers two kinds of grants supporting projects that encourage girls and young women to study mathematics. MAA/Tensor Grants provide direct project support with funds provided by the Tensor Foundation. Women & Mathematics Grants are for planning projects; they are administered under the guidance of MAA's Women & Mathematics Program and funded by the National Security Agency.

The Tensor program provides funds for student-centered projects conducted by high school, college, or university mathematics faculty. Ten grants of up to $5,000 each will be made in April 1997 for projects that will begin by the end of the 1997-98 academic year. The deadline for MAA/Tensor grant proposals is February 28, 1997.

Women & Mathematics Grants support the planning of projects conducted by college and university faculty which encourage young women to study mathematics. Five grants of up to $2,500 in matching funds will be awarded for activities such as visits to successful programs, feasibility studies, and pilot projects, to take place by the end of the 1997-98 academic year. The deadline for Women & Mathematics grant proposals is February 14, 1997.

Announcements detailing the objectives of each program, along with submission procedures and evaluation criteria for proposals, are available at the MAA home page (http://www.maa.org) or from the Member Services and Programs Department, Mathematical Association of America, 1529 18th Street, NW, Washington, DC 20036; telephone 202-387-5200; e-mail programs@maa.org.

— MAA Announcement

ICM-98 Travel Grants for Young Mathematicians from Developing Countries

The International Mathematical Union (IMU) will award travel grants to young mathematicians to help them attend
the International Congress of Mathematicians (ICM) in Berlin, Germany, August 18–27, 1998. The grants are intended primarily for young mathematicians from developing countries (which are not necessarily members of IMU).

The age limit for the grantees is 35 years at the occasion of the Congress. The candidates should present evidence of research work on the postdoctoral level, and they should be able to benefit from the interaction with mathematicians from other countries attending the Congress.

In addition to the name and address of the candidate, the applications should contain a brief curriculum vitae, including date of birth, plus a list of publications (papers published or accepted for publication).

The Local Organizing Committee of the ICM will provide a special allowance to the grantees to cover their registration, board, and lodging.

Applications for the travel grant may be sent directly to the secretary of the IMU. Applications may also be submitted through the National Committees for Mathematics, which will send all the relevant information about the candidates to the secretary.

All applications should reach the secretary by January 1, 1998, and should be sent to: IMU Secretariat, International Mathematical Union, Professor Jacob Palis, Secretary, Estrada Dona Castorina, 110, Jardim Botanico, 22.460-320–Rio de Janeiro, RJ, Brazil; fax 55-21-512-4112; e-mail imu@impa.br.

Information about the IMU and ICM-98 may be found on the World Wide Web server http://elib.zib-berlin.de/IMU/.

—from ICM-98 Announcement

Toyota USA Foundation Seeks Math and Science Education Proposals

The Toyota USA Foundation is seeking proposals for innovative mathematics and science programs for children in kindergarten through twelfth grade. The Foundation has an endowment of $25 million and annually makes grants totalling more than $1.2 million.

The Toyota Foundation is looking for programs which are systemic, have a broad scope, and incorporate interdisciplinary curricula. They are also interested in programs that build partnerships among educational, business, and community groups. Grants are made to organizations such as higher-education institutions, community colleges, and nonprofit groups. Individuals and for-profit organizations are not eligible.

For further information contact: Toyota USA Foundation, 19001 S. Western Avenue, Torrance, CA 90509; telephone 310-618-6766; World Wide Web http://www.toyota.com/inside_toyota/toyota_foundation.

—Toyota USA Foundation

New NSF Initiative on Learning and Intelligent Systems

It is likely that the National Science Foundation will be announcing an opportunity later this fall for interdisciplinary research in Learning and Intelligent Systems (LIS). The LIS activity is expected to stimulate interdisciplinary research that will unify concepts related to learning and learning-based intelligent systems and that will promote the use of information technologies in learning across a wide variety of fields. The formation of interdisciplinary teams will be encouraged. It is expected that mathematicians will be able to play a significant role. More information on this opportunity will likely be available later this fall. The deadline for preproposals will likely be in early January 1997. Details were not available at the time of this writing. However, those interested in learning more can consult the DMS World Wide Web page http://www.nsf.gov/mps/dms.

—DMS
For Your Information

Math Education Center Launched at Wisconsin

The new School Mathematics and Science Achievement Center, funded by the U.S. Department of Education, Office of Research and Development, has begun operation under the auspices of the Wisconsin Center for Education Research at the University of Wisconsin-Madison. The director of the center is Thomas Romberg of the University of Wisconsin, and the associate directors are Angelo Collins of Vanderbilt University, and Richard Lehrer and Walter Secada of the University of Wisconsin. The center was established to develop a set of principles for the design of K-12 classrooms that promote understanding in mathematics and science. The center emphasis on designing instructional innovations in teaching, curriculum, instructional technology, and assessment will build on the work of other organizations.

A key element of this new project will be dissemination. The center will develop newsletters, related informational briefs, and appropriate online technology to ensure that information on research findings reaches a broad audience promptly. For further information, write to: School Mathematics and Science Achievement Center, University of Wisconsin-Madison, 1025 West Johnson Street, Room 576, Madison, WI 53706.

—from SMSAC Announcement

Problems, Programs, and Prospects of 21ST Century Mathematics: Meeting of the AMS in August 2000

Upon recommendation by the Society's Year 2000 Blue Ribbon Committee chaired by Felix Browder, the Society has approved a meeting to be held during the first week of August in the year 2000 with the broad theme "Problems, Programs, and Prospects of 21st Century Mathematics". This meeting is part of the celebration of that year as "World Mathematical Year 2000" organized by the International Mathematical Union. The purpose of the meeting is to consider the challenges and possible growing points for the mathematical sciences in the next century.

The Program Committee for the meeting, chaired by Professor Felix Browder, has determined a broad outline for the meeting. It will consist of approximately twenty-five plenary addresses held over a five day period.

A site for this meeting has not yet been determined. In fact, the Society is seeking a suitable site for the meeting and requests and welcomes proposals for hosting this meeting. Proposals should take into account that the meeting may be fairly large. They may be sent to the secretary (rmf@ams.org) or to the director of the Meetings and Conferences Department, Ms. Hope Daly (hhd@ams.org). Either of these or the chair of the Program Committee, Felix Browder (browder@math.rutgers.edu), is willing to answer
questions about format and structure of the meeting. The details of the meeting will be continually updated on the calendar available on e-MATH, http://www.ams.org/amsmtgs/wmy2000.html.

—Robert Fossum

Web Information on Jobs and Conferences

TIPTOP (The Internet Pilot to Physics) offers information on jobs and conferences in physics and related fields. The service is free. http://www.tp.umu.se/蒂 topp/FORUM/JOBS/ is the address for “TIPTOP: Physics Jobs On-Line.”

—from TIPTOP Announcement
The August 1996 Council Meeting in Seattle

The Council of the Society met at 1:00 p.m. on Friday, 09 August, 1996, in Seattle, Washington. About twenty members were in attendance. President Morawetz presided. In addition to usual business, the Council received and acted on recommendations from its Editorial Boards Committee and it considered a report from its Committee on Academic Freedom, Tenure, and Employment Security while sitting in executive session. The action taken on all these items are reported in these open minutes.

The Minutes of the April 24 Council that were mailed to members were approved as presented.

The Mathematical Association of America and the Society for Industrial and Applied Mathematics have agreed to the establishment of a joint Accessibility for the Handicapped Committee. However there is still the matter of a charge which has not been settled. The Council assigned to the president the matter of negotiating the final charge for this committee with the other three cosponsoring organizations.

The Editorial Boards Committee (EBC) submitted recommendations that were considered in Executive Session and approved. In addition, the Council agreed to the recommendation from EBC that membership on the Mathematical Surveys and Monographs Editorial Committee remain as three on an interim basis.

The Committee on the Profession (CoProf) forwarded to the Council its report Committee on the Profession Review of AMS Public Awareness Activities. This report was filed and is available on the Society's Web site.

The Council adopted two resolutions proposed by its Committee on Publications.

Editors for journals of the American Mathematical Society are expected to follow the Society's ethical guidelines, treating all potential authors with reasonable professional courtesy, responding promptly to submissions and making decisions based on the merit of the paper as well as its suitability to the journal. Editors are not obliged, however, to provide a rationale for not accepting a paper, nor are editors obliged to provide an author with a detailed list of errors and corrections. When information is available to help the author improve a paper, whether it is accepted or not, the editor should communicate that information to the author if appropriate.

Ease of access and use is one of the main attractions of electronic publications. For the AMS to gain a significant role in electronic information dissemination and to provide service to all mathematicians, especially those with inadequate communication and computing facilities, it is important that AMS electronic products should strive to be as user friendly as possible. In particular, the Council urges that access by e-mail be provided and that as many input and
output formats be accepted as feasible, financially prudent, and editorially wise.

The determination of this amount must reduce the dues payment by the “fair value” of the benefits received as a member. When journals or magazines are privileges of membership, the “fair value” of membership rights includes the price that nonmembers would have to pay for the journals or magazines. Other benefits of membership are less easily quantified, and include such items as the availability of discounts on publications and meeting registration fees.

Staff of the Society have studied these issues and consulted with other professionals, and have concluded that no portion of a member’s dues to the AMS is tax deductible as a charitable contribution. However, a member’s dues payment to the AMS may be tax deductible under other provisions of the Internal Revenue Code, such as those addressing professional expenses. Members should consult with their personal tax advisors.

Members Dues Information

The Internal Revenue Code requires that not-for-profit organizations advise their members of the amount of their dues which is tax deductible as a charitable contribution.

Honorary Members of the AMS

Listed below are the Honorary Members of the American Mathematical Society, those who have been members for fifty years or more.

The American Mathematical Society offers congratulations to all its Honorary Members on their longstanding affiliation with the AMS and extends appreciation for their continued commitment to the mathematics profession.

James Abbott  Eben E Betz  Shing S Chern
Clarence M Ablow  Garrett Birkhoff  Herman Chernoff
L V Ahlfors  Z William Birnbaum  Kai Lai Chung
H L Alder  Clair J Blackall  Paul Civin
R Lucile Anderson  David Blackwell  Charles Clark
Richard D Anderson  Charles Blanc  Charles L Clark
Theodore W Anderson  Albert A Blank  Robert A Clark
Thomas B Andrews Jr  William A Blankinship  Helen E Clarkson
Tom M Apostol  William M Boothby  Mary Dean Clement
Richard F Arens  Truman A Botts  Herman J Cohen
Bradford H Arnold  Julia W Bower  Harvey Cohn
Winifred A Asprey  Harold E Bowie  Richard M Cohn
Silvio Aurora  Evelyn Hull Royle  Charles A Cole
Christine W Ayoub  Joel L Brenner  A John Coleman
Edward G Baker  Nelson A Brigham  Myron A Coler
George A Baker Sr  Foster Brooks  Henry D Colson
Richard W Ball  Arthur A Brown  E Allen Cook Jr
Donald H Ballou  Arthur B Brown  H S MacDonald Coxeter
S F Barber  Richard H Brown  Stephen H Crandall
William J Barr  Hugh D Brunk  Florence G Critchlow
Robert C F Bartels  Mildred C Brunschwig  Edwin L Crow
Paul T Bateman  Ellen F Buck  George B Dantzig
Grace E Bates  R Creighton Buck  Donald A Darling
Helen P Beard  Royce E Buehler  Douglas Derby
Marjorie Heckel Beaty  Leonard P Burton  Ainsley H Diamond
Ross A Beaumont  John H Butchart  David J Dickinson
Janie L Bell  Leonard Carlitz  Bernard Dimsdale
Philip O Bell  Bengt G Carlson  Charles L Dolph
Theodore J Benac  Charles L Carroll Jr  Joseph L Doob
Agnes Berger  C Ronald Cassity  Harold L Dorwart
Peter G Bergmann  Thomas E Caywood  Francis G Dressel
Salvatore D Bernardi  Y W Chen  Daniel M Dribin
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<td>Edwin Hewitt</td>
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<td>Bjarni Jonsson</td>
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<td>D J Lewis</td>
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<td>R J Marcou</td>
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<td>Brockway McMillan</td>
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<td>Paul Meier</td>
<td>Herman Meyer</td>
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<tr>
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<td>Wayne W Gutzman</td>
<td>Hugh J Miser</td>
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<td>Paul R Halmos</td>
<td>Paul R Halmos</td>
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<tr>
<td>George H Handelman</td>
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</tr>
</tbody>
</table>

NOTICES OF THE AMS

VOLUME 43, NUMBER 12

1546
Edwin E Moise
Harriet F Montague
Marvin G Moore
Charles W Moran
Morris Morduchow
Kathryn A Morgan
David C Morrow
Thirza A Mossman
George Daniel Mostow
Benjamin N Moya
M Evans Munroe
David C Murdoch
Francis J Murray
David Nelson
Cecil J Nesbitt
Albert Newhouse
August Newlander Jr
Morris Newman
Ivan Niven
Andrew R Noble
Edward A Nordhaus
Anne F O'Neill
P S Olmstead
John M H Olmsted
A C Olshen
Alexander Oppenheim
Lowell J Paige
Theodore P Palmer
Herbert C Parrish
Anthony J Penico
Paul M Pepper
Sam Perlis
George W Petrie III
Ralph S Phillips
Edmund Pinney
George Piranian
Everett Pitcher
Emily C Pixley
Theresa L Podmele
Harry Polachek
Hillel Poritsky
Donald H Potts
Walter Prenowitz
G Bailey Price
Murray H Protter
W T Puckett Jr
Alfred I Putnam
Calvin R Putnam
Grace S Quinn
George N Raney
Lawrence L Rauch
Maxwell O Reade
Ottis W Rechard
Mina S Rees
Paul K Rees
Haim Reingold
Eric Reissner
Charles E Rickart
Karlem Riess
Eugene K Ritter
J H Roberts
Malcolm S Robertson
Robin Robinson
Gene F Rose
Israel H Rose
Robert A Rosenbaum
J H Rosenbloom
Jenny E Rosenthal
Arnold E Ross
Fritz Rothberger
William Salkind
Charles Saltzer
Herbert E Salzer
Hans Samelson
Pierre Samuel
Jane Cronin Scanlon
Henry M Schaerf
Alice T Schafer
Richard D Schafer
Samuel Schechter
Lowell Schoenfeld
K C Schraut
Jewell E Schubert
Augusta L Schurrer
Irving E Segal
Bernard Sherman
Marlow C Sholander
Darrell R Shreve
Annette Sinclair
Frank Smithies
Ernst Snapper
John J Sopka
Edwin H Spanier
Edward J Specht
Domina E Spencer
Abraham Spitzbart
George Springer
David W Starr
F H Steen
Robert Steinberg
Clarence F Stephens
Arthur H Stone
William J Strange
Dirk J Struk
Eric A Sturley
Sister M Helen Sullivan
Fred Supnick
Charles S Sutton
P P Sutton
Taffee T Tanimoto
Abraham H Taub
Angus E Taylor
George B Thomas Jr
D L Thomsen Jr
Charles J Thorne
Robert M Thrall
Wolfgang J Thron
William R Transue
Bryant Tuckerman
Atwell R Turquette
E F Tyler
W Roy Utz Jr
F A Valentine
A H Van Tuyl
Elbridge P Vance
D G Velesz
Bernard Vinograde
Azelle B Waltcher
Eleanor B Walters
James A Ward
John V Wehausen
Everett T Welmers
James G Wendel
William Wernick
D W Western
Marion D Wetzel
Charles H Wheeler III
Myron E White
George W Whitehead
Kathleen B Whitehead
Philip M Whitman
D Ramsay Whitney
Arthur S Wightman
L R Wilcox
J Ernest Wilkins Jr
Robert L Wilson
G Milton Wing
Eva P Winter
Yung-Chow Wong
Rhoda M Wood
Max A Woodbury
John W Wrench Jr
Marie A Wurster
Fumio Yagi
Bertram Yood
Gail S Young
Laurence C Young
Paul M Young
Eduardo H Zarantonello
Daniel Zelinsky
Josep A Zilber
Delbert E Zilmer
J W Zimmer
Hyman J Zimmerberg

I. Introduction
The Report of the Treasurer is presented annually and discusses the financial condition of the Society as of the immediately preceding fiscal year end, and the results of its operations for the year then ended. This Section contains summary information regarding the operating results and financial condition of the Society for 1995. Section II, Review of 1995 Operations, contains more detailed information regarding the Society's operations. Section III, Summary Financial Information, presents information regarding the operations, financial condition and long-term investments of the Society in financial statement format. Section IV discusses the assets and liabilities of the Society.

The Society's 1995 financial statements are subject to new accounting requirements. In accordance with new requirements, the Society must now segregate its net assets, and the activities that increase or decrease net assets, into three types. Unrestricted net assets are those which have no requirements as to their use placed on them by donors outside the Society. A substantial majority of the Society's net assets and activities are in this category. Temporarily restricted net assets are those with donor-imposed restrictions or conditions that will lapse upon the passage of time or the accomplishment of a specified purpose. Examples of the Society's temporarily restricted net assets and related activities include grant awards and the spendable income from prize and other income-restricted endowment funds. Permanently restricted net assets are those which must be invested in perpetuity and are commonly referred to as endowment funds. The accompanying financial information principally relates to the unrestricted net assets, as this category includes the operating activities of the Society.

Unrestricted revenue in excess of unrestricted expenses for the year ended December 31, 1995, totaled approximately $4,436,000. Of this amount, net returns on the unrestricted portion of the long term investment portfolio totaled $4,626,000 and net income from operations totaled $576,000. These positive amounts were offset by $1,080,000 recorded in 1995 to recognize the Society's cumulative obligation as of the beginning of the year for post-retirement benefits other than pensions (this is one of the new accounting requirements I mentioned above). Exceptionally strong financial markets in the U.S. during the year contributed to returns on our long term portfolio that exceeded more than 31%, the highest in Society's recent history. These and other matters are discussed in more detail in the next Section.

The Society's net assets totaled $24,482,000 at December 31, 1995. $1,242,000 is permanently restricted, consisting principally of donor restricted gifts and bequests received by the Society. $1,447,000 is temporarily restricted, whose use is restricted by some donor-imposed limitation, which will lapse upon the passage of time or the use of the asset for its intended purpose. $21,793,000 is unrestricted, of which $17,644,000 has been designated by the Board of Trustees, principally in the form of the Economic Stabilization Fund. This Fund's purpose is to provide a source of cash in the event of a financial crisis. It has met the target established by the Board of Trustees of 75% of operating expenses plus the unfunded liability for post-retirement benefits. Assets underlying this fund are long-term investments, whose performance is monitored to ensure that the target is maintained. The remaining unrestricted net assets consist of $6,406,000 invested in fixed assets offset by an undesignated cumulative deficit of $2,257,000. This undesignated deficit has resulted from the fact that, historically, cash projected not to be required in the near future for continuing operations has been designated as part of the Economic Stabilization Fund. In 1992, 1993, 1994, and 1995 such transfers (which include reinvested income from the underlying long-term investments) equalled $1,900,000, $3,169,000, $865,000, and $4,484,000, respectively.

II. Review of 1995 Operations
The following is a more detailed discussion of 1995 operations:

BOOKS: Book revenues comprised 12% of total revenues in both 1995 and 1994. In 1995 the Society published a total of 73 volumes compared to 78 volumes in 1994. Over the past several years the Society has reorganized its Publication Division to devote more resources to marketing as well as to the acquisition and sale of high quality books and manuscripts. The sales prices of selected volumes have been reduced in order to generate a higher quantity of unit sales. Unit sales of books in a series have increased accordingly—the total number of volumes sold equaled 34,000, 39,000, and 49,000 in 1993, 1994, and 1995, respectively. It is planned that the growth in unit sales will soon correspond to a growth in book program revenues, eventually allowing for less reliance by the Society on the net income generated by the Journal program.

JOURNALS: Journals provide the second largest percentage of the Society's revenues, a little less than a quarter of the total. For many years journals and Mathematical Reviews have provided a very significant portion of the Society's surplus (the excess of revenues over expenses in the summary financial statements above). However, the amount of surplus generated by journals is expected to decrease in future years as the Russian journal program is reduced. Additionally, there is constant pressure from libraries to keep prices low and an overall attrition in paying subscribers. Cost saving opportunities and alternative sources of support are being sought to compensate for lower revenues and higher expenses.

MATH REVIEWS: Published by the Society's Ann Arbor division, Mathematical Reviews and related activities comprise more than a third of the Society's total revenues. Effective in 1994 the Society changed its subscription pricing model for all Mathematical Reviews and MathSci products. Electronic access fees for the MR Database have replaced paper subscription income as the most significant source of MR revenues. The cost of developing and maintaining the MR bibliographic database, from which all products are derived,
is separated from the cost of the individual product deliveries. Sites that support mathematicians contribute to the development and maintenance of the database just once annually by paying a Data Access Fee. MR products are then purchased by those sites in a variety of electronic formats by paying Product Delivery Fees.

MEETINGS: Meetings have generally been operated at approximately break-even or at a small deficit, as a service to the mathematics community. The 1995 excess of revenues of expenses equaled approximately $16,000. Revenues for 1995 were approximately $59,000 higher than in 1994, primarily due to an increase in registrations for the joint meetings.

DUES, MEMBERSHIP ACTIVITIES, AND MEMBERSHIP RECORDS: The Society had 493 institutional members and 29,793 individual members at December 31, 1995, compared to 488 and 29,732, respectively, at the end of 1994. Of the latter, over 11,000 pay no dues because they are student nominees or emeritus members. Individual member dues are two-tiered to provide some relief to lower paid members. Increases in dues for individual members are set annually by a cost-of-living index. Costs which can be considered to be partially covered by dues include the cost of maintaining membership records, the deficits of Abstracts, Bulletin, EiMS, Notices and the Professional Directory; deficits from meetings, including the Employment Register, and the AMS support of the Joint Policy Board on Mathematics.

GRANTS AND CONTRACTS: Federal grant programs comprise approximately 4% of total revenues. Grant support is used primarily for travel and subsistence for participants in research conferences, institutes, and seminars. The most significant grant receipts in 1995 were from the NSF for the Summer Research Conferences and Seminars.

INVESTMENT INCOME: Income in this category includes earnings from the short term investment portfolio. In 1995 and 1994, $317,000 and $194,000 were earned from these types of investments, equalling an overall rate of return of about 6.4% and 3.7%, respectively.

### III. Summary Financial Information

The treasurer presents to the membership the following financial information of the Society. A copy of the Society's audited financial statements, as submitted to the Trustees and the Council, will be sent from the Providence Office to any member who requests it from the treasurer. The treasurer will be happy to answer any questions members may have regarding the financial affairs of the Society.

#### STATEMENTS OF ACTIVITIES (IN 000’S)

<table>
<thead>
<tr>
<th>Unrestricted Net Assets</th>
<th>Years Ended December 31, 1995, and 1994</th>
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<tbody>
<tr>
<td>Other</td>
<td>40  -%  77  -%</td>
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<tr>
<td>Total publication revenue</td>
<td>15,079 73% 14,685 75%</td>
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<td>Membership and professional services, including assets released from restrictions of $466 and $360 in 1995 and 1994, respectively:</td>
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<tr>
<td>Meetings</td>
<td>742  4%  683  3%</td>
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<tr>
<td>Dues and membership services</td>
<td>3,435 16% 3,081 16%</td>
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<tr>
<td>Grants, prizes and awards</td>
<td>741  4%  755  4%</td>
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<tr>
<td>Total membership and professional services revenue</td>
<td>4,918 24% 4,519 23%</td>
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<tr>
<td>Short-term investment income</td>
<td>317  2%  194  1%</td>
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<tr>
<td>Other</td>
<td>217  1%  297  1%</td>
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<tr>
<td>Total operating revenues</td>
<td>$20,531 100% $19,695 100%</td>
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<td>Operating Expenses</td>
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<tr>
<td>Publication:</td>
<td></td>
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<td>Mathematical Reviews and related activities</td>
<td>$4,983 25% $4,599 24%</td>
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<td>Journals (excluding MR)</td>
<td>1,645 8% 1,756 9%</td>
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<tr>
<td>Books</td>
<td>1,738 9% 1,682 9%</td>
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<tr>
<td>Publication—divisional indirect</td>
<td>1,375 7% 1,567 8%</td>
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<td>Warehousing and distribution</td>
<td>570 3% 535 3%</td>
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<td>Sale of services</td>
<td>296 1% 544 3%</td>
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<td>Other</td>
<td>21  -%  155  1%</td>
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<td>Total publication expense</td>
<td>10,628 53% 10,838 57%</td>
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<td>Membership and professional services:</td>
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<td>Meetings</td>
<td>726  4%  713  4%</td>
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<td>Dues and member services</td>
<td>2,702 14% 2,300 12%</td>
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<td>Grants, prizes and awards</td>
<td>817  4%  798  4%</td>
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<td>Governance</td>
<td>437  2%  427  2%</td>
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<td>Divisional indirect</td>
<td>269  1%  207  1%</td>
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<td>Total membership and professional services expense</td>
<td>4,951 25% 4,445 23%</td>
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<tr>
<td>Miscellaneous</td>
<td>429  2%  249  1%</td>
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<td>Membership and customer services</td>
<td>917 5% 987 5%</td>
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<td>General and administrative</td>
<td>3,030 15% 2,640 14%</td>
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<tr>
<td>Total operating expenses</td>
<td>$19,955 100% $19,159 100%</td>
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<td>Excess of operating revenue over operating expenses</td>
<td>576 536</td>
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<td>Long-term investment income (losses)</td>
<td>4,626 (216)</td>
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<td>Cumulative effect of a change in accounting principle</td>
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<td>Increase in unrestricted net assets</td>
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<td>Unrestricted net assets, beginning of year</td>
<td>17,671 17,351</td>
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<tr>
<td>Unrestricted net assets, end of year</td>
<td>$21,793 $17,671</td>
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### BALANCE SHEETS (In 000's)
*December 31, 1995, and 1994*

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<thead>
<tr>
<th>Assets</th>
<th>1995</th>
<th>1994</th>
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<tr>
<td>Cash and cash equivalents</td>
<td>$487</td>
<td>$275</td>
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<td>Short-term investments</td>
<td>6,468</td>
<td>6,783</td>
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<td>Receivables:</td>
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<td>Customers, less allowance for doubtful</td>
<td>928</td>
<td>831</td>
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<tr>
<td>accounts of $23 and $29 at December 31,</td>
<td>2%</td>
<td>2%</td>
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<tr>
<td>1995, &amp; 1994, respectively</td>
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<td>Grants and other</td>
<td>519</td>
<td>386</td>
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<tr>
<td>Deferred prepublication costs</td>
<td>412</td>
<td>656</td>
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<td>Completed books</td>
<td>1,012</td>
<td>1,296</td>
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<tr>
<td>Prepaid expenses and deposits</td>
<td>904</td>
<td>1,085</td>
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<tr>
<td>Land, buildings and equipment,</td>
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<tr>
<td>less accumulated depreciation</td>
<td>6,406</td>
<td>6,173</td>
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<tr>
<td>Long-term investments</td>
<td>21,961</td>
<td>16,580</td>
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<tr>
<td><strong>Total liabilities</strong></td>
<td><strong>$39,097</strong></td>
<td><strong>$33,975</strong></td>
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#### Liabilities and Net Assets

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<th>Liabilities</th>
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<th>1994</th>
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<td>Accounts payable</td>
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<td>$1,414</td>
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<td>Accrued expenses:</td>
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<tr>
<td>Severance and study</td>
<td>757</td>
<td>978</td>
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<td>Leave pay</td>
<td>445</td>
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<tr>
<td>Vacation and sick pay</td>
<td>793</td>
<td>526</td>
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<tr>
<td>Deferred revenue:</td>
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<tr>
<td>Subscriptions</td>
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<td>8,599</td>
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<tr>
<td>Dues</td>
<td>1,402</td>
<td>1,420</td>
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<tr>
<td>Other</td>
<td>526</td>
<td>532</td>
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<tr>
<td>Post-retirement benefit obligation</td>
<td>1,219</td>
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<tr>
<td><strong>Total liabilities</strong></td>
<td><strong>14,615</strong></td>
<td><strong>13,930</strong></td>
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</tbody>
</table>

#### Net assets (deficit) :

- **Unrestricted:**
  - Undesignated: (2,257) (1,663)
  - Designated: 17,644 13,161
  - Invested in fixed assets: 6,406 6,173
- **Total unrestricted:** 21,793 17,671
- **Temporarily restricted:** 1,447 1,152
- **Permanently restricted:** 1,242 1,217

**Total net assets:** 24,482 20,045

**Total liabilities and net assets:** $39,097 $33,975

### LONG TERM INVESTMENT INFORMATION

#### Allocation to Net Asset Types and Related Subfunds
*December 31, 1995, and 1994*

<table>
<thead>
<tr>
<th>Asset Types</th>
<th>1995</th>
<th>1994</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unrestricted net assets:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undesignated</td>
<td>$2,465,651</td>
<td>$1,831,514</td>
</tr>
<tr>
<td>Designated:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Economic Stabilization Fund</td>
<td>17,502,715</td>
<td>13,019,127</td>
</tr>
<tr>
<td>Friends of Math</td>
<td>123,572</td>
<td>123,572</td>
</tr>
</tbody>
</table>

### Russian Royalties

**Total allocated to unrestricted net assets:** 20,109,883 14,992,158

**Temporarily restricted net assets, principally net gains on income-restricted endowment funds:** 608,261 370,702

**Permanently restricted net assets:**

- **Unrestricted use of income:**
  - Robert Henderson: 548,223 548,223
  - Endowment: 100,000 100,000
  - Joseph Fels Ritt: 22,521 22,521
  - Eliakim Hastings: 2,575 2,575

- **Restricted use of income:**
  - Tjitzinsky Prize Funds: 213,834 188,600
  - Centennial Research Fund: 195,780 195,780
  - Pooled Income Fund: 5,000 5,000
  - Karl Menger Fund: 2,550 2,550
  - C.V. Newsom Fund: 100,000 100,000

**Total allocated to permanently restricted net assets:** 1,242,483 1,217,249

**Total investment portfolio, at market:** $21,960,627 $16,580,109

### IV. Assets and Liabilities

So far, this report has dealt with sources of revenue and expenditures that affect unrestricted net assets. Another aspect of the Society's finances is what it owns and owes, or its assets and liabilities, which are reported above in the Balance Sheets. As discussed previously, the Society's net assets and activities that increase or decrease net assets are classified as unrestricted, temporarily restricted or permanently restricted. A majority of the assets and liabilities detailed on the accompanying Balance Sheets relate to the unrestricted net assets. The permanently restricted net assets are supported by investments in the long-term investment portfolio and the temporarily restricted net assets are supported by investments in the long-term and short-term investment portfolios. The Long-Term Investment Information shows the allocation of the portfolio among the three types of net assets, as well as related subfunds.

The Society's fiscal year coincides with the period covered by subscriptions and dues. Since dues and subscriptions are generally received in advance, the Society reports a large balance of cash and short-term investments on its financial statements at year-end. This amounted to about $6,955,000 and $7,058,000 at December 31, 1995, and 1994, respectively. The recorded liability for the revenues received in advance was about $10,128,000 and $10,551,000 at December 31, 1995, and 1994, respectively. The differ-
ence can be thought of as having been invested in the Society's other assets—principally the long-term investment portfolio. Effectively, the Society borrows from its subscribers to finance current operations and long-term investments. This is a common practice in the publishing industry and allows the Society to operate free of short-term or long-term bank debt.

The Society's property and equipment include land, buildings and improvements, office furniture, and equipment as well as software. The Society also owns a small amount of transportation equipment. The land, buildings, and improvements include the Society's Rhode Island headquarters with buildings in Providence and Pawtucket and the Mathematical Reviews in Ann Arbor. The largest part of the Society's office equipment is its investment in computer facilities.

Respectfully submitted,
Franklin P. Peterson
Treasurer

American Mathematical Society

AMS Preprint Server
Now on e-MATH on the World Wide Web

The AMS Preprint Server provides a comprehensive collection of abstracts of mathematical preprints in all areas of the mathematical sciences, with links from abstracts to the associated preprints.

The AMS Preprint Server is accessible from e-MATH.

The URL is:
http://www.ams.org/
or
http://www.ams.org/preprints/

For more information:
cust-serv@ams.org
800-321-4267
401-455-4000
Fax: 401-331-3842
Statistics on Women Mathematicians Compiled by the AMS

At its August 1985 meeting, the Council of the AMS approved a motion to regularly assemble and report in the Notices information on the relative numbers of men versus women in at least the following categories: membership in the AMS, invited hour addresses at AMS meetings, speakers at special sessions at AMS meetings, percentage of women speakers in AMS Special Sessions by gender of organizers, and members of editorial boards of AMS journals.

It was subsequently decided that this information would be gathered by determining the sex of the individuals in the above categories based on name identification and that additional information on the number of Ph.D.s granted to women would also be collected using the AMS-IMS-MAA Annual Survey. Since name identification was used, the information for some categories necessitated the use of three classifications:

- **Male**: names that were obviously male;
- **Female**: names that were obviously female;
- **Unknown**: names that could not be identified as clearly male or female (e.g., only initials given, non-gender-specific names, etc.)

The following is the eleventh reporting of this information. Updated reports will appear annually in the Notices.

### Members of the AMS Residing in the U.S.

<table>
<thead>
<tr>
<th>Year</th>
<th>Male</th>
<th>Female</th>
<th>Unknown</th>
<th>Total Checked</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>14,106</td>
<td>3,704</td>
<td>2,470</td>
<td>20,280</td>
</tr>
</tbody>
</table>

<table>
<thead>
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<th>Female</th>
<th>Unknown</th>
<th>Total Checked</th>
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<tbody>
<tr>
<td>1994</td>
<td>176</td>
<td>177</td>
<td>178</td>
<td>421</td>
</tr>
<tr>
<td>1993</td>
<td>159</td>
<td>163</td>
<td>165</td>
<td>493</td>
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<tr>
<td>1992</td>
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<td>159</td>
<td>474</td>
</tr>
<tr>
<td>1990</td>
<td>156</td>
<td>159</td>
<td>159</td>
<td>474</td>
</tr>
<tr>
<td>1989</td>
<td>156</td>
<td>159</td>
<td>159</td>
<td>474</td>
</tr>
<tr>
<td>1988</td>
<td>156</td>
<td>159</td>
<td>159</td>
<td>474</td>
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<tr>
<td>1987</td>
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<td>159</td>
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</tr>
<tr>
<td>1986</td>
<td>156</td>
<td>159</td>
<td>159</td>
<td>474</td>
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### Invited Hour Address Speakers at AMS Meetings (1986–1995)

<table>
<thead>
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<th>Number</th>
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<tbody>
<tr>
<td>Male</td>
<td>370</td>
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<tr>
<td>Female</td>
<td>53</td>
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<tr>
<td>Unknown</td>
<td>4</td>
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<tr>
<td>Total checked</td>
<td>427</td>
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### Speakers at Special Sessions at AMS Meetings (1991–1995)

<table>
<thead>
<tr>
<th>Gender</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>6,518</td>
<td>81%</td>
</tr>
<tr>
<td>Female</td>
<td>914</td>
<td>11%</td>
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<tr>
<td>Unknown</td>
<td>603</td>
<td>8%</td>
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<tr>
<td>Total checked</td>
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### Percentage of Women Speakers in AMS Special Sessions by Gender of Organizers (1995)

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<th>Special Sessions</th>
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<th>Female</th>
<th>Unknown</th>
<th>Total Number of Speakers</th>
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</thead>
<tbody>
<tr>
<td>with at Least One Woman Organizer</td>
<td>34</td>
<td>14</td>
<td>1</td>
<td>318</td>
</tr>
<tr>
<td>with No Women Organizers</td>
<td>1,570</td>
<td>241</td>
<td>175</td>
<td>1,986</td>
</tr>
</tbody>
</table>

### Trustees and Council Members

<table>
<thead>
<tr>
<th>Year</th>
<th>Male</th>
<th>Female</th>
<th>Unknown</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>48</td>
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<td>76</td>
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<td>1993</td>
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<td>14</td>
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<tr>
<td>1992</td>
<td>51</td>
<td>14</td>
<td>14</td>
<td>81</td>
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</table>

### Members of Editorial Boards of AMS Journals

<table>
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<th>Year</th>
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<th>Female</th>
<th>Unknown</th>
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</thead>
<tbody>
<tr>
<td>1995</td>
<td>567</td>
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<td>526</td>
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<tr>
<td>1994</td>
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<td>461</td>
<td>401</td>
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<td>287</td>
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</tr>
<tr>
<td>1986</td>
<td>386</td>
<td>289</td>
<td>200</td>
</tr>
</tbody>
</table>

### Ph.D.s Granted to U.S. Citizens

<table>
<thead>
<tr>
<th>Year</th>
<th>Male</th>
<th>Female</th>
<th>Unknown</th>
</tr>
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<tbody>
<tr>
<td>1995</td>
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<td>1993</td>
<td>349</td>
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<td>1992</td>
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</tr>
<tr>
<td>1986</td>
<td>386</td>
<td>289</td>
<td>200</td>
</tr>
</tbody>
</table>
The Reference section of the Notices is intended to provide the reader with frequently sought information in an easily accessible manner. New information is printed as it becomes available and is referenced after the first printing. As soon as information is updated or otherwise changed, it will be noted in this section.

Upcoming Deadlines

December 4, 1996: Target date for proposals for support from fiscal year 1997 funds from the Division of Mathematical Sciences (DMS) of the National Science Foundation. (Computational Mathematics) dms-dm@nsf.gov; (Analysis) dms.cm@nsf.gov; (Mathematical Biology) dms-mbio@nsf.gov.


January 15, April 15, August 15, 1997: Deadline for applications for NRC Resident, Cooperative, and Postdoctoral Research Associateship Programs. Information and application materials: e-mail: rap@nas.edu; World Wide Web http://www.nas.edu/rap/welcome.html.

January 30, 1997: Nominations for the D. Ray Fulkerson Prize in Discrete Mathematics. Eva Tardos, chair of the Fulkerson Prize Committee, Department of Computer Science, Cornell University, Ithaca, NY 14850; e-mail: eva@cs.cornell.edu.

Where to Find It

A brief index to information which appears in this and previous issues of the Notices.

Advanced Research Projects Agency, program officers
October 1996, p. 1198

Air Force Office of Scientific Research, program officers
October 1996, p. 1198

AMS e-mail addresses
October 1996, p. 1166

AMS Ethical Guidelines
June 1995, p. 694

AMS Officers and Committee Members
September 1996, p. 1009

AMS Proposed Amendments to the Bylaws
June 1995, p. 692; September 1995, p. 1022

Army Research Office, program officers
October 1996, p. 1198

Board on Mathematical Sciences
May 1996, p. 581

Board on Mathematical Sciences Staff
April 1996, p. 460

Department of Energy Mathematics Program, program officers
October 1996, p. 1199

JPBM Public Information Office (new address)
December 1995, p. 1563

Mathematical and Physical Sciences (MPS) Advisory Board
November 1996, p. 1380

April 1996, p. 460

Mathematics Education Program Officers at NRC
October 1995, p. 1161

Mathematics Research Institutes Contact Information: The Fields Institute, The Geometry Center, Institute for Advanced Study (IAS), Institute for Mathematics and its Applications (IMA), Mathematical Sciences Institute (MSI), Mathematical Sciences Research Institute (MSRI), Center for Discrete Mathematics and Theoretical Computer Science (DIMACS), Centre de Recherches Mathématiques (CRM) April 1996, p. 461

National Science Board of NSF, members
November 1996, p. 1380

NSF, mathematical scientists on the Advisory Committee for the Mathematical and Physical Sciences Directorate
April 1996, p. 460

NSF, program officers in math
October 1996, p. 1200

NSF, program officers in math education
October 1996, p. 1199

National Security Agency, program officers
October 1996, p. 1199

Office of Naval Research, program officers
October 1996, p. 1199

December 1996

2-5 Differential Equations and Applications, St. Petersburg State Technical University, St. Petersburg, Russia. (Sept. 1996, p. 1053)


4-6 DIMACS Workshop on Network Threats, DIMACS Center, Rutgers University, Piscataway, New Jersey.

Sponsor: DIMACS.

Organizers: S. Bellovin, P. Neumann, R. Wright.

Contacts: R. Wright, AT&T Research, rwright@research.att.com; tel: 908-582-5484.

Local Arrangements: P. Pravato, DIMACS Center, pravato@dimacs.rutgers.edu; tel: 908-445-5929.

WWW Information: http://dimacs.rutgers.edu/Workshops/index.html.

Short Description: A photocopied booklet of abstracts and/or papers will be handed out at the workshop. Authors will be invited to submit complete papers for publication in a DIMACS volume.

4-6 8th Nordic Workshop on Programming Theory, Oslo, Norway. (Sept. 1996, p. 1054)


9-20 Workshop on Time-reversal Symmetry in Dynamical Systems, Mathematics Research Center, University of Warwick, Coventry CV4 7AL, United Kingdom. (Aug. 1996, p. 883)


16-18 Mathematics and its Applications in Engineering and Industry, University of Roorkee, Roorkee, India. (Sept. 1996, p. 1054)

16-19 International Conference on Functional Analysis with Applications, Aligarh Muslim University, Aligarh, India. (July 1996, p. 793)

17-20 Modern Banach Space Theory, Kent State University, Kent, Ohio. (Sept. 1996, p. 1054)

*30-January 6 Singularities and Control Theory, Technion, Haifa, Israel.

Program Committee: V. Arnold (Moscow, Paris), J. P. Gauthier (Rouen), B. Jakubczyk (Warsaw), L. Kupka (Paris, Toronto), M. Zhitomirskii (Haifa).

Local Organizer: M. Zhitomirskii (Haifa).

Invited Speakers: A. Agrachev (Moscow), V. Arnold (Moscow, Paris), Z. Artstein (Rehovot), B. Bonnard (Dijon), R. Bryant (Durham), J. P. Dufour (Montpellier), E. Falbel (Paris), J. P. Gauthier (Rouen), B. Jakubczyk (Warsaw), L. Kupka (Paris, Toronto), R. Montgomery (Santa Cruz), P. Mormul (Warsaw), F. Pelletier (Chambery), W. Respondek (Rouen, Warsaw), R. Roussarie (Dijon), H. J. Sussmann (Rutgers), M. A. Teixeira (Campinas), A. Vershik (St. Petersburg).

Conference Fee: US $50 payable by November 30, 1996.

Information: For further information and applications please contact M. Zhitomirskii, Department of Mathematics, Technion, 32000 Haifa, Israel; e-mail: mzh@technion.ac.il.

This section contains announcements of meetings and conferences of interest to some segment of the mathematical public, including ad hoc, local, or regional meetings, and symposia devoted to specialized topics, as well as announcements of regularly scheduled meetings of national or international mathematical organizations. A complete listing of meetings of the Society, and of meetings sponsored by the Society, will be found on the first page of the Meetings and Conferences section.

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 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 every third 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. Asterisks (*) mark those announcements containing new or revised information.

In general, announcements of meetings and conferences held in North America carry only the 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. In any case, if there is any application deadline with respect to participation in the meeting, this fact should be noted. All communications on meetings and conferences in the mathematical sciences should be sent to the Editor of the Notices in care of the American Mathematical Society in Providence or electronically to notices@math.ams.org.

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.

The complete listing of the Mathematics Calendar will be published only in the September issue of the Notices. The March, June, and December issues will include, along with new announcements, references to any previously announced meetings and conferences occurring within the twelve-month period following the month of those issues. New information about meetings and conferences that will occur later than the twelve-month period will be announced once in full and will not be repeated until the date of the conference or meeting falls within the twelve-month period.

The Mathematics Calendar, as well as Meetings and Conferences of the AMS, is now available electronically through e-MATH on the World Wide Web. To access e-MATH, use the URL: http://e-math.ams.org/ (or http://www.ams.org/). (For those with VT100-type terminals or for those without WWW browsing software, connect to e-MATH via Telnet (telnet e-math.ams.org; login and password e-math) and use the lynx option from the main menu.)

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Information: For details of the program, see the November 1, 1996, issue of Science, or contact W. Page, e-mail: wpage@uwyum.edu.


27-March 1 Symposium on Theoretical Aspects of Computer Science, Univer­sitet Luebeck, Institut fur Theoretische Informatik, Luebeck, Germany. (Oct. 1996, p. 1203)

March 1997

10-12 Workshop on Scientific Computing 97, Hong Kong. (Oct. 1996, p. 1203)


Program: This workshop will bring together experts in applications, numerical methods, and software development for SAMR. Applications include compressible flows, cosmology, and electronic structures arising in local spin-density calculations.


Information: For more information, contact the Institute for Mathematics and Its Applications, University of Minnesota, 206 Church St SE, Minneapolis, MN 55455.


*21–22 Southeastern Section, University of Memphis, Memphis, Tennessee. Information: R. Cascella, AMS, P.O. Box 6887, Providence, RI 02940; e-mail: rgc@math.ams.org.


23–29 Georgia Tech-UAB International Conference on Differential Equations and Mathematical Physics, Georgia Institute of Technology, Atlanta, Georgia. (Oct. 1996, p. 1204)


*28–30 Sixth Annual Meeting of the Boise Extravaganza in Set Theory (BEST 6), Department of Mathematics, Boise State University, Boise, Idaho.

Invited Speakers: D. H. Fremlin (Essex), M. Magidor (Jerusalem), A. Kanamori (Boston) and J. Roitman (Lawrence, Kansas). Information: Persons interested in giving a talk or attending should contact either of the organizers, T. Bartoszynski or M. Scheepers, at tomek@math.idbsu.edu or marion@cantor.idbsu.edu respectively.

April 1997

1–3 IMACS Seminar on Monte Carlo Methods, Brussels, Belgium. (July 1996, p. 793)


Information: The meeting will start at 1 p.m. on April 4. Limited support has been obtained from the Midwest PDE Seminar, NSF, IMA, and the School of Mathematics at the University of Minnesota. Limited partial support for graduate students (not to exceed $100) will be available. Blocks of rooms have been set aside at the following hotels: (Reservations must be made before March 4, 1997) Days Inn University, Rate $60.48, phone 1-800-375-9900; Holiday Inn Metrodome, Rate $81.76, phone 1-800-448-3663; Radisson Hotel Metrodome, Rate $100, phone 1-800-822-6757. On Saturday April 5 there will be a banquet honoring Professor Fabs at the Campus Club, West Wing. The cost will be $22 per person. Please inform M. Safonov (safonov@math.umn.edu) of your intention to participate in the meeting, and/or the banquet, before March 4, 1997.


11–13 Southwest Dynamical Systems Conference, University of North Texas, Denton, Texas. (Nov. 1996, p. 1383)

*12–13 Eastern Section, University of Maryland, College Park, Maryland. Information: R. Cascella, AMS, P.O. Box 6887, Providence, RI 02940; e-mail: rgc@math.ams.org.


*19–20 AMS Western Sectional Meeting, Oregon State University, Corvallis, Oregon. Information: For more information, contact W. Drady, wad@ams.org.

*19–20 Twentieth Annual Texas Partial Differential Equations Conference, University of North Texas, Denton, Texas. Program: This is the Twentieth Annual Texas Partial Differential Equations Conference. In keeping with tradition, the meeting will have no principal speakers, and all talks will be 20 minutes in length. A party is planned for Saturday night.

Call for Papers: Those wishing to speak at the meeting should submit title and short abstract (preferably by electronic mail) by April 5, 1997.

Information: Send abstracts and requests for information to J. Jia, Mathematics Dept., University of North Texas, Denton, TX 76203-1116; tel: 817-565-2155; fax: 817-565-4805; e-mail: jia@math.uin. unt.edu.


Focus: The focus of the symposium will be on the frontiers of real-time, interactive 3D computer graphics and multimedia. The symposium will consist of formal paper sessions and hands-on demonstrations where research groups and vendors will demonstrate the state-of-the-art in the field.

Topics: The topics of interest for technical sessions and demonstrations include: navigating, working and playing in complex, real-time environments, including virtual worlds, Web-based systems, and visualization systems; high-performance 3D graphics architectures, hardware, and software for interacting with virtual worlds and teleoperation systems; innovative human–machine interface paradigms for creating and navigating in complex, real-time graphics environments, including virtual worlds, hypermedia, and visualization systems; novel sensory I/O devices for "seeing, hearing and feeling" in the virtual world; perceptual and psychological issues regarding multimodal interaction and operation in complex virtual spaces; interactive model building tools for shaping, building or sculpting of objects, and the interactive assembly and manipulation of objects or parts; languages or APIs for specifying geometry and behaviors for interactive and network-based applications; algorithms for animating complex reactive characters; authoring tools for constructing reactive models; interactive simulations distributed over local and long-haul networks; software for representing, designing, visualizing and interacting with complex geometry, structure and behavior.

Information: For more information, see: http://www.research.microsoft.com/research_graphics/cohen/cal2.htm.


28–May 2 International Conference on Random Dynamical Systems, University of Bremen, Germany. (Nov. 1996, p. 1383)
Mathematics Calendar

December 1996

May 1997

1-6 AMS-SIAM Summer Seminar in Applied Mathematics: Neuroscience and Dynamical Systems in Neuroscience, Arizona State University, Tempe, Arizona.


Goal: The scope of brain research has moved well beyond the confines of one discipline. Major advances have been made toward understanding better the brain and how its parts work by medical and life scientists, engineers, computer scientists, and mathematicians. Mathematical and computer sciences and engineering have played important roles in these studies up to now, and they will contribute significantly in the future. The proposed meeting is timely in helping to reduce barriers to cross-disciplinary work in understanding the brain. It is important to have meetings that bring together mathematical scientists with engineers, computer scientists, and medical/life scientists working to understand the organization and function of the brain. Particularly important are integrated models of parts of the brain, engineering of neuromechanical interfaces that can be used in prosthetics, and general mathematical studies of large networks to guide and suggest experiments.

In addition there is a need to interface neurophysiologists and computational neuroscientists. Many computational models of the brain developed in the past have limited practical relevance because they do not integrate biological knowledge into the computational structure. An important goal of this meeting is to initiate and facilitate such interfaces.

Funding: It is expected that the conference will be supported by funds from federal and other agencies. A special invitation is extended to junior scientists. To request an invitation and to apply for support funds, please provide the following information to DLS@AMS.ORG, or send to AMS-SIAM Summer Seminar, c/o AMS, PO Box 6857, Providence, RI 02940, NO LATER THAN FEB. 1, 1997: Full name, mailing address, telephone and fax numbers, e-mail address, scientific background relevant to the conference, and whether or not financial assistance is requested (please indicate a requested dollar amount).

Information: Invitations including specific offers of support, information on housing, and program developments to date will be sent in March 1997.

2-4 8th Int'l Conf on Rewriting Techniques and Applications (RTA-97), Sitges, Barcelona, Spain. (Nov. 1996, p. 1384)

2-6 SIAM Congress, University of Delaware, Newark, Delaware. (Sept. 1996, p. 1204)


Topics: The topics of the conference cover all aspects related to the application of computers to the analysis, design and management of water resources. Physical and mathematical modelling, numerical and experimental techniques, engineering applications, and software developments are all included.

Call for Papers: A one-page abstract is due at the conference secretariat no later than November 30, 1996.

Organizers: The conference is organized by The Ministry of Hydraulic and Electric Resources of Lebanon in collaboration with the Lebanese American University (Byblos, Lebanon), The Wessex Institute of Technology, The University of Delaware, and The Johns Hopkins University.

Information: The conference secretariat is at WIT: Wessex Institute of Technology, Ashurst Lodge, Ashurst, Southampton, SO47AA, UK. Additional information can be obtained from cm1@rl.ac.uk or yassem@beirut.lan.uwb. 1b. The home-page for the conference, allowing for the electronic submission of abstracts, is at http://venus.co.jhu.edu/cmwr/.


16-20 Third European Conference on Elliptic and Parabolic Problems, Ponte-Mousson, France.

Organizers: A. Amann (Zürich), C. Bandle (Basel), M. Chipot (Zürich), F. Conrad (Nancy), and I. Shafrir (Haifa).

Information: For more information, contact pantomou@math.unizh.ch.

19-22 The Second Asian Technology Conference in Mathematics (ATCM-2), Universiti Sains Malaysia, Penang, Malaysia. (Sept. 1996, p. 1057)


Aim: The organizers intend to bring together researchers in molecular biology, statistics, probability theory, computer science, and computational biology to facilitate this important interdisciplinary work.


Organizing Committee: F. Sellier-Moiseiwitsch, (University of North Carolina), chair.

Information: For more information see http://www.ams.org/committee/meetings/src.html or contact at the AMS, R. G. Cascella, SRC Conference Coordinator at 800-321-4267.

23-25 Third International Conference on Coastal Engineering (COASTAL 97), La Coruna, Spain.

Organizer: Wessex Institute of Technology and Universidad de La Coruna, Spain.

Information: Contact S. Owen, COASTAL 97 Conference Secretariat, Wessex Institute of Technology, Ashurst Lodge, Ashurst, Southampton SO40 7AA, UK; tel: 44-1703-293-223; fax:44-1703-292-833; e-mail: sue@wessex.ac.uk. Or go to Web page http://www.wessex.ac.uk/ and click on the conference information link.


* 26–28 Joint Meeting of the AMS, London Mathematical Society (LMS) and the South African Mathematical Society, University of Pretoria, Republic of South Africa.

Information: Contact W. Drady, wsd@ams.org.

* 29–July 2 Twelfth Annual IEEE Symposium on Logic in Computer Science, Warsaw, Poland.

Sponsor: The symposium is sponsored by the IEEE Technical Committee on Mathematical Foundations of Computing in cooperation with the Association for Symbolic Logic, the European Association for Theoretical Computer Science, and the Association for Computing Machinery. The symposium is hosted by Warsaw University, Poland.

Call for Papers: The LICS Symposium aims to attract original papers of high quality on theoretical and practical topics in computer science that relate to logic in a broad sense, including algebraic, categorical and topological approaches.

Paper submission: Send 12 copies of an extended abstract (not a full paper) to the program chair to be received by December 11, 1996. This deadline is firm; late submissions will not be considered. Authors without access to copiers may submit a single copy. Authors will be notified of acceptance or rejection by February 19, 1997. Accepted papers in a specified format for the proceedings will be due by April 9, 1997.

The first page of the extended abstract should include the title of the paper, names and affiliations of authors, a brief synopsis, and the contact author's name, address, phone number, fax number, and e-mail address, if available.

The extended abstract may not exceed 10 typed pages in no less than 11-point font. It must be in English and provide sufficient detail to allow the program committee to assess the merits of the paper. It should begin with a succinct statement of the issues, a summary of the main results, and a brief explanation of their significance and relevance to the conference, all phrased for the nonspecialist. References and comparisons with related work should be included. Technical development directed to the specialist should follow. Submissions departing significantly from these guidelines risk rejection.

The results must be unpublished and not submitted for publication elsewhere, including the proceedings of other symposia or workshops. All authors of accepted papers will be expected to sign copyright release forms. One author of each accepted paper will be expected to present the paper at the conference.

Student Paper Award: The Kleene Award for Best Student Paper (an award of $500), in honor of the late S. C. Kleene, will be given to the best paper, as judged by the program committee, written solely by one or more students. A submission is eligible if all authors are full-time students at the time of submission. This should be indicated in the submission letter. The program committee may decline to make the award or may split it among several papers.

Information: L. Libkin, Bell Laboratories/Lucent Technologies, 600-700 Mountain Avenue, Murray Hill, NJ 07974; e-mail: libkin@research.bell-labs.com.


Aim: Perhaps the most central idea of statistical science is the assessment of dependencies among a set of statistical variables. The familiar concepts of correlation, regression, and prediction are manifestations of this idea in various forms, and many, if not most, aspects of causal relationships ultimately rest on representations of multivariate dependence.

Organizing Committee: D. Madigan (University of Washington), co-chair; M. D. Perlman (University of Washington), co-chair.

Information: For more information, see Website http://www.ams.org/committee/meetings/src.html or contact R. Cascella, AMS Conference Coordinator at rgc@ams.org.


Focus: The topic of this conference is to discuss recent developments in experimental designs for biomedical, industrial, and other applications. The broad emphasis will be on applications. Each speaker will exhibit a specific application, and mathematics will be applications-driven. The goal is to bridge the gap between theory and practice and to introduce statisticians working on causal relationships ultimately rest on representations of multivariate dependence.

Organizing Committee: T. O'Brien (University of Georgia), co-chair; W. Rosenberger (University of Maryland), co-chair.

Information: For more information, see Website http://www.ams.org/committee/meetings/src.html or contact R. Cascella, AMS Conference Coordinator at rgc@ams.org.

* 29–July 4 LICS'97: The Second International Mathematica Symposium, Rovaniemi Institute of Technology, Rovaniemi, Finland.

Topics: Applications of Mathematica computer algebra environment in mathematics and computer science, physical and biological sciences, and the disciplines of economics, education and engineering.

IMS '97 follows the successful symposium in Southampton, England, in July 1995 where more than 60 papers were reviewed and over 100 delegates from 17 countries attended.

Objectives: The International Mathematica Symposium (IMS) was conceived to hold a series of conferences devoted to applications of Mathematica computer algebra system in different fields of science. The IMS intends to keep pace with Mathematica as its influence extends in every field of computing in research, education, industry and business.

The conference will provide a forum for users from diverse fields to present original papers covering their Mathematica-based research, and to learn about current developments and uses of advanced scientific computing.

Besides paper presentations and a variety of keynote lectures, the symposium will include several tutorials covering different fields, discussion forums, poster presentations and software demonstrations.

Call for Papers: Deadline for abstracts: December 13, 1996.


Information: V. Keranen, Rovaniemi Institute of Technology, Jokivaara 11, FIN-96530 Rovaniemi, Finland; e-mail: veikko.keranen@ramk.fi; http://algebra.rotol.rank.fi.

* 29–July 19 IAS/Park City Mathematics Institute Summer Session. The Inn at Prospector Square, Park City, Utah.

Program: The IAS/Park City Mathematics Institute (PCMI) is a flagship mathematics program built on the premise that interaction among researchers, graduate students, undergraduates, and high school teachers is essential to the optimal functioning of the mathematical enterprise.

Program Organizers: Y. Eliashberg (Stanford Univ.), and L. Traynor (Bryn Mawr College).

Graduate Summer School Lecturers: A. Givental (Univ. of California, Berkeley), H. Hofer (Eidgen Tech Hochschule, Zurich), L. Jeffrey (McGill Univ.) R. MacPherson (Institute for Advanced Study), J. Marsden (California Institute of Technology), D. McDuff (SUNY, Stony Brook), D. Salamon (Univ. of Warwick), C. Taubes (Harvard Univ.).

Undergraduate Program Lecturer: R. Bryant (Duke University).

High School Teacher Program Lecturers: N. Fisher (Univ. of Illinois, Chicago), C. Hays (McCallum High School, Texas), J. King (Univ. of Washington), and J. Polking (Rice Univ.).

Funding: All applicants are invited to apply for financial support. Application deadline is February 15, 1997. PCMI is sponsored by the Institute for Advanced Study, Princeton, New Jersey, and receives major funding from the National Science Foundation.
July 1997


Focus: Representation theory of Lie groups has its roots in the work of Lie, Killing, Frobenius, and Cartan in the late nineteenth century. In the last 50 years it has been understood to deal with representation of groups such as real Lie groups, p-adic groups, finite Chevalley groups, as well as finite and infinite dimensional Lie algebras. By its nature it uses techniques from many fields: analysis, algebra, geometry and algebraic geometry; and finds application in areas such as harmonic analysis, combinatorics, number theory, and mathematical physics. This conference plans to cover a few of the areas that have seen recent development, and to put this progress in perspective.

Organizing Committee: J. Adams (Univ. of Maryland), co-chair; D. Barbasch (Cornell Univ.), co-chair; A. Moy (Univ. of Maryland), co-chair.

Information: For more information see Web site http://www.ams.org/committee/meetings/src.html or contact R. Cascella, AMS Conference Coordinator at rgb@ams.org.

6–11 International Conference on the Theory of Radicals and Rings, University of Port Elizabeth, South Africa. (May 1996, p. 587)

"7–9 Twelfth International Conference on Artificial Intelligence in Engineering (AIENG 97), Capri, Italy.

Sponsor: Sponsored and organized by Wessex Institute of Technology and University of Naples "Federico II".

Purpose: The purpose of the conference is to provide an international forum for the presentation of work on the State of the Art in Applications of Artificial Intelligence to Engineering problems. It also aims to encourage and enhance the development of this most important area of research. It will be chaired by R. A. Adey (Wessex Institute of Technology); G. Rzevski (Open Univ.); and R. Teti (Univ. of Naples).

Call for Papers: Papers are invited on the topics given below, and others which fall within the general scope of the conference. Submit four copies of draft papers as soon as possible and no later than November 1, 1996, to C. Day, AIENG 97 Conference Secretariat, Wessex Institute of Technology, Ashurst Lodge, Ashurst, Southampton, UK SO40 7AA; tel: 44-1703-293-223; fax 44-1703-292-853; e-mail: cday@wessex.ac.uk. Papers should be no longer than 20 pages, including figures, diagrams and tables. Submissions should identify the subject area of the paper based upon the conference themes. Authors must be able to attend the conference to present their papers. Final acceptance will be based upon a satisfactory final paper which must be received by February 28, 1997. Particular attention will be paid to description of implementation and discussion of the outcome, whatever it may be, success or failure.

Topics: Papers are invited on the following topics: integration of design and manufacturing, concurrent engineering, intelligent vehicles, robotics and control, planning and scheduling, process engineering and control, surveillance systems, fault diagnosis, reliability, multimedia & man/machine communication, evaluation & selection, analysis & simulation, AI tools, implementation & integration strategies, and modelling uncertainties. Acceptable application domains for papers include: aeronautics & space, agriculture, automobile engineering, biomedical engineering, chemical engineering, civil engineering, the electronics industry, energy, environmental engineering, manufacturing, and transportation.

Information: For more information, contact C. Day, AIENG 97 Conference Secretariat, Wessex Institute of Technology, Ashurst Lodge, Ashurst, Southampton, UK SO40 7AA; tel: 44-1703-293-223; fax 44-1703-292-853; e-mail: cday@wessex.ac.uk. Or go to Webpage http://www.wessex.ac.uk and click on the conference information link.


Conference Themes: Numerical linear algebra, numerical methods for PDEs, and numerical simulations and applications.

Information: http://math.uwyo.edu/~imacs/imacs.html; e-mail: imacs97@schwarz.uwyo.edu; anonymous FTP: math.uwyo.edu (go to pub/IMACS/). Or J. Wang, e-mail: jpsang@math.tamu.edu; tel: 409-845-1204; fax: 409-862-4190.

13–19 Xllth International Congress of Mathematical Physics, Brisbane, Australia. (Mar. 1996, p. 351)


Focus: Algebraic K-theory is a subject which has undergone a rapid change in direction during the last five years. However, there are still some important common themes which pervade the whole subject. We hope to bring these new developments together, presenting the subject as a whole to the next generation: 1. algebraic K-theory, arithmetic and algebraic geometry; 2. K-theory and topology; 3. K-theory and operator algebras.

Organizing Committee: E. L. Green (Virginia Polytechnic Institute), co-chair; B. Huisgen-Zimmermann (Univ. of California), co-chair.

Information: For more information see Web site http://www.ams.org/committee/meetings/src.html or contact R. Cascella, AMS Conference Coordinator at rgb@ams.org.

14–18 9th International Conference on Formal Power Series and Algebraic Combinatorics (FPSAC97), University of Vienna, Vienna, Austria. (Nov. 1996, p. 1384)

14–18 SIAM 45th Anniversary Meeting, Stanford University, Stanford, California. (June 1996, p. 702)


Topics: The following three topics will be covered: (1) interactions between representation theory and algebraic geometry; (2) homological methods, including Hochschild cohomology, cyclic cohomology, functorial finiteness of categories and Koszul algebras; (3) applications of representation theory to the study of quantum groups.

Organizing Committee: E. Green (Virginia Polytechnic Institute), co-chair; B. Huisgen-Zimmermann (Univ. of California), co-chair.

Information: For more information see Web site http://www.ams.org/committee/meetings/src.html or contact R. Cascella, AMS Conference Coordinator at rgb@ams.org.


Topics: The topics to be included are broadly classified as follows: A) Galois groups of coverings over finite fields. This includes the inverse Galois problems over finite fields, Abhyankar conjectures, exceptional coverings, applications of the classification of finite simple groups in finite fields; B) L-functions and modular curves over finite fields. This includes various consequences of Deligne-Weil estimate for character sums, Dworsky's P-adic approach
KGC'97 is the fifth in a series of biennial colloquia on logic, theoretical computer science, and philosophy of mathematics.

The scientific program will consist of invited lectures and short contributions, which will be selected from the submitted papers. Accepted papers will be published in a proceedings volume.

**Scope:** The colloquium is intended for logicians and computer scientists interested in the proof-theoretic and algorithmic aspects of logic. Topics include, but are not limited to: proof theory, automated theorem proving, unification theory, complexity theory, logics of programs, non-standard logics for theoretical computer science and AI, recursion theory, logic programming, lambda-calculus.

**Paper Submission:** Authors are kindly requested to submit 3 copies of a full draft paper (in English) not exceeding 12 pages no later than January 31, 1997 to the program committee chairman A. Leitsch, Technische Universität Wien, Institut f. Computergeschen 182.2 Resselgasse 3/1 A-1040 Vienna, Austria.

Authors should submit their papers to:

**Organizing Committee:**
M. Fried (Univ. of California), chair.

**Information:** For more information, please contact M. Cascella, rgc@ams.org.

The following new announcements will not be repeated until the criteria in the next to the last paragraph at the bottom of the first page of this section are met.
New Publications
Offered by the AMS

AMS/IP Studies in Advanced Mathematics

Nonlinear Evolutionary Partial Differential Equations
Xia-Xi Ding and Tai-Ping Liu, Editors

This volume contains the proceedings from the International Conference on Nonlinear Evolutionary Partial Differential Equations held in Beijing in June 1993. The topic for the conference was selected because of its importance and for its mathematical significance. Discussion topics include conservation laws, dispersion waves, Einstein's theory of gravitation, reaction-diffusion equations, the Navier-Stokes equations, and more. New results were presented and are featured in this volume.

Titles in this series are co-published with International Press, Cambridge, MA.

Contents
L. Fagui, Cauchy problem of nonsentropic gas dynamics equations; L. Guo-fu, Existence and uniqueness of global solution for certain degenerate reaction-diffusion systems; T. Makino, On the spherically symmetric motion of self-gravitating isentropic gas surrounding a solid ball; Y. Morita, Dynamics on the attractor for reaction-diffusion systems in higher space dimensions; Q. Chaochun and C. Fengxin, Finite dimensionality of attractors of magnetic flow equation; S. K. Ng, On a complex dynamical and dissipative structure of partial differential equations; M.-X. Wang, Global behavior of positive solutions to quasilinear parabolic equation with nonlinear boundary absorption; W. Weike, Interaction of three progressing waves with different singularities for semilinear wave equations; W. Xuefeng, The bidimensional Stefan problem with nonlinear convection; W. Yuanming and G. Ping, Some problems on semiconductor equations; W. Yong-hui and W. Ming-Xin, Existence and nonexistence of global solution of nonlinear parabolic equation with nonlinear boundary condition; S. Yang, Spirals for Riemann problems in multipieces for 2-D Euler equations by using MmB schemes; Y. Wanli, Global existence of solutions for the reaction-diffusion systems which don't satisfy a zero sum condition; Z. Yang and G. Chen, Nonexistence of global solutions to a class of generalized improved Boussinesq equations; N. Yoshida, Zeros of solutions of hyperbolic equations with functional arguments; H. Zhao, C. Zhu, and Z. Yu, Existence and convergence of solutions to higher order generalized KdV-Burgers equations; J. J. Zhao and D. Hoff, Convergence and error bound analysis of a finite-difference scheme for the one-dimensional Navier-Stokes equations; Y.-S. Zheng, Vacuum problem for the damped p-system.

December 1996, 637 pages (soft cover), ISBN 0-8218-0661-0, LC 96-45112, ISSN 0160-7642 1991 Mathematics Subject Classification: 05-XX

To order, please specify CBMS/92N

Contemporary Mathematics

Geometry and Nature
Hanna Nencka and Jean-Pierre Bourguignon, Editors

This volume is the outgrowth of a conference devoted to William K. Clifford entitled, "New Trends in Geometrical and Topological Methods", which was held at the University of Madeira in July and August 1995. The aim of the conference was to bring together active workers in fields linked to Clifford's work and to foster the exchange of ideas between mathematicians and theoretical physicists. Divided into 6 one-day sessions, each session was devoted to a specific aspect of Clifford's work.

This volume is an attempt to bring the Clifford legacy in a new perspective to a larger community of mathematicians and physicists. New concepts, ideas, and results stemming from Clifford's work are discussed. Containing papers presented or submitted to the conference, each article is self-contained.

Contents
Extremal Riemann Surfaces
J. R. Quine and Peter Sarnak, Editors
Volume 201

This volume is an outgrowth of the AMS Special Session on Extremal Riemann Surfaces held at the Joint Mathematics Meeting in San Francisco, January 1995. The book deals with a variety of extremal problems related to Riemann surfaces. Some papers deal with the identification of surfaces with longest systole (element of shortest nonzero length) for the length spectrum and the Jacobian. Parallels are drawn to classical questions involving extremal lattices. Other papers deal with maximizing or minimizing functions defined by the spectrum such as the heat kernel, the zeta function, and the determinant of the Laplacian, some from the point of view of identifying an extremal metric.

There are discussions of Hurwitz surfaces and surfaces with large cyclic groups of automorphisms. Also discussed are surfaces which are natural candidates for solving extremal problems such as triangular, modular, and arithmetic surfaces, and curves in various group theoretically defined curve families. Other allied topics are theta identities, quadratic periods of Abelian differentials, Teichmüller disks, binary quadratic forms, and spectral asymptotics of degenerating hyperbolic three manifolds.

Features:
- Includes papers by some of the foremost experts on Riemann surfaces.
- Outlines interesting connections between Riemann surfaces and parallel fields.
- Follows up on investigations of Sarnak concerning connections between the theory of extreme lattices and Jacobians of Riemann surfaces.
- Contains papers on a variety of topics relating to Riemann surfaces.

Contents
P. Sarnak, Extremal geometries; P. S. Schaller, Extremal Riemann surfaces with a large number of systoles; N. Näätänen and T. Kuusalo, On arithmetic genus 2 subgroups of triangle groups; M. Bernstein and N. J. A. Sloane, Some lattices obtained from Riemann surfaces; J. R. Quine, Jacobian of the Picard curve; R. E. Rodriguez and V. González-Aguilera, Fermat's quartic curve, Klein's curve, and the tetrahedron; J. F. X. Ries, The splitting of some Jacobl varieties using their automorphism groups; R. S. Kulkarni, Riemann surfaces admitting large automorphism groups; R. Brooks, H. M. Farkas, and I. Kra, Number theory, theta identities, and modular curves; R. Brooks and Y. Kopeliovich, Uniformization of some quotients of modular curves; C. J. Earle and F. P. Gardiner, Teichmüller disks and Veech's ℋ-structures; J. Dodziuk and J. Jorgenson, On the geometry and spectral asymptotics of degenerating hyperbolic three manifolds; D. Curtis and M. Treiloff, Differential equations for the quadratic periods of abelian differentials; C. Morpurgo, Zeta functions on $S^2$; A. Baernstein II, A minimum problem for heat kernels of flat tori.

To order, please specify CONM-201N.
and S. Linton, Constructive recognition of a black box group isomorphic to $\text{GL}(n, 2)$. B. Eck, Special presentations for finite soluble groups and computing (pre-)Frattini subgroups; T. Grüner, R. Laue and M. Meringer, Algorithms for group actions applied to graph generation; J. S. Leon, Partitions, refinements, and permutation group computation; E. H. Lo, A polycyclic quotient algorithm; E. M. Luks and A. Seress, Computing the Fitting subgroup and solvable radical for small-base permutation groups in nearly linear time; D. K. Maslen and D. M. Rockmore, Generalized FFT's—A survey of some recent results; T. Miyazaki, The complexity of McKay's canonical labeling algorithm; P. Morje, On nearly linear time algorithms for Sylow subgroups of small base permutation groups; A. C. Niemeyer and C. E. Praeger, Implementing a recognition algorithm for classical groups; G. Ostheimer, Algorithms for polycyclic-by-finite matrix groups; L. Pyber, Asymptotic results for simple groups and some applications; D. M. Rockmore, Some applications of generalized FFT's; M. Tseltlman, Computing permutation representations for matrix groups in parallel environments.

January 1997, approximately 382 pages (hardcover), ISBN 0-8218-0516-9, LC 96-43191, ISSN 1032-1798
1991 Mathematics Subject Classification: 20B40, 20C40
Individual member $47, List $79, Institutional member $63
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**Fields Institute Communications**

**Free Probability Theory**

Dan-Virgil Voiculescu, Editor

**Volume 12**

Free probability theory is a highly noncommutative probability theory, with independence based on free products instead of tensor products. The theory models random matrices in the large $N$ limit and operator algebra free products. It has led to a surge of new results on the von Neumann algebras of free groups.

This is a volume of papers from a workshop on Random Matrices and Operator Algebra Free Products, held at The Fields Institute for Research in the Mathematical Sciences in March 1995. Over the last few years, there has been much progress on the operator algebra and noncommutative probability sides of the subject. New links with the physics of masterfields and the combinatorics of noncrossing partitions have emerged. Moreover there is a growing free entropy theory. The idea of this workshop was to bring together people working in all these directions and from an even broader free products area where future developments might lead.

**Contents**


December 1996, 312 pages (hardcover), ISBN 0-8218-0675-0, LC 96-46680, ISSN 1069-5265
1991 Mathematics Subject Classification: 46L50, 46L35, 46L10, 47B80, 05A18, 81Q99
Individual member $47, List $79, Institutional member $63
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**Operator Algebras and Their Applications**

Peter A. Fillmore and James A. Mingo, Editors

Volume 13

The study of operator algebras, which grew out of von Neumann's work in the 1920s and the 1930s on modelling quantum mechanics, has in recent years experienced tremendous growth and vitality. This growth has resulted in significant applications in other areas—both within and outside mathematics. The field was a natural candidate for a 1994–1995 program year in Operator Algebras and Applications held at The Fields Institute for Research in the Mathematical Sciences.

This volume contains a selection of papers that arose from the seminars and workshops of the program. Topics covered include the classification of amenable $C^*$-algebras, the Baum-Connes conjecture, $\mathbb{C}^n$ semigroups, subfactors, $E$-theory, quantum groups, and the solution to a long-standing problem in operator theory: Can almost commuting self-adjoint matrices be approximated by commuting self-adjoint matrices?

**Contents**

Fields Institute Monographs

Lifting Solutions to Perturbing Problems in C*-Algebras
Terry A. Loring
Volume 8

The nature of C*-algebras is such that one cannot study perturbation without also studying the theory of lifting and the theory of extensions. Approximation questions involving representations of relations in matrices and C*-algebras are the central focus of this volume. A variety of approximation techniques are unified by translating them into lifting problems: from classical questions about transitivity of algebras of operators on Hilbert spaces to recent results in linear algebra. One chapter is devoted to Lin's theorem on approximating almost normal matrices by normal matrices.

The techniques of universal algebra are applied to the category of C*-algebras. An important difference, central to this book, is that one can consider approximate representations of relations and approximately commuting diagrams. Moreover, the highly algebraic approach does not exclude applications to very geometric C*-algebras.

K-theory is avoided, but universal properties and stability properties of specific C*-algebras that have applications to K-theory are considered. Index theory arises naturally, and very concretely, as an obstruction to stability for almost commuting matrices.

Multiplier algebras are studied in detail, both in the setting of rings and of C*-algebras. Recent results about extensions of C*-algebras are discussed, including a result linking amalgamated products with the Busby/Hochschild theory.

Contents
Introduction; Part I. Rings and C*-Algebras: Unital C*-algebras; Order and factoring; Generators and relations; Basic perturbation; Push-outs and pull-backs; Matrix algebras; Multipliers; Part II. Lifting: Easy lifting; Multiplier algebras; Projectivity; Properties of projective C*-algebras; Heavy lifting; Part III. Perturbing: Inductive limits; Stable relations; Applications; Extensions; Part IV. Almost Normal: Normals, limits; Almost normal elements; Almost normal matrices; Bibliography; Index.

November 1996, 323 pages (hardcover), ISBN 0-8218-0522-3, LC 96-40681, ISSN 1069-5265

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Mathematical Surveys and Monographs

Monotone Operators in Banach Space and Nonlinear Partial Differential Equations
R. E. Showalter
Volume 49

The objectives of this monograph are to present some topics from the theory of monotone operators and nonlinear semigroup theory which are directly applicable to the existence and uniqueness theory of initial-boundary-value problems for partial differential equations and to construct such operators as realizations of those problems in appropriate function spaces.

A highlight of this presentation is the large number and variety of examples introduced to illustrate the connection between the theory of nonlinear operators and partial differential equations. These include primarily semilinear or quasilinear equations of elliptic or of parabolic type, degenerate cases with change of type, related systems and variational inequalities, and spatial boundary conditions of the usual Dirichlet, Neumann, Robin or dynamic type.

The discussions of evolution equations include the usual initial-value problems as well as periodic or more general nonlocal constraints, history-value problems, those which may change type due to a possibly vanishing coefficient of the time derivative, and other implicit evolution equations or systems including hysteresis models. The scalar conservation law and semilinear wave equations are briefly mentioned, and hyperbolic systems arising from vibrations of elastic-plastic rods are developed. The origins of a representative sample of such problems is given in the Appendix.

Contents
PDE examples by type; Linear problems... An introduction; Nonlinear stationary problems; Nonlinear evolution problems; Accretive operators and nonlinear Cauchy problems; Appendix; Bibliography; Index.

November 1996, 278 pages (hardcover), ISBN 0-8218-0500-2, LC 96-43343, ISSN 0076-5376

1991 Mathematics Subject Classification: 47H15, 35A05; 34G20, 35A15, 35J65, 35J85, 35K60, 35K65, 35K85, 47H05, 47H06, 47H20

Individual member $45, List $75, Institutional member $60
To order, please specify SURV/49N
Compact Connected Lie Transformation Groups on Spheres with Low Cohomogeneity. II
Eldar Straume
Volume 125, Number 595
In this book, the author carries out a systematic investigation and construction of all possible differentiable (homotopy) G-spheres with 2-dimensional orbit space, where G is any compact connected Lie group. Based on the geometric weight system classification of Part I, the possible orbit structures are determined, and the exotic G-spheres are constructed by equivariant twisting of the orthogonal models.

Contents
Organization of orthogonal models and orbit structures; Orbit structures for G-spheres of cohomogeneity two; The reconstruction problem; G-spheres of cohomogeneity two with at most two isolated orbits; G-spheres of cohomogeneity two with three isolated orbits; Figures; References.

CR-geometry and Deformations of Isolated Singularities
Ragnar-Olaf Buchweitz and John J. Millson
Volume 125, Number 597
In this memoir, it is shown that the parameter space for the versal deformation of an isolated singularity (V, O)—whose existence was established by Grauert in 1972—is isomorphic to the space associated to the link M of V by Kuranishi using the CR-geometry of M.

Contents
Introduction; Controlling differential graded Lie algebras; Vector-valued differential forms on complex manifolds; Kuranishi’s CR deformation theory; The global tangent complex of a complex analytic space; The local tangent complex controls the flat deformations of an analytic local ring; The global tangent complex controls the flat deformations of a complex analytic space; The comparison of the tangent complex and the Kodaira-Spencer algebra of a complex manifold; The Akahori complexes; A controlling differential graded Lie algebra for Kuranishi’s CR-deformation theory; Counterexamples; References.

Cyclic Phenomena for Composition Operators
Paul S. Bourdon and Joel H. Shapiro
Volume 125, Number 596
The cyclic behavior of a composition operator is closely tied to the dynamical behavior of its inducing map. Based on analysis of fixed-point and orbital properties of inducing maps, Bourdon and Shapiro show that composition operators exhibit strikingly diverse types of cyclic behavior. The authors connect this behavior with classical problems involving polynomial approximation and analytic functional equations.

Features:
• Complete classification of the cyclic behavior of composition operators induced by linear-fractional mappings,
• Application of linear-fractional models to obtain more general cyclicity results,
• Information concerning the properties of solutions to Schroeder’s and Abel’s functional equations.

This pioneering work forges new links between classical function theory and operator theory, and contributes new results to the study of classical analytic functional equations.

Contents
Introduction; Preliminaries; Linear-fractional composition operators; Linear-fractional models; The hyperbolic and parabolic models; Cyclicity: Parabolic nonautomorphism case; Endnotes; References.

Maximality Properties in Numerical Semigroups and Applications to One-Dimensional Analytically Irreducible Local Domains
Valentina Barucci, David E. Dobbs, and Marco Fontana
Volume 125, Number 598
If k is a field, T an analytic indeterminate over k, and n_1, . . . , n_h are natural numbers, then the semigroup ring A = k[[T^{n_1}, . . . , T^{n_h}]] is a Noetherian local one-dimensional domain whose integral closure, k[[T]], is a finitely generated A-module. There is clearly a close connection between A and the numerical semigroup generated by n_1, . . . , n_h. Moreover, let A be a Noetherian local domain which is analytically irreducible and one-dimensional (equivalently, whose integral closure V is a DVR and a finitely generated A-module).

As noted by Kunz in 1970, some algebraic properties of A such as “Gorenstein” can be characterized by using the numerical semigroup of A (i.e., the subset of N consisting of all the images of nonzero elements of A under the valuation associated
to V). This book’s main purpose is to deepen the semigroup-theoretic approach in studying rings \( A \) of the above kind, thereby enlarging the class of applications well beyond semigroup rings. For this reason, Chapter I is devoted to introducing several new semigroup-theoretic properties which are analogous to various classical ring-theoretic concepts. Then, in Chapter II, the earlier material is applied in systematically studying rings \( A \) of the above type.

As the authors examine the connections between semigroup-theoretic properties and the correspondingly named ring-theoretic properties, there are some perfect characterizations (symmetric \( \cong \) Gorenstein; pseudo-symmetric \( \cong \) Kunz, a new class of domains of Cohen-Macaulay type 2). However, some of the semigroup properties (such as “Artin” and “maximal embedding dimension”) do not, by themselves, characterize the corresponding ring properties. To forge such characterizations, one also needs to compare the semigroup- and ring-theoretic notions of “type”. For this reason, the book introduces and extensively uses “type sequences” in both the semigroup and the ring contexts.

Contents

Maximality properties in numerical semigroups; Maximality properties in one-dimensional analytically irreducible local domains; References.

January 1997, 78 pages (softcover).
ISBN 0-8218-0544-4, LC 96-44757, ISSN 0065-9266
Individual member $22, List $36, Institutional member $29
To order, please specify MEMO/125/598N

Large Time Behavior of Solutions for General Quasilinear Hyperbolic-Parabolic Systems of Conservation Laws
Tai-Ping Liu and Yanni Zeng
Volume 125, Number 599
Physical models of conservation form—such as the compressible Navier-Stokes equations, and MHD and full nonlinear elasticity equations—are not uniformly parabolic, but rather hyperbolic-parabolic. This memoir gives a self-contained analysis of nonlinear interactions of dissipation waves as well as the hyperbolic aspects of general systems. It introduces the new pointwise estimates of Green functions and coupling of nonlinear waves.

Contents

Introduction; Viscous conservation laws; Diffusion waves; Systems with diagonalizable linearizations; Green’s function for a \( 2 \times 2 \) linear system; Green’s functions for \( n \times n \) systems with applications; Energy estimate; Systems with non-diagonalizable linearizations; Applications to continuum mechanics; References.

January 1997, 120 pages (softcover).
ISBN 0-8218-0545-2, LC 96-44759, ISSN 0065-9266
1991 Mathematics Subject Classification: 35K55, 76N10; 35B40, 35A08, 35L65, 76W05
Individual member $23, List $38, Institutional member $31
To order, please specify MEMO/125/599N

Proceedings of Symposia in Applied Mathematics

Proceedings of the Norbert Wiener Centenary Congress, 1994
V. Mandrekar and P. R. Masani, Editors

A mathematician on par with the greatest in the century, Norbert Wiener was a universal thinker of colossal proportions. This book contains the proceedings of the Norbert Wiener Centenary Congress held at Michigan State University on November 27-December 2, 1994. The aim of the Congress was to reveal the depth and strong coherence of thought that runs through Wiener’s legacy, and to exhibit its continuation in ongoing research.

This volume brings together the great minds who have furthered Wiener’s ideas in physics, stochastics, harmonic analysis, philosophy, prosthesis and cybernetics. The presentations coherently lay out the developments of the subject from their inception. This volume provides an excellent pathway for new investigators who may wish to pursue these developments by following the footsteps of world experts.

There is no other book available in which experts in the various fields in which Wiener worked have presented his thoughts and contributions in such a coherent and lucid manner.

Contents

New Publications Offered by the AMS

Professor C. E. Shannon (in absentia); D. Gabor, Wiener and the art of communication; Academic vita of Norbert Wiener; Bibliography of Norbert Wiener; List of participants (Norbert Wiener centenary congress).

February 1997, approximately 600 pages (hardcover), ISBN 0-8218-0452-9, LC 96-43346, ISSN 0160-7634
1991 Mathematics Subject Classification: 60H30, 42A38, 94A05, 31C15, 81P20; 60G46, 60H05, 94A15
Individual member $59, List $99, Institutional member $79
To order, please specify PSAPM-MASANIN

AMS Publications Not in Series

Mathematical Sciences Professional Directory

This annual directory provides a handy reference to various organizations in the mathematical sciences community. Listed in the directory are officers and committee members of over thirty professional mathematical organizations (terms of office and other pertinent information are also provided in some cases); key mathematical sciences personnel of selected government agencies; academic departments in the mathematical sciences; mathematical units in nonacademic organizations; and alphabetic listings of colleges and universities. Current addresses, telephone numbers, and electronic addresses for individuals are listed in the directory when provided.

February 1997, approximately 220 pages (softcover), ISBN 0-8218-0192-9, ISSN 0737-4356
1991 Mathematics Subject Classification: 00
List $50, Institutional member $40
To order, please specify PRODIR/97N

Astérisque

Le Théorème D'Hyperbolisation pour les Variétés Fibrées de Dimension 3
Jean-Pierre Otal
Number 235

This book presents a complete proof of Thurston's hyperbolization theorem in the case of 3-manifolds which are fibered over the circle. The fundamental step is "the double limit theorem" that establishes a criterion of convergence for a sequence of quasi-Fuchsian groups. The proof given of this result uses real trees—entirely different from Thurston's, which used the theory of pleated surfaces. Text is written in French.

Titles in this series are published by the Société Mathématique de France and distributed by the AMS in the United States, Canada, and Mexico. Orders from other countries should be sent to the SMF, Maison de la SMF, B.P. 67, 13274 Marseille Cedex 09, France, or to Institut Henri Poincaré, 11 rue Pierre et Marie Curie, 75231 Paris Cedex 05, France. Members of the SMF receive a 30% discount from list.

Contents

Espaces de Teichmüller et groupes kleiniens; Dégénérescences de structures hyperboliques et arbres réels; Laminations géodésiques et arbres réels; Laminations géodésiques et convergence de Grorov; Le théorème de la limite double; Le théorème d'hyperbolisation pour les variétés fibrées; Le théorème de Sullivan; Actions des groupes de surface sur les arbres réels; Deux exemples de variétés hyperboliques fibrées sur le cercle; Appendice. Les laminations géodésiques; Bibliographie; Index.

July 1996, 159 pages (softcover), ISSN 0303-1179
1991 Mathematics Subject Classification: 57M07, 57M50, 20E08, 51M10
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These AMS publications have been chosen for mathematicians and physicists interested in various aspects of mathematical physics. Here you will find lectures, research monographs, and proceedings of important conferences. For a selection of new and recently published titles in mathematical physics, contact customer service for a brochure: 1-800-321-4AMS (4267).

**Algebraic Analysis of Solvable Lattice Models**
Michio Jimbo and Tetsuji Miwa, Kyoto University, Japan

The book provides a very clear exposition on the subject, and meanwhile gives an elementary introduction to representation theory ... serves very well as both introduction and reference. — *Mathematical Reviews*

**Differential Geometry and Mathematical Physics**
John K. Beem, Columbia, MO, and Krishan L. Duggal, University of Windsor, ON, Canada

**Dynamical Zeta Functions for Piecewise Monotone Maps of the Interval**
David Ruelle, Institut des Hautes Etudes Sciences, Bures-Sur-Yvette, France

This is a welcome guide to the problems and methods of this area. The bibliography should help to take the reader further, and along alternative but related directions. — *Bulletin of the London Mathematical Society*

**Symplectic Geometry and Quantization**
Yoshiaki Maeda, Keio University, Yokohama, Japan, Hideki Omori, Science University of Tokyo, Japan, and Alan Weinstein, University of California, Berkeley, Editors

This collection provides insight into how these different topics relate to one another and presents intriguing new problems. — *SciTech Book News*

**Variations on a Theme by Kepler**
Victor Guillemin, Massachusetts Institute of Technology, Cambridge, MA, and Shlomo Sternberg, Harvard University, Cambridge, MA

The brilliant style and clarity of the exposition makes this book interesting for a large part of the mathematical and physical community. — *Mathematical Reviews*
Positions available, items for sale, services available, and more

ALABAMA

THE UNIVERSITY OF ALABAMA AT BIRMINGHAM

Applications are invited for a tenure-track position to begin September 1, 1997. Applicants should have demonstrated a strong research potential in mathematics as well as a commitment to teaching. Preference will be given to junior candidates whose research is compatible with that of our current faculty: this includes dynamical systems, mathematical physics, nonlinear analysis, differential equations, differential geometry and topology including computational aspects of these areas. In addition to a demonstrated research program in mathematics, applicants showing a clear ability for establishing interdisciplinary research (including medical research) will receive strong consideration.

For additional information on UAB, see our home page at http://www.math.uab.edu. To apply please send the AMS standard cover sheet (available from the AMS), a curriculum vita and arrange for at least three letters of reference to be sent. Applications received by December 15, 1996, will be given full consideration. Send applications to: Search Committee, Dept. of Math., U. of Alabama at Birmingham, Birmingham, AL 35294-1170. UAB is an AA/EO Employer.

UNIVERSITY OF ALABAMA IN HUNTSVILLE

The Mathematical Sciences Department of the University of Alabama in Huntsville invites applications for one anticipated tenure-track faculty position with the rank of assistant professor beginning in August 1997. The availability of the position is contingent upon budgetary approval. A Ph.D. in mathematics or related field with emphasis in applied mathematics and evidence of an outstanding commitment to effective teaching with a strong research ability is essential. Send letter of application, vita with an AMS standard cover sheet, and three letters of reference to M. H. Chang, Chair, Department of Mathematical Sciences, University of Alabama in Huntsville, Huntsville, AL 35899. Review of applicants will begin February 1, 1997, and will continue until the position is filled. The University of Alabama in Huntsville is an Affirmative Action, Equal Opportunity Institution.

ARIZONA

NORTHERN ARIZONA UNIVERSITY
Assistant Professor Mathematics

Tenure-track assistant professorship starting fall 1997. A doctorate in mathematics or applied mathematics is required. Candidates should have a strong theoretical background and interest in numerical analysis, as well as the ability to contribute to an interactive research group in dynamical systems and applied mathematics and to teach a wide variety of courses. Experience or interest in teaching mathematics in a multicultural environment would be desirable. Qualifications also include substantial evidence of high-quality teaching and potential for a productive research program. Send a letter of application, transcripts, a curriculum vitae, and three letters of reference to: Mathematics Screening Committee, Northern Arizona University, Box 5717, Flagstaff, AZ 86011. Review of applications begins December 1, 1996. The search will remain open until the position is filled.

NAU is an Equal Opportunity/Affirmative Action Institution. Minorities, persons with disabilities, veterans, and women are encouraged to apply.

CALIFORNIA

UNIVERSITY OF CALIFORNIA, IRVINE
Department of Mathematics
Irvine, CA 92697-3875

Applications are invited for three tenure-track assistant professor positions with
the possibility of upgrading one of them to a tenured level position for an appropriate candidate. The search will be in areas that complement the existing strengths of the department. Priorities will be placed on the following areas: 
1) algebra with emphasis in algebraic and arithmetic geometry
2) applied and computational mathematics
3) analysis and PDE
4) geometry and topology
Candidates must possess a Ph.D. Very strong potential in research and teaching is required for the position. Applicants should send a curriculum vitae; a list of publications, preprints, reprints; and a research plan to the Assistant Professor Search Committee at the above address. They should also arrange for four letters of recommendation to be sent to the Assistant Professor Search Committee. Applicants are encouraged to use the AMS Cover Sheet.

The deadline for applications is December 31, 1996, or until the positions are filled. The University of California is an Equal Opportunity Employer committed to excellence through diversity.

UNIVERSITY OF CALIFORNIA, LOS ANGELES
Department of Mathematics
Regular Positions in Pure and Applied Mathematics

The UCLA Department of Mathematics invites applications for two or more tenure-track positions in pure or applied mathematics. Exceptional promise in research and teaching is required. Positions are initially budgeted at the assistant professor level, but sufficiently outstanding candidates will be considered at higher levels. Teaching load is an average of 4.5 quarter-courses per year. Positions subject to availability of resources and administrative approval. To apply, send electronic mail to search@math.ucla.edu or open http://www.math.ucla.edu/~search/ on the World Wide Web, or write to: John B. Garnett, Chair, Department of Mathematics, University of California, Los Angeles, CA 90095-1555, Attn: Staff Search. UCLA is an Equal Opportunity/Affirmative Action Employer.

UNIVERSITY OF CALIFORNIA, IVEINE
Department of Mathematics
Irvine, CA 92697-3875

Applications are invited for several one- or two-year visiting assistant professor positions in the following areas of research: 1) applied and computational mathematics, 2) geometry and topology (includes geometric analysis), 3) analysis and PDE (includes mathematical physics), 4) algebra and number theory (includes algebraic and arithmetic geometry), 5) logic and set theory, 6) probability. Candidates must possess a Ph.D. Strong promise in research and teaching is required. Current annual salary is set at $37,700. Teaching load: 5 to 6 quarter-courses per year. Applicants should send a resume, preprints, dissertation abstract, and three letters of recommendation to: Visiting Assistant Professor Search Committee at the above address. The deadline for applications is January 3, 1997. The University of California is an Equal Opportunity Employer committed to excellence through diversity.

UNIVERSITY OF SOUTHERN CALIFORNIA
Los Angeles, California

The Department of Mathematics expects two tenure-track positions at the assistant or associate professor level, in addition to several visiting and postdoctoral positions. Applicants must show exceptional promise in research and teaching.

To apply, please submit the following materials in a single package: letter of application (including your e-mail address and fax number), the AMS Cover Sheet, and a curriculum vitae. Candidates for assistant professor, visiting and/or postdoctoral positions should also arrange for three letters of recommendation to be sent. Mail all materials to: Chair of Appointment Committee, Department of Mathematics - DRB 155, University of Southern California, Los Angeles, CA 90089-1113. Review of applications will begin Dec. 1, 1996. Additional information about USC can be found on the Web at http://www.usc.edu/. USC is an Equal Opportunity/Affirmative Action Employer.

UNIVERSITY OF CALIFORNIA, LOS ANGELES
Department of Mathematics
Temporary Positions

Subject to availability of resources and administrative approval:

(1) Three E. R. Hedrick Assistant Professorships. Applicants must show very strong promise in research and teaching. Salary $42,900. Three-year appointment. Teaching load: four quarter-courses per year, which may include one advanced course in the candidate’s field. Preference will be given to applications completed by January 6, 1997.

(2) One or two research assistant professorships in computational and applied mathematics. Applicants must show very strong promise in research and teaching. Salary $42,900. One-year appointment, probably renewable up to two times. Teaching load: at most four quarter-courses per year, which may include one advanced course in the candidate’s field. Preference will be given to applications completed by January 6, 1997.

(3) One adjunct assistant professorship or lectureship in the Program in Computing (PIC). Applicants for the adjunct position must show very strong promise in teaching and research in an area related to computing. Teaching load: four quarter-course equivalents and one more advanced quarter-course per year. One-year appointment, probably renewable once. Salary $45,800. Applicants for the lectureship must show very strong promise in the teaching of programming. An M.S. in computer science or equivalent degree is preferred. Teaching load: six quarter-course equivalents per year. One-year appointment, probably renewable one or more times, depending on the needs of the program. Salary is $38,904 or more, depending on experience. Preference will be given to applications completed by February 1, 1997.


(5) Possibly one or more positions for visitors.

To apply, send electronic mail to: search@math.ucla.edu or open http://www.math.ucla.edu/~search/ on the World Wide Web, or write to: John B. Garnett, Chair, Department of Mathematics, University of California, Los Angeles, CA 90095-1555, Attn: Staff Search. UCLA is an Equal Opportunity/Affirmative Action Employer.

HARVEY MUDD COLLEGE
Assistant Professor of Mathematics

Harvey Mudd College invites applications for a tenure-track position in mathematics at the assistant professor level. Excellence in teaching is absolutely essential, as is evidence of a strong and ongoing research program. Preference will be given to applicants in applied mathematics, especially in the areas of applied analysis, PDEs, ODEs, continuous dynamical systems, and numerical equations. Applicants should also have wide mathematical interests and be able to teach across the undergraduate mathematics curriculum. Candidates must be willing to supervise undergraduate research and work with others in the development of departmental programs.

Harvey Mudd College is a highly selective undergraduate institution of science and engineering. More than one-third of the student body are National Merit Scholarship finalists. The college enrolls about 630 students and is associated with four other undergraduate colleges and the Claremont Graduate School, forming together an academic community of about 5,000 students. There are over forty mathematicians in Claremont.

Applicants should send a curriculum vitae, a description of their current research, and arrange to have three letters of reference sent directly to the address that appears below. Letters should, as much as possible, assess the quality of the applicant’s scholarship, potential as a
mathematician, and abilities as a teacher. Preference will be given to applications received by January 15, 1997. Harvey Mudd College is an Equal Opportunity Employer and is committed to the recruitment of candidates historically underrepresented on college faculties.

Address for applications:
Search Committee
Department of Mathematics
Harvey Mudd College
Claremont, CA 91711-5990

CLAREMONT McKENNA COLLEGE
Department of Mathematics
Claremont McKenna College invites applications for a tenure-track position in mathematics, at the assistant professor level, starting in Fall of 1997. Candidates must have a Ph.D. in mathematics, demonstrated excellence in teaching across a broad range of undergraduate courses, and a productive, ongoing research program. Preference will be given to applicants whose research areas lie in pure mathematics.

Claremont McKenna College is a highly selective undergraduate institution enrolling approximately 1,000 students. CMC is a member of The Claremont Colleges, which also include Pomona, Scripps, Pitzer, Harvey Mudd, and The Claremont Graduate School. Collectively, The Claremont Colleges constitute an academic community of 6,000 students; their combined faculties include over forty mathematicians. Claremont is located 35 miles east of Los Angeles.

Applicants should provide a curriculum vitae, three letters of reference, and a professional statement describing their experience and philosophy in both teaching and research. Evaluation of applications will begin by December 31, 1996, and will continue until a candidate is selected. All materials should be sent to:
Search Committee
Department of Mathematics
Claremont McKenna College
500 E. 9th Street
Claremont, California 91711-6400

FLORIDA

FLORIDA INTERNATIONAL UNIVERSITY
Department of Mathematics
The Department of Mathematics invites applications for tenure-track positions, subject to administrative approval, effective August 1997. Most of the positions will be at the assistant professor level. Duties for all positions will include teaching, research, and service. Applicants must have a Ph.D. in mathematics.

Florida International University is a member of the State University System of Florida, with approximately 30,000 students. The department offers bachelor's and master's degrees. Current research interests of the faculty include algebra, number theory, analysis/PDE, logic and differential geometry/topology. The department is also particularly interested in applicants who are specialists in numerical analysis or operations research.

To apply, send a letter of application, a vita, and three letters of recommendation to:
Recruitment Committee
Department of Mathematics
Florida International University
Miami, FL 33199
http://www.fiu.edu/
Florida International University is an Equal Opportunity/Equal Access Employer.

GEORGIA

EMORY UNIVERSITY
Mathematics and Computer Science Department
Atlanta, Georgia 30322

Applications are invited for two anticipated appointments effective 1997-98.

Position 1: A tenure-track assistant professorship or a tenured appointment at the rank of associate professor or professor; applicants must have a research program in numerical analysis/computational science and hold a Ph.D. in mathematics, computer science, or a closely related field.

Position 2: A tenure-track assistant professorship or a tenured appointment at the rank of associate professor or professor; applicants must have a research program in algebra and hold a Ph.D. in mathematics.

As the department supports several undergraduate programs within Emory College, a Ph.D. in mathematics, and M.S. in computer science/mathematics, applicants are expected to have strong records or promise as undergraduate and graduate teachers.

Applications must specify one of Positions 1 and 2 and include CVs (with at least three recommenders’ names). Please see that recommendation letters are sent to Professor Dwight Duffus.

GEORGIA INSTITUTE OF TECHNOLOGY

The School of Mathematics expects to have some visiting and tenure-track positions in several areas of mathematics at various levels beginning in fall 1997. Current interests of the school include analysis, discrete mathematics, and probability and statistics. Candidates with strong research and teaching records or potential should arrange for a resume at least three letters of reference, and a summary of future research plans to be sent to the Hiring Committee, School of Mathematics, Georgia Institute of Technology, Atlanta, Georgia 30332-0160. Georgia Tech, an institution of the University System of Georgia, is an Equal Opportunity/Affirmative Action Employer.

VALDOSTA STATE UNIVERSITY
Mathematics Position

Applications are invited for a tenure-track position at the assistant professor level beginning September 1997. Duties include teaching three courses per quarter, continuing research/scholarly activities, and service. A strong commitment to undergraduate education and a record of excellence in teaching are essential. ABD with a master's degree in mathematics required; Ph.D. strongly preferred. Preference will
be given to the candidates in the area of applied mathematics.

Valdosta State University is a multipurpose regional university in the University System of Georgia, with a current enrollment of over 9,700 students. The Department of Mathematics and Computer Science includes twenty full-time faculty and over 250 undergraduate majors; six degree programs are offered in the department, including applied mathematics and computer information systems.

Send a letter of application, résumé, a statement of teaching philosophy, unofficial transcript(s) of all graduate and undergraduate work, and three letters of recommendation, at least one of which should address teaching, to:

Mathematics Search Committee
Department of Mathematics and Computer Science
Valdosta State University
Valdosta, GA 31698-0040

Complete applications received by January 2, 1997, will receive full consideration. Valdosta State University is an Equal Opportunity/Affirmative Action Employer.

ILLINOIS

NORTHWESTERN UNIVERSITY
Department of Mathematics
2033 Sheridan Road
Evanston, Illinois 60208-2730

Applications are invited for an anticipated tenure-track assistant professor position starting September 1997. Priority will be given to exceptional research mathematicians. Fields of interest within the department include algebra, analysis, dynamical systems, probability, partial differential equations, and topology.

Candidates should arrange to have their application material sent to Chairperson, Personnel Committee, at the department address and include: (1) The American Mathematical Society’s Application Cover Sheet for Academic Employment in Mathematics, (2) a curriculum vitae, and (3) at least three letters of recommendation. Inquiries may be sent via e-mail to hire@math.nwu.edu, in order to receive full consideration, applications should be received by December 15, 1996.

The Department of Mathematics, (2) a curriculum vitae, and (3) three letters of recommendation. Inquiries may be sent via e-mail to search@math.nwu.edu, in order to receive full consideration, applications should be submitted by January 15, 1997.

Northwestern University is an Affirmative Action/Equal Opportunity Employer committed to fostering a diverse faculty; women and minority candidates are especially encouraged to apply.

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Postdoctoral Positions

The Department of Mathematics of the University of Illinois at Urbana-Champaign is proud to announce the creation of six new postdoctoral positions. The first two appointments will be made starting August 21, 1997; each appointment is for 3 years and is not renewable. These positions are for recent Ph.D. recipients. They will provide an excellent scientific environment to pursue research in pure and applied mathematics. The position carries a salary of $37,000 per year plus a start-up $3,000 research fund.

Applications should include a curriculum vitae and a brief statement of research interests and activities. The use of the AMS Cover Sheet will be appreciated. Applications should be sent by regular mail to the Postdoctoral Search Committee, Department of Mathematics, University of Illinois at Urbana-Champaign, 1409 W. Green Street, Urbana, Illinois 61801-2975.

Applications should be sent to:

Professor Erna Yakel, Department of Mathematics, University of Illinois, 1409 W. Green Street, Urbana, Illinois 61801-2975.

For more information, visit our Web page at http://www.math.uiuc.edu. Inquiries may be sent to: postdocs@math.uiuc.edu.

Applications are considered for at least three letters of recommendation to be sent to the same address.

INDIANA

PURDUE UNIVERSITY CALUMET
Two Tenure-Track Positions in Mathematics Education

The Department of Mathematics, Computer Science and Statistics is seeking to expand an already active research program in mathematics education. The department seeks applications for two tenure-track positions in mathematics education available August 1, 1997, one of which focuses on mathematics education at the secondary school level. Duties and responsibilities include teaching a range of mathematics education and mathematics courses for prospective K-12 teachers, supervising field experience, and working collaboratively with public schools. A doctorate in mathematics education with the equivalent of a master's degree in mathematics or a Ph.D. in mathematics with extensive experience in mathematics education research is required. Experience with secondary schools is highly desirable. Candidates must have a commitment to teacher education, to excellence in teaching, and to continued scholarly activity. Applicants with extensive research and teaching experience may be considered for appointment at the associate level or above. To apply, submit a letter of application, curriculum vitae, graduate transcript, and three letters of recommendation, at least one of which provides evidence of scholarly potential in mathematics education and at least one of which addresses teaching ability. Applications should be sent to: Professor Erna Yakel, Department of Mathematics, Computer Science and Statistics, Purdue University, Calumet, Hammond, IN 46323, e-mail: yakel@calumet.purdue.edu. Review of applications will begin January 20, 1997, and will continue until the positions are filled.

Purdue University Calumet is an Equal Opportunity, Affirmative Action employer.

DEC 1996
NOTICES OF THE AMS
MANCHESTER COLLEGE
The Department of Mathematical Sciences invites applications for a tenure-track position to begin fall semester 1997. A Ph.D. in mathematics is preferred; ABD will be considered. The position requires the teaching of a wide variety of undergraduate mathematics courses with the ability to teach applied mathematics and statistics as an advantage. A commitment to excellent teaching in a liberal arts environment is essential. Manchester College, with an enrollment of approximately 1,000 students, is a private liberal arts college affiliated with the Church of the Brethren. Send letter of application, vita, transcripts, and three letters of recommendation to: Dr. Stan Becry, Chair, Department of Mathematical Sciences, Manchester College, Box 161, North Manchester, Indiana 46962. Review of applications will begin January 15, 1997. AA/EOE.

INDIANA UNIVERSITY, PURDUE UNIVERSITY, INDIANAPOLIS Indianapolis, Indiana
The Department of Mathematical Sciences invites applications for a tenure-track position in statistics to begin August, 1997. A Ph.D. in statistics or biostatistics and a strong commitment to research and undergraduate and graduate teaching are required. Candidates with interest in applied and interdisciplinary research are especially encouraged to apply. Rank and salary commensurate with qualifications. A letter of application, resume, and at least three letters of recommendation should be sent to: Benzion Boukal, Statistics Search Committee, Department of Mathematical Sciences, Indiana University Purdue University Indianapolis, 402 N. Blackford St., Indianapolis, IN 46202. Review of applications will begin January 15, 1997, and will continue until the position is filled. Women and minorities are encouraged to apply. AA/EOE.

IOWA
UNIVERSITY OF NORTHERN IOWA
Assistant Professor of Mathematics
Tenure-track position to teach courses offered by the mathematics department at both the undergraduate and graduate levels. Applicants should have a Ph.D. in mathematics and be committed to quality education and scholarship at a comprehensive university. Candidates with research interests in algebra or analysis compatible with those of present faculty and with experience using technology in the classroom are preferred. Appointment begins in August 1997. Salary is competitive; fringe benefits are excellent. Application must be received by February 14, 1997, to receive full consideration. For more information contact Gregory Dotseth, Department of Mathematics, University of Northern Iowa, Cedar Falls, IA 50614-0506; tel: 319-273-2397; e-mail dotseth@math.uni.edu. AA/EOE.

KANSAS
KANSAS STATE UNIVERSITY
Department of Mathematics
Subject to budgetary approval, applications are invited for tenure-track and visiting positions commencing August 10, 1997; rank and salary commensurate with qualifications. The department seeks candidates whose research interests mesh well with those of our faculty. The department has research groups in the areas of analysis, algebra, geometry/topology, and differential equations. Applicants must have strong research credentials and a commitment to excellence in teaching. Ph.D. in mathematics or a Ph.D. dissertation accepted with only formalities to be completed is required. Letter of application, current vita, description of research, and three letters of recommendation should be sent to:
Louis Pigno
Department of Mathematics
Cardwell Hall 138
Kansas State University
Manhattan, KS 66506
Offers may begin by December 9, 1996, but applications for positions will be reviewed until February 1, 1997, or until positions are closed. AA/EOE.

LOUISIANA
CENTENARY COLLEGE
Centenary College invites applications for a tenure-track appointment in mathematics. Centenary is a member of the Associated Colleges of the South with Centre, Furman, Rhodes, Richmond, Sewanee, Trinity, and six other selective institutions and is listed in Peterson’s Guide as one of the 200 best math/science programs in the U.S. Founded in 1825, it enjoys a $71 million endowment supporting sixteen endowed chairs and a national ranking among the nation’s finest small colleges. Responsibilities include the teaching of 11 to 13 contact hours. Ph.D.s with strong teaching skills please submit vita, statement of teaching philosophy and research agenda, and three letters of reference to: Search Committee (AMS), Office of the Provost, Centenary College, Shreveport, LA 71134-1188. Ability to involve undergraduate students in research a strong plus. Applications accepted until the position is filled. Women/men/critics urged to apply.

MASSACHUSETTS
SMITH COLLEGE
Department of Mathematics
The Mathematics Department of Smith College invites applications for a three-year non-tenure-track position to begin in the fall of 1997. Candidates must have a Ph.D. in mathematics or statistics and must provide evidence of excellent teaching and an active research program. Send a curriculum vitae and arrange to have three letters of reference sent to: Mathematics Search Committee, Clark Science Center, Smith College, Northampton, MA 01063. To receive full consideration, you must provide a complete application before February 1, 1997. It is possible that more than one position will be available. Smith College is an Equal Opportunity/Affirmative Action Institution. Minorities and women are encouraged to apply.

MICHIGAN
WESTERN MICHIGAN UNIVERSITY
Department of Mathematics & Statistics
Western Michigan University seeks applications for two tenure-track assistant professor positions in mathematics to begin fall 1997, pending budgetary approval. A doctorate in mathematics, excellent teaching ability, and a strong commitment to research are required for both positions. 1) Combinatorics/graph theory. Preference will be given to someone with specialties that complement and broaden the department’s expertise, such as algebraic
combinatorics, combinatorial algorithms, coding theory, or combinatorial designs. Outstanding applicants at the associate professor level may be considered.

2) Mathematics/applied mathematics with a strong background in partial differential equations. Preference will be given to someone with research compatible with the interests of the faculty.

Salary and fringe benefits are competitive. Western Michigan University, a Carnegie Classification Doctoral Institution and Equal Opportunity Employer, has an affirmative action program which encourages applications from underrepresented groups. Send letter of application, vita, statement of research plans, academic transcripts, and three letters of recommendation to: John W. Petro, Chair, Department of Mathematics and Statistics, Western Michigan University, Kalamazoo, MI 49008. Email: john.petro@wmich.edu, fax: 616-387-4530. For information about Western Michigan University see http://www.wmich.edu/. Review of applications will begin November 1, 1996, and applications will be accepted until the positions are filled.

HILLSDALE COLLEGE
Department of Mathematics and Computer Science

Applications are invited for a tenure-track position in mathematics beginning in August 1997, at the rank of assistant professor. Candidates must have a Ph.D. in mathematics with a specialty in applied mathematics and a strong commitment to excellence in teaching undergraduate mathematics. Duties include a 12 hour (3 course) teaching load per semester which will include teaching all levels of undergraduate mathematics and possibly a computer survey class, academic advising and college service, and continued mathematical activity.

Hillsdale College, founded in 1844, is an independent, coeducational, four year liberal arts college of 1,200 students. Located in the southern Michigan city of Hillsdale, it lies midway between Chicago and Cleveland. Hillsdale has traditionally upheld two concepts: academic excellence and institutional independence.

Send letter of application, three letters of recommendation, résumé, a statement of teaching philosophy, and a short summary of any teaching evaluations to: Professor Mark J. Watson, Chair, Department of Mathematics and Computer Science, Hillsdale College, Hillsdale, Michigan 49242. Application review will begin February 1, 1997, and continue until the position is filled. EOE.

MISSOURI
UNIVERSITY OF MISSOURI-COLUMBIA
Department of Mathematics
Columbia, MO 65211

Our department is now in the last stage of completing its enhancement program. In the last three years, we have successfully hired 11 outstanding young faculty members in competition with some of the best departments in the country. We have created several postdoctoral positions and several graduate fellowships. Salary increases for our department averaged between 6.5% and 9% during the last three years. To join a successful department, you are invited to apply for two tenure-track positions at the advanced assistant professor level and several post-doctoral positions beginning August 1997. The tenure-track positions require a Ph.D. in mathematics, two to three years’ experience after the Ph.D., quality teaching, and a distinguished research record in algebra/analytic geometry or mathematical physics. The postdoctoral positions will be in the three enhanced areas, which include modern analysis/harmonic analysis, algebra/analytic geometry and mathematical physics for a period of one to three years.

Send a curriculum vitae along with a letter of application, a completed AMS Standard Cover Sheet, and three letters of recommendation to: Elias Saab, Chair, at the address above. The application deadline is January 31, 1997, or until the positions are filled. Applications after February 28, 1997, will not be guaranteed consideration. Visit our home page at http://math.missouri.edu/ and read our recent newsletter at http://math.missouri.edu/news/issue11/front.html, AA/EOE.

UNIVERSITY OF MISSOURI-ROLLA
Department of Mathematics and Statistics
Rolla, MO 65409-0020

Possible entry-level tenure-track position available for fall 1997. We are specifically seeking applicants whose training is in complex analysis with a preference for an area of complex analysis which would complement the research efforts of the department. Applicants must have completed the Ph.D. by August 15, 1997. Both research potential and teaching ability will be considered in the selection. Submit AMS Cover Sheet, curriculum vitae, summary of research, copies of transcripts, and three letters of reference to W. T. Ingram, Chair. In your cover letter and on the outside of the envelope, please clearly identify your area of specialty. Applicant review will begin in January 1997. In order to receive full consideration, please have all materials in by January 1. AA/EOE.

NEBRASKA
THE UNIVERSITY OF NEBRASKA LINCOLN

The Department of Computer Science and Engineering (CSE) invites applications and nominations for the position of department chair. CSE has 20 faculty, 350 undergraduates, and 94 grad students. The department offers degrees in Computer Science and Computer Engineering, with programs leading to the B.S., M.S., and Ph.D. CSE has internationally recognized research programs and seeks to further improve its standing in communication theory and foundations; performance, dependability, and security in distributed systems; signal processing and image understanding; and human centered systems and multimedia.

The University of Nebraska-Lincoln (UNL) is the state’s land grant institution and premiere research campus. UNL has approximately 24,000 students. UNL is committed to a pluralistic campus community through Affirmative Action and Equal Opportunity and is responsive to the needs of dual career couples. We assure reasonable accommodation under the Americans with Disabilities Act. Contact Dr. Samuel B. Treves at 402-472-0872 for assistance.

Qualifications: an earned doctorate in computer science, computer engineering or a closely related field, strong leadership for research and academic programs, and credentials appropriate for appointment as a tenured full professor. The candidate’s academic credentials or background should permit him/her to be a credible and effective advocate for CSE in both the College of Arts and Sciences and the College of Engineering and Technology.

Application screening will begin January 15, 1997, and continue until the position is filled. Salary will be commensurate with qualifications. Women and minorities are particularly encouraged to apply.

For a complete job announcement, details of the application process, and additional information about CSE and UNL, please visit http://http.cs.unl.edu/ or contact Dr. Samuel B. Treves at 402-472-0872 or strevess@unlinfo.unl.edu.

NEVADA
UNIVERSITY OF NEVADA, LAS VEGAS
Department of Mathematical Sciences

Pending budgetary approval, the Department of Mathematical Sciences at the University of Nevada, Las Vegas, will have four tenure-track positions open in four specific areas starting fall of 1997. Applicants must indicate the position they are applying for by addressing their application to the respective chair of the Search Committee for Position Number 1, 2, 3, or 4 applicable to them and as advertised below:

DECEMBER 1996
NOTICES OF THE AMS
1575
NEW JERSEY

RUTGERS UNIVERSITY-NEWARK
Assistant Professor of Mathematics

The Department of Mathematics and Computer Science invites applications for an anticipated tenure-track assistant professorship in pure mathematics to begin in September 1997. Applications for a higher-level appointment may be considered if a position becomes available. Candidates must have a Ph.D. and a strong research record, show outstanding promise for future work in mathematics, and demonstrate a commitment to effective teaching. Preference will be given to candidates with research interests related to those of faculty in the department.

Each candidate should include an AMS cover sheet and a curriculum vitae with the application. At least four letters of recommendation, one of which addresses teaching, should be sent in support of the application. The application and letters should be sent to:

Personnel Committee
Department of Mathematics and Computer Science
Rutgers University
Newark, NJ 07102

Applications received by December 16, 1996, will receive first consideration. Rutgers University is an Equal Opportunity/Affirmative Action Employer.

NEw HampshiRE

DARTMOUTH COLLEGE
John Wesley Young Research Instructorship in Mathematics

The John Wesley Young Research Instructorship is a two-year postdoctoral appointment for promising new or recent Ph.D.'s whose research interests overlap a department member's. Current departmental interests include areas in algebra, analysis, combinatorics, differential geometry, logic and set theory, number theory, probability, and topology. Teaching duties of four-ten-week courses spread over two or three quarters typically include at least one course in the instructor's specialty and include elements of advanced, advanced, and (instructor's option) graduate courses. Nine-month salary of $38,000 supplemented by summer research stipend of $8,444 for instructors in residence for two months in summer. Send letter of application, résumé, graduate transcript, thesis abstract, description of other research activities and interests if appropriate, and three or preferably four letters of recommendation (at least one should discuss teaching) to Betty Harrington, Department of Mathematics, 6188 Bradley Hall, Hanover, NH 03755-3551. Applications received by January 15 receive first consideration; applications will be accepted until position is filled. Dartmouth College is committed to Affirmative Action and strongly encourages applications from minorities and women.

NEW MEXICO

THE UNIVERSITY OF NEW MEXICO
Albuquerque, New Mexico
Department of Mathematics and Statistics

Subject to administrative and budgetary approval, the department anticipates that two tenure-track appointments will be made in the fall of 1997.

One appointment is to be in applied mathematics. We are interested in outstanding candidates at the assistant professor level in applied analysis. Preference will be given to applicants with research interests in the areas of fluid dynamics, solid mechanics, material sciences, or mathematical biology, but other areas of applied analysis will also be considered. Exceptionally well-qualified senior candidates may also be considered. Minimal qualifications include a Ph.D. in applied mathematics or mathematics and postdoctoral experience. Selection criteria include research accomplishments as well as potential interactions and contributions to the research interests of the department and its educational program.

Another appointment is to be in pure mathematics. Preference will be given to
outstanding candidates at the assistant professor level in C*-algebras, dynamical systems, K-theory, number theory or several complex variables. Exceptionally well-qualified senior candidates may also be considered. Minimal qualifications include a Ph.D. and postdoctoral experience. Selection criteria include research accomplishments in mathematics, as well as potential interactions and contributions to the research interests of the department and its educational program.

The department currently has thirty-three faculty members and an active and expanding graduate program. Many faculty members have research ties with Los Alamos and Sandia National Laboratories. The department is closely associated with Maui HPCC, a national center committed to the development of scalable processing technologies. Further information is available at http://www.math.unm.edu/.

Applicants should send a curriculum vitae and arrange to have three letters of recommendation sent to:

Search Committee, (specify applied or pure)
Department of Mathematics and Statistics
The University of New Mexico
Albuquerque, NM 87131.

To assure full consideration, complete applications including letters of recommendation must be received by January 10, 1997. Candidates providing an electronic address will be informed when their application is complete. The University of New Mexico is an Equal Opportunity and Affirmative Action Employer.

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NEW YORK

NAZARETH COLLEGE
Department of Mathematics & Computer Science

Nazareth College invites applications for a tenure-track position in mathematics, effective fall 1997. Doctorate in mathematics and demonstrated interest and excellence in teaching required. Responsibilities include 4 courses per semester (at various levels) and continued scholarly growth. Preference to qualified candidates committed to the "reform" movement in undergraduate mathematics; preparation of mathematics teachers; the ability and desire to direct student research activities; and an interest in applied areas such as probability, statistics, modeling, and numerical analysis. Nazareth College is a thriving, independent, coeducational, liberal arts college with an undergraduate student body of approximately 1,400. The College is located near Rochester, New York, the third largest city in the state. Rochester is noted for its cultural diversity. Salaries are competitive.

Letter of application, philosophy of teaching, résumé, transcripts, and three letters of reference, at least one of which addresses teaching history/potential, should be sent to: Professor Nelson Rich, Mathematics Search Committee, Nazareth College, 4245 East Avenue, Rochester, NY 14618-3795; e-mail: rich@naz.edu. We will be interviewing at the Employment Register at the January AMS/MAA Joint Meetings in San Diego. Please indicate in your cover letter if you also will be interviewing there. Applications will be considered as received until the position is filled.

RENSSELAER POLYTECHNIC INSTITUTE
Department of Mathematical Sciences

Applications are invited for a tenure-track assistant professor position in applied mathematics, to begin in August 1997. Applicants are expected to have demonstrated outstanding research potential and to have a strong interest and ability in teaching. Applicants should submit a letter of application, curriculum vitae, a description of research interests, and three letters of recommendation to: Mark H. Holmes, Chair, Department of Mathematical Sciences, Rensselaer Polytechnic Institute, Troy, NY 12180. Evaluation of applications will begin December 15, 1996.

Rensselaer is an Equal Opportunity/Affirmative Action Employer and strongly encourages applications from women and underrepresented minorities.

STATE UNIVERSITY OF NEW YORK COLLEGE AT POTSDAM
44 Pierrepont Avenue
Potsdam, New York 13676-2294

Assistant Professor—Mathematics: The State University of New York College at Potsdam, the oldest higher-education institution in the SUNY system, invites applications for one (possibly two) full-time tenure-track position(s) effective September 1, 1997, at the rank of assistant professor. Responsibilities of the positions are to teach twelve hours per semester of undergraduate and first-year graduate courses. Required qualifications are a Ph.D. in any area of mathematics with a strong interest in preparation for teaching undergraduate major mathematics courses. In addition, some preparation in statistics is desirable though not essential. Applications, which must include a letter of interest, a statement of the applicant's philosophy of teaching, a résumé, three letters of recommendation describing teaching experience and abilities, and a transcript (a copy is acceptable) should be sent to Dr. Cheryl Chute Miller, Staffing Committee Chair, Mathematics Department, SUNY Potsdam, Potsdam, NY 13676 (millercc@potsdam.ed). To ensure full consideration, complete applications must be received by January 22, 1997. SUNY Potsdam is an Equal Opportunity/Affirmative Action Employer committed to excellence through diversity.

NEW YORK UNIVERSITY
Courant Institute of Mathematical Sciences

The Courant Mathematics and Computing Laboratory (CMCL) of the Courant Institute expects to have a postdoctoral research fellowship available starting on or around January 1, 1997.

The CMCL has ongoing research activities in a number of areas of computational mathematics, including combustion, heat transfer, computational fluid dynamics, and materials science. Our interests range from applied analysis to the development of numerical algorithms and software for a variety of advanced computer architectures.

The fellowship is supported by the DOE Office of Energy Research, through the division of Mathematical, Information and Computational Sciences.

Interested candidates should send a résumé, research statement, preprints or thesis if available, and three letters of recommendation to: Peter Lax, Chair, DOE Fellowship Committee, Courant Institute, 251 Mercer Street, New York, NY 10012.

The Courant Institute/New York University is an Equal Opportunity, Affirmative Action Employer.

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NORTH CAROLINA

WAKE FOREST UNIVERSITY
Department of Mathematics and Computer Science

Applications are invited for a tenure-track position in mathematics at the assistant professor level, beginning August 1997. Duties include teaching mathematics at the undergraduate and graduate levels and continuing research. A Ph.D. is required. Only applicants whose research expertise is in topology or geometry will be considered. Women and minorities are encouraged to apply. The department has twenty-four faculty members and offers a B.S. and M.A. in mathematics and a B.S. and M.S. in computer science. Send a letter of application and résumé to Richard D. Carmichael, Chair, Department of Mathematics and Computer Science, Wake Forest University, P.O. Box 7388, Winston-Salem, NC 27109-7388. AA/EO Employer.

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WAKE FOREST UNIVERSITY
Department of Mathematics and Computer Science

Applications are invited for two positions as instructor or visiting assistant professor of mathematics. The terms are one
year, renewable for up to three years. Rank is dependent upon qualifications, and a Master's or Ph.D. degree in mathematics or statistics is required. Duties consist only of teaching three courses per semester. A strong interest and preparation for teaching calculus and introductory statistics is desirable. The department has 24 members, offers a B.S. and M.A. in mathematics, and a B.S. and M.S. in computer science. Send a letter of application and résumé to Richard D. Carmichael, Chairman, Department of Mathematics and Computer Science, Wake Forest University, Box 7388, Winston-Salem, NC 27109. AA/EO Employer.

DUKE UNIVERSITY

Applications and nominations are invited for one tenure-track position as assistant professor in pure or applied mathematics. Salary is open; the position is to start September 1, 1997.

Applicants please send (a) a completed application cover sheet (available in the September 1996 edition of the Notices of the AMS); (b) a vita; (c) a description of past research (1-3 pages); and (d) plan for future research.

Applications should be filed by December 15; early application is advisable. The applicant should have at least three letters of recommendation, including one which evaluates teaching, sent directly to Duke by mid-January. All correspondence, including references, should be addressed to:

Faculty Search Committee
Department of Mathematics
Box 90321
Duke University
Durham, NC 27708-0321

Duke University is an Affirmative Action/Equal Opportunity Employer.

OHIO

MUSKINGUM COLLEGE
Mathematics/Physics

Tenure-track position at assistant professor rank to teach a range of mathematics courses as well as several physics courses per year, beginning late August 1997. Must have a Ph.D. in mathematics by August 1997, a Bachelor's degree in physics, significant graduate coursework in physics, and teaching experience at the college or university level. For full consideration, applications must be received by January 20, 1997. Please send letter, vita, copies of transcripts, and three letters of recommendation to Dr. David Craft, Department of Mathematics and Computer Science, Muskingum College, New Concord, OH 43762. EOE. e-mail: craft@muskingum.edu.

OKLAHOMA

OKLAHOMA STATE UNIVERSITY
Department of Mathematics

Postdoctoral Positions

The department invites applications for several temporary postdoctoral positions beginning fall 1997. The appointments are for new or recent recipients of the Ph.D. and have an expected appointment term of two years. Applications are welcome from individuals who have held postdoctoral appointments; an appointment to one of these positions does not exclude an individual from future consideration for a tenure-track position. The duties incorporate a blend of research and teaching; the usual teaching load is 5 or 6 hours each semester. Applicants should submit a curriculum vitae, abstracts of completed research, a statement regarding teaching experience and philosophy, and three letters of recommendation to the address below. One letter of recommendation should address the applicant's teaching experience. Mathematicians with research interest close to that of a member of the regular faculty will receive preference. Applicants should use the AMS standardized form, Academic Employment in Mathematics Application Cover Sheet, and indicate their subject area using the AMS subject classification numbers.

Oklahoma State University is located in Stillwater, a town of approximately forty thousand in north central Oklahoma. The department boasts a very dynamic faculty, with over 40 members successfully engaged in mathematics research and education. An active Ph.D. program, support for colloquium speakers and other visitors, approximately 6-8 postdoctoral fellows, as well as involvement of undergraduates in research experiences add to the lively and scholarly atmosphere of the department. The department has received national recognition for the research of its faculty and for the faculty's contributions to mathematics education. More information on the department and university can be obtained through its Web page, http://www.math.okstate.edu/. Decisions will be made soon after January 1, 1997; however, full consideration will be given to applications until all positions are filled. Application materials should be sent to the address below. Electronic applications are encouraged and may be sent to mathposition@math.okstate.edu. Oklahoma State University is an Equal Opportunity/Affirmative Action Employer.

Professor William Jaco, Chair
Appointments Committee
Department of Mathematics
Oklahoma State University
Stillwater, OK 74078

OKLAHOMA STATE UNIVERSITY
Department of Mathematics

Tenure-track or Tenured Positions

The Department invites nominations and applications for tenure-track (assistant or associate professor-level) or tenured (associate or full professor-level) positions beginning fall 1997. Tenure-track applicants should have demonstrated outstanding research potential and have made major contributions beyond their doctoral dissertations. Applicants for a tenured position should have demonstrated past leadership in research. Duties include a blend of research and teaching, and all applicants should have a commitment to excellence in undergraduate and graduate education; the usual teaching load is 5 or 6 hours each semester. The Department has several research groups, and preference will be given to applicants with research interests related to one or more of these groups.

Tenure-Track Positions. Applicants should submit a curriculum vitae, abstracts of completed research, and a statement regarding teaching experience and philosophy, and four letters of recommendation.
to the address below. One letter of recommendation should address the applicant's teaching experience. Applicants for a tenure-track position are responsible for having letters of recommendation sent to the Department.

Tenured Positions. Applicants should submit a curriculum vitae including a list of publications, abstracts of selected completed research, a statement regarding educational philosophy, and the names and addresses of three individuals who may be contacted for recommendations. Letters of recommendation for individuals applying for only a tenured position do not need to be sent; the Department will solicit needed letters of recommendation.

Oklahoma State University is located in Stillwater, a town of approximately forty thousand in north central Oklahoma. The Department boasts a very dynamic faculty, with over 40 members successfully engaged in mathematics research and education. An active Ph.D. program, support for colloquium speakers and other visitors, approximately 6-8 postdoctoral fellows, as well as involvement of undergraduates in research experiences add to the lively and scholarly atmosphere of the Department. The Department has received national recognition for the research of its faculty and for the faculty's contributions to mathematics education. More information on the Department and University can be obtained through its Web page, http://www.math.okstate.edu.

Applicants should use the AMS standardized form, Academic Employment Application Cover Sheet, and indicate their subject area using the AMS subject classification numbers. Consideration of applications will begin December 15, 1996; however, full consideration will be given to all applications until the available positions are filled. Application materials should be sent to the address below. Electronic applications are encouraged and may be sent to mathposition@math.okstate.edu. Oklahoma State University is an Equal Opportunity/Affirmative Action Employer.

Professor William Jaco, Chair
Appointments Committee
Department of Mathematics
Oklahoma State University
Stillwater, OK 74078

THE UNIVERSITY OF OKLAHOMA
Department of Mathematics

The department invites applications for a tenure-track assistant professor position in mathematics beginning August, 1997. Candidates must have a Ph.D. or equivalent degree in mathematics and demonstrate potential for excellence in both research and teaching. Preference will be given to candidates whose research interests are compatible with existing faculty in the area of algebra, analysis/applied math, geometry and topology. Postdoctoral experience is desirable but not essential. Faculty members normally teach two classes each semester, do research, and contribute university and department service appropriate to their experience. Salary will be commensurate with qualifications and experience. For full consideration send a completed AMS Cover Sheet, curriculum vitae, and a description of current and planned research; and have three letters of recommendation, at least one of which discusses the candidate's teaching, sent by January 15, 1997. Applications will be considered until the position is filled. All correspondence should be addressed to: Search Committee, Department of Mathematics, University of Oklahoma, 601 Elm, Phsc 423, Norman, OK 73019-0315. Telephone 405-325-6711; fax 405-325-7484; e-mail: search@math.ou.edu. The University of Oklahoma is an Equal Opportunity/Affirmative Action Employer.

OREGON
UNIVERSITY OF OREGON
Department of Mathematics

Assistant professor tenure-track position in pure mathematics or statistics beginning September 1997. Qualifications are a Ph.D. in mathematics or statistics, a strong record of research accomplishment, and evidence of teaching ability. Preference given to candidates with research interests that complement those currently represented. Competitive salary with excellent fringe benefits. Send complete résumé and three letters of recommendation. Closing date is January 3, 1997. Women and minorities are encouraged to apply. An Equal Opportunity/Affirmative Action Employer.

Professor Gary Seitz, Chair
Department of Mathematics
University of Oregon
Eugene, OR 97403
E-mail: seitz@math.uoregon.edu

PA
CARNEGIE MELLON UNIVERSITY
Department of Mathematical Sciences
Richard J. Duffin and Zeev Nehari Visiting Assistant Professorships

The Richard J. Duffin Visiting Assistant Professorship and the Zeev Nehari Visiting Assistant Professorship were established to honor Professor Emeritus Duffin and the memory of Professor Nehari, both of whom had long and distinguished careers in the Department of Mathematical Sciences. Each position is available for a period of three years, beginning in September 1997, and carries a reduced academic-year teaching load of six hours a week during one semester and three hours a week during the other. Applicants are expected to show exceptional research promise, as well as clear evidence of achievement, and should have research interests which intersect those of current faculty of the department. Applicants should send a vita, list of publications, a statement describing current and planned research, and three letters of recommendation to the committee. All communications should be addressed to: Appointments Committee, Department of Mathematical Sciences, Carnegie Mellon University, Pittsburgh, PA 15213. Carnegie Mellon University is an Affirmative Action/Equal Opportunity Employer.

PENN STATE ERIE, BEHREND COLLEGE
Mathematics Faculty Position: A tenure-track assistant professor position beginning fall 1997. Candidates must have a strong commitment to undergraduate teaching. We seek applicants in an area of pure mathematics whose research interests complement those of our applied mathematics group (e.g., dynamical systems or applied analysis). The successful candidate will be expected to seek external funding and to develop a research program involving undergraduates. Ph.D. required; postdoctoral and teaching experience desirable. Behrend is a 4-year and graduate college offering the B.S. in mathematics within the Penn State system. Application deadline is January 10, 1997. Send résumé, transcripts, a brief description of research interests, a teaching statement, and arrange that three letters of reference be sent to Dr. Roger Knacke, Division of Science, Department MATH-N2, The Pennsylvania State University at Erie, Erie, PA 16563-0203.


RHODE ISLAND
BROWN UNIVERSITY
J. D. Tamarkin Assistant Professorship

Three-year nontenure, nonrenewable appointment, beginning July 1, 1997. Teaching load: two courses per semester (6 hours per week). Applicants (regardless of age) should have received the Ph.D. degree before the start of the appointment, but no earlier than January 1, 1995. Applicants should have strong research potential and a commitment to teaching. Field of research interest will be taken into account. A curriculum vitae, a completed application form, and three letters of recommendation should be received by December 31, 1996. Requests for application forms and all other inquiries should be addressed to Tamarkin Search Committee, Department of Mathematics, Brown University, Providence, RI 02912. Brown University is an
Equal Opportunity/Affirmative Action Employer and encourages applications from women and minorities.

SOUTH CAROLINA

COLLEGE OF CHARLESTON
Department of Mathematics

Applications are invited for at least three tenure-track positions in mathematics at the assistant professor level starting in August 1997. The Mathematics Department at the College of Charleston has twenty-eight full-time faculty and offers the B.S. and M.S. degrees in mathematics. Candidates must have a Ph.D. in one of the mathematical sciences, a commitment to undergraduate and graduate teaching, and potential for outstanding research. Preference will be given to candidates who would add a strong applied or computational component to our existing faculty. Preference for two of the positions will be given to applicants in statistics and those in some area of computational mathematics. The normal teaching load is 9 hours per week for those engaged in research. The salary is competitive. Faculty from the College of Charleston will be available to meet with applicants at the AMS/MAA Annual Meeting in San Diego. Applicants should send a vita and three letters of recommendation sent to Deanna Caveny, Chair, Department of Mathematics, College of Charleston, Charleston, SC 29424-0001. Questions or requests for additional information may be addressed to caveny@math.cofc.edu. The process of evaluating applications will begin on January 13, 1997, but applications will be considered until the positions are filled. The College of Charleston is an Equal Opportunity/Affirmative Action Employer and encourages applications from minority and women candidates.

TEXAS

RICE UNIVERSITY

Griffith Conrad Evans Instructorships

Postdoctoral appointments for two to three years for promising research mathematicians with research interests in common with the active research areas at Rice, particularly geometric topology, geometric analysis, differential geometry, mathematical physics, and ergodic theory. Duties will include research and classroom teaching. Applications received by December 31, 1996, will receive full consideration. Rice University is an Equal Opportunity/Affirmative Action Employer and strongly encourages applications from women and minority group members. Inquiries and applications should be addressed to Chair, Evans Committee, Department of Mathematics, Rice University, P.O. Box 1892, Houston, TX 77251-1892. Submitting the AMS Application Cover Sheet (available in Notices, EIMS, or e-MATH) would be greatly appreciated.

TEXAS A&M UNIVERSITY

Department of Mathematics

Applications are invited for tenure-track/tenured faculty positions beginning fall 1997.

Field is open, but we particularly seek applications from individuals whose mathematical interests would act as a bridge between some of our current research groups or who would add a strong applied or computational component to our existing strengths.

For a senior position the applicant should have an outstanding research reputation and would be expected to fill a leadership role in the department. An established research program, including success in attracting external funding and supervision of graduate students, and a demonstrated ability and interest in teaching are required.

For an assistant professorship, we seek strong research potential and evidence of excellence in teaching. Research productivity beyond the doctoral dissertation will normally be expected.

In order to expedite the application process we request that the AMS Application Cover Sheet be used. Applicants should send the completed form, a vita, and letters of recommendation sent to:

Faculty Hiring
Department of Mathematics
Texas A&M University
College Station, Texas 77843-3368

Our URL is http://www.math.tamu.edu/.

Texas A&M University is an EOE/AA employer, and the department encourages applications from women and minorities.

TENNESSEE

VANDERBILT UNIVERSITY
Department of Mathematics

We anticipate a non-tenure-track opening in algebra at the assistant professor level beginning fall 1997. This position carries an initial two-year appointment and is normally renewable for a third year. It is intended for a recent Ph.D. recipient with outstanding research potential and a strong commitment to teaching who would like to spend time in a department with a vigorous research atmosphere. Only specialists in algebra need to apply for this position, and strong preference will be given to applicants with research interests in universal algebra and lattice theory, set-theoretic algebra, abelian groups, semigroups, ring theory, and logic with applications to computer science. To apply, send the following materials in a single mailing by 12/20/96: letter of application (including e-mail address and fax number if available), curriculum vitae, and brief research summary. Additional information, including letters of recommendation, will be requested from selected candidates after an initial screening. Only solicited letters of recommendation will be accepted.

Vanderbilt University is an Equal Opportunity/Affirmative Action Employer.

TEXAS A&M UNIVERSITY

Visiting Positions in Mathematics

The department expects to have several visiting appointments available beginning fall 1997. Senior positions may be for a semester or one-year period. Junior positions will be for a two-year period and are intended for those who have recently received their Ph.D.

The expectation is for collaborative efforts with our existing faculty. Candidates should identify in their application the permanent department members or groups with which they have close research interests.

Application materials must include an application letter, a vita, and three letters of recommendation. Junior candidates must present evidence of teaching ability and experience and include a statement of research goals. In order to facilitate the process we request that applicants use the AMS Application Cover Sheet. For full consideration, the complete dossier should be sent by January 15, 1997, to:

Visiting Appointments
Department of Mathematics
Texas A&M University
College Station, Texas 77843-3368

Our URL is http://www.math.tamu.edu/.

There will be two research instructorships that are specifically targeted to geometry, analysis, and topology. These will be for a period of two years, carry a two-course-per-year teaching load, and a stipend of $35,000 for the academic year. Additional information is available at http://search.tamu.edu/programs/research/GAT/. Applicants for these positions should mark their letters for the attention of the Research Group in Geometry at the above address.

Texas A&M University is an EOE/AA employer, and the department encourages applications from women and minorities.

TEXAS TECH UNIVERSITY
Department of Mathematics

The Department of Mathematics anticipates at least one and possibly three tenure-track appointments at the assistant professor level, beginning fall, 1997. All fields will be considered but candidates in the areas of algebraic geometry, combinatorics, computational mathematics and biomathematics/statistics are especially invited to apply. Candidates must have an earned doctorate by the starting date and show evidence of excellence in teaching and strong research potential.
Applicants should exhibit research interests that complement ongoing programs in the department and a willingness and ability to work with students at both the undergraduate and graduate level.

To apply, please send a résumé and have three letters of recommendation sent to Lawrence Schovanec, Chair of the Hiring Committee, Department of Mathematics, Texas Tech University, P.O. Box 41042, Lubbock, TX 79409. e-mail: schov@math.ttu.edu. Texas Tech is an Equal Opportunity/Affirmative Action Employer.

UNIVERSITY OF TEXAS AT ARLINGTON
Department of Mathematics

The department invites applications for a position of assistant professor in mathematics education. The candidates must show strong potential for excellence in teaching and research in math education. The department is seeking to extend its expertise in the areas of undergraduate mathematics; mathematics programs for future elementary, middle, and secondary teachers; and Master's and Ph.D. degrees in mathematics education. The University of Texas at Arlington is a comprehensive research institution of over 22,000 students located midway between Dallas and Fort Worth. UT Arlington has an established national program for in-service teachers and serves as host site for T³, Teachers Teaching with Technology.

Please send résumé and three letters of recommendation to: Chairperson, Faculty Recruiting Committee, University of Texas at Arlington, Department of Mathematics, Box 19408, Arlington, TX 76019-0408. Application deadline is January 15, 1997.

The University of Texas at Arlington is an Affirmative Action/Equal Opportunity Employer.

THE UNIVERSITY OF TEXAS AT AUSTIN
Department of Mathematics

Austin, Texas 78712

Openings for fall 1997 include a number of instructorships, some of which have R. H. Bing Faculty Fellowships attached to them, and two or more positions at the tenure-track/tenure level.

Instructorships: The University of Texas at Austin are postdoctoral appointments, renewable for two additional years. It is assumed that applicants for instructorships will have completed all Ph.D. requirements by August 31, 1997. Other factors being equal, preference will be given to those whose doctorates were conferred in 1996 or 1997. Candidates should show superior research ability and have a strong commitment to teaching. Consideration will be given only to persons whose research interests have some overlap with those of the permanent faculty. Duties consist of teaching undergraduate or graduate courses and conducting independent research. The projected salary is $33,500 for the nine-month academic year.

Each R. H. Bing fellow holds an instructorship in the mathematics department, with a teaching load of two courses in one semester and one course in the other. The combined instructorship-fellowship stipend for nine months is $36,500, which is supplemented by a travel allowance of $1,000. Pending satisfactory performance of teaching duties, the fellowship can be renewed for two additional years. Applicants must show outstanding promise in research. Bing Fellowship applicants will automatically be considered for other departmental openings at the postdoctoral level, so a separate application for such a position is unnecessary.

An applicant for a tenure-track or tenured position must present a record of exceptional achievement in her or his research area and must demonstrate a proficiency at teaching. In addition to the duties indicated above for instructors, such an appointment will typically entail the supervision of M.A. or Ph.D. students. The salary will be commensurate with the level at which the position is filled and the qualifications of the person who fills it.

Those wishing to apply for any of the aforementioned positions are asked to send a vita and a brief research summary to the above address, c/o Recruiting Committee. Transmission of the preceding items via e-mail (address: recruit@math.utexas.edu) is encouraged. Applications must be supported by three or more letters of recommendation, at least one of which speaks to the applicant's teaching credentials. The screening of applications will begin on December 1, 1996.

The University of Texas at Austin is an Equal Opportunity Employer.

UTAH

UTAH STATE UNIVERSITY
Department of Mathematics and Statistics

Applications are invited for a tenure-track position at the assistant professor level, to begin September 1997. Requirements include a Ph.D. (by September 1997) in mathematics with a strong research record/potential in a currently active area of topology. Applicants with recent postdoctoral experience are especially encouraged to apply. All applicants should send a current résumé, together with a completed AMS Standard Cover Sheet, and four letters of reference, with one letter addressing teaching history/potential, to Mathematics Search Committee Department of Mathematics and Statistics Utah State University Logan, Utah 84322-3900

The search committee review process will begin on January 15, 1997, and the position will remain open until filled.

Utah State University, with a student body of 20,000, is located in Logan, Utah, in the Wasatch Range of the Rocky Mountains. The university offers competitive salaries and excellent medical, retirement, and professional benefits.

General information about the department can be found at Web site http://www.math.usu.edu/ and information regarding professional amenities and benefits at Utah State University can be found at http://www.usu.edu/~persinfo/jobs.htm. Utah State University is an Equal Opportunity/Affirmative Action Employer.

VIRGINIA

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Department of Mathematics

Applications are solicited for a tenure-track assistant professorship in combinatorics/discrete mathematics. Candidates must have a Ph.D. in mathematics or the equivalent and must demonstrate strength in research and teaching. Preference will be given to applicants with postdoctoral experience. The department seeks candidates who will interact well with research groups in computational algebra and representation theory.

Please send the AMS Standard Cover Sheet, a letter of application, curriculum vitae, and summary of research plans to: Combinatorics Search Committee Department of Mathematics Virginia Tech Blacksburg, VA 24061-0123

Four letters of recommendation, including one which focuses on teaching skills, should be sent to the same address. Review of applications will begin on December 15, 1996, and will continue until the position is filled.

Virginia Tech has a strong commitment to the principle of diversity and, in that spirit, seeks a broad spectrum of candidates, including women, minorities, and people with disabilities. Individuals with special needs desiring accommodations in the application process should contact Ezra Brown, Department of Mathematics; brown@math.vt.edu; 540-231-6950 (TDD/PC 1-800-828-1120 or Voice 1-800-828-1140).

WASHINGTON

UNIVERSITY OF WASHINGTON
Department of Mathematics

Applications are invited for several positions starting September 1997. There is one three-year non-tenure-track acting assistant professorship available. There are
also two positions initially budgeted as tenure-track assistant professorships, but sufficiently outstanding candidates may be considered at the associate professor or professor level. Applicants must have the Ph.D. degree in hand by the starting date. Duties include undergraduate and graduate teaching and independent research. Applications should include a curriculum vitae, statement of research and teaching interests, three letters of recommendation, and a Mathematics Subject Classification (as found in the December index volumes of *Mathematical Reviews*) of their primary research interest.

Applications should be sent to: Appointments Committee Chair, Department of Mathematics, Box 354350, University of Washington, Seattle, WA 98195-4350. Priority will be given to applications received by December 15, 1996. The University of Washington is building a culturally diverse faculty and strongly encourages applications from female and minority candidates. The University is an Equal Opportunity/Affirmative Action Employer. Availability of positions is subject to budgetary approval.

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**WESTERN WASHINGTON UNIVERSITY**

**Tenure-Track Position: Mathematics**

Begin fall 1997. Candidates with interests in modelling (particularly biological sciences) are particularly welcome, but strong candidates in other areas will be considered. Ph.D. and evidence of effective teaching required. Independent grant-funded research expected. Commitment to innovative undergraduate instruction essential. Teaching assignments include large lower-division classes. WWU has 500 faculty and 12,000 students beside Bellingham Bay between Seattle and Vancouver, with access to excellent recreational opportunities and metropolitan facilities. Obtain Position Announcement and WWU summary sheet from http://www.math.washington.edu/conf/ or address below, and submit WWU summary sheet, AMS Cover Sheet, vita, transcripts, description of research and teaching accomplishments and interests, and four letters of recommendation addressing both teaching and research by January 17, 1997, to: Search Committee, Math, Western Washington University, Bellingham, WA 98225-9063. Fax: 360-650-7788. Tel: 360-650-3785. E-mail: mathdept@cc.wwu.edu. No electronic applications. AA/EOE.

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**WYOMING**

**UNIVERSITY OF WYOMING**

The Department of Mathematics invites applications for tenure-track assistant professorships in applied mathematics. We seek candidates with an earned doctorate, proven teaching ability, and strong research in areas of interest in the department, including numerical analysis and the mathematics of porous-media flows. Applications received by January 15, 1997, will receive first consideration. For more information, visit our Web site, http://math.uwyce.edu/.

The University of Wyoming is an Equal Opportunity Employer, and we welcome applications from women and underrepresented minorities. Please send vita, three letters of reference, and a statement of teaching qualifications to Myron B. Allen, Head, Department of Mathematics, University of Wyoming, Laramie, WY 82071.

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**CANADA**

**McMASTER UNIVERSITY**

**Department of Mathematics & Statistics**

**Britton Postdoctoral Fellowship in Mathematics**

Applications are invited for the Britton Postdoctoral Fellowship in Mathematics. Named after Dr. Ronald Britton, the Britton Fellowship is intended for talented research mathematicians with a recent Ph.D.

The Britton Fellowship is open to candidates of any nationality, and selection will be based upon the candidate's research potential. In this year's competition, preference will be given to candidates working in algebraic K-theory and arithmetic, with emphasis on applications to the Beilinson conjectures.

McMaster is committed to Employment Equity and encourages applications from all qualified candidates, including aboriginal peoples, persons with disabilities, members of visible minorities, and women.

Starting July 1, 1997, the stipend will be $34,000 plus a $2,000 grant for research expenses.

Applications and three letters of reference should be sent by January 15, 1997, to:

Dr. C. R. Riehm, Acting Chair
Mathematics & Statistics
McMaster University
Hamilton, Ontario, Canada L8S 4K1

All replies this advertisement are appreciated, but only those applicants being seriously considered will be contacted.

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**QUEEN'S UNIVERSITY AT KINGSTON**

**Department of Mathematics and Statistics**

The department will be making a renewable (tenure-track) appointment in applied mathematics for its mathematics and engineering program at the assistant professor level to begin July 1997. Membership or eligibility for membership in a Canadian professional engineering association is required. The department is particularly interested in applicants in communications theory or information theory, but other areas will be considered. The successful applicant will have a strong research record, be expected to develop an independent research program, be willing and competent to teach a broad range of applied mathematics courses, and be willing to supervise graduate students.

Interested candidates should arrange that a curriculum vitae, a description of teaching and research interests, at least three letters of recommendation, and copies of their three most significant publications arrive at the address below before December 16, 1996. At least one letter should comment on the candidate's teaching.

Professor James A. Mingo, Associate Head
Department of Mathematics
In accordance with Canadian immigration requirements, this advertisement is directed to Canadian citizens and permanent residents. Queen's University has an Employment Equity program and encourages applications from all qualified candidates, including women, aboriginal peoples, people with disabilities, and visible minorities.

Fax: 613-545-2964; e-mail: position@ mast.queensu.ca. WWW: http://www.mast.queensu.ca.

FRANCE

UNIVERSITÉ DE LILLE I
URA CNRS
UFR de Mathématiques
59655 Villeneuve d’Ascq Cedex
France

The University of Lille expects to have two openings at the level of "Professeur d'université" (with tenure) starting September 1, 1997. The focus is mainly on algebraic geometry and algebraic topology. Teaching takes place in French.

We encourage applications from well-known specialists and from young outstanding mathematicians.

The hiring process takes place at the national level and starts usually at the end of December or beginning of January.

For more information on the application process contact: poste@gat.univ-lille1.fr.

GERMANY

MAX-PLANCK INSTITUTE FOR MATHEMATICS IN THE SCIENCES
Leipzig, Germany

Five-Year Visiting Professorship

This newly founded Max-Planck Institute invites applications for a distinguished five-year visiting research professorship in nonlinear partial differential equations. Applicants should have demonstrated outstanding research potential and clear evidence of achievement. The successful candidate will contribute actively to the new Institute’s profile as a centre at the interface of mathematics and the sciences, and candidates whose work has strong interaction with the sciences, in particular in the areas of continuum mechanics, phase transitions, or material science, are particularly encouraged to apply.

The Institute offers excellent research facilities, including a large visitor program. Salary will be on the German C3 scale (comparable to an associate professorship in North America). Applications should be sent to: Prof. Dr. E. Zeidler, Acting Director, Max-Planck Institute for Mathematics in the Sciences, Inselstr. 22-26, D-04103 Leipzig, Germany. The deadline for applications is January 31, 1997. Employment will start on October 1, 1997, or at a mutually agreeable date.

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44 Integral transforms, operational calculus
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68 Computer science
70 Mechanics of particles and systems
73 Mechanics of solids
76 Fluid mechanics
78 Optics, electromagnetic theory
80 Classical thermodynamics, heat transfer
81 Quantum theory
82 Statistical mechanics, structure of matter
83 Relativity and gravitational theory
85 Astronomy and astrophysics
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92 Biology and other natural sciences, behavioral sciences
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Application for Membership 1997
(January–December)

Date ........................................ 19

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EME Education/Mathematics Education
00 General
01 History and biography
03 Mathematical logic and foundations
04 Set theory
05 Combinatorics
06 Order, lattices, ordered algebraic structures
08 General algebraic systems
11 Number theory
12 Field theory and polynomials
13 Commutative rings and algebras
14 Algebraic geometry
15 Linear and multilinear algebra; matrix theory
16 Associative rings and algebras
17 Nonassociative rings and algebras
18 Category theory, homological algebra
19 K-theory
20 Group theory and generalizations
22 Topological groups, Lie groups
26 Real functions
28 Measure and integration
30 Functions of a complex variable
31 Potential theory
32 Several complex variables and analytic spaces
33 Special functions
34 Ordinary differential equations
35 Partial differential equations
39 Finite differences and functional equations
40 Sequences, series, summability
41 Approximations and expansions
42 Fourier analysis
43 Abstract harmonic analysis
44 Integral transforms, operational calculus
45 Integral equations
46 Functional analysis
47 Operator theory
49 Calculus of variations and optimal control; optimization
51 Geometry
52 Convex and discrete geometry
53 Differential geometry
54 General topology
55 Algebraic topology
57 Manifolds and cell complexes
58 Global analysis, analysis on manifolds
60 Probability theory and stochastic processes
62 Statistics
65 Numerical analysis
68 Computer science
70 Mechanics of particles and systems
73 Mechanics of solids
74 Fluid mechanics
78 Optics, electromagnetic theory
80 Classical thermodynamics, heat transfer
81 Quantum theory
82 Statistical mechanics, structure of matter
83 Relativity and gravitational theory
85 Astronomy and astrophysics
86 Geophysics
90 Economics, operations research, programming, games
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For ordinary members whose annual professional income is below $45,000, the dues are $93; for those whose annual professional income is $45,000 or more, the dues are $124.

The CMS cooperative rate applies to ordinary members of the AMS who are also members of the Canadian Mathematical Society and reside outside of the U.S. For members whose annual professional income is $45,000 or less, the dues are $79; for those whose annual professional income is above $45,000, the dues are $105.

For a joint family membership, one member pays ordinary dues, based on his or her income; the other pays ordinary dues based on his or her income, less $20. (Only the member paying full dues will receive the Notices and the Bulletin as a privilege of membership, but both members will be accorded all other privileges of membership.)

Minimum dues for contributing members are $186.

For either students or unemployed individuals, dues are $31, and annual verification is required.

The annual dues for reciprocity members who reside outside the U.S. and Canada are $92. To be eligible for this classification, members must belong to one of those foreign societies with which the AMS has established a reciprocity agreement, and annual verification is required. Reciprocity members who reside in the U.S. or Canada must pay ordinary member dues ($93 or $124).

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Members can purchase a multi-year membership by prepaying their current dues rate for either two, three, four or five years. This option is not available to ordinary members, unemployed, or student members.

1997 Dues Schedule (January through December)

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Reciprocity member (please verify)3 ................... $62 $93 $124

Category-S member4 .................................. $16

Multi-year membership ...................................... for years

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Meetings & Conferences of the AMS

San Diego, California
San Diego Convention Center
January 8–11, 1997

Meeting #918
Joint Mathematics Meetings, including 103rd Annual Meeting of the AMS, 80th Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM), the National Association of Mathematicians (NAM), and winter meeting of the Association for Symbolic Logic (ASL).

Associate secretary: Lesley M. Sibner
Announcement issue of Notices: October 1996
Program issue of Notices: January 1997
Issue of Abstracts: Volume 18, Issue 1

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired
For summaries of papers to MAA organizers: Expired

Program Updates
AMS Sessions
A Tribute to Paul Erdős: Friday, 7:00 p.m. to 9:00 p.m., organized by Joel H. Spencer, NYU-Courant Institute.

Other AMS Events
Discussion Sessions for Special Sessions: These informal gatherings may take place in the early evening hours after some of the Special Sessions. Details and a schedule will be published in the program.

Mathematical Reviews (MR), Reception: Friday, 6:00 p.m. to 7:00 p.m. All reviewers are encouraged to come to this reception, and others who are interested in MR are also invited. Members of the MR Editorial Committee and the MR staff will make some brief comments, and there will be an opportunity for reviewers to ask questions and make comments and suggestions. Refreshments will be provided.

MAA Sessions
In the discussion on Using Real-World Data To Motivate the Teaching and Learning of Mathematics on Wednesday panelists include David Lomen, University of Arizona; David Smith, Duke University; and John Kenelly, Clemson University; Sheldon Gordon, Suffolk Community College; and Mercedes McGowen, William Rainey Harper College. The session will be moderated by Florence Gordon.

In the discussion on Where Will Mathematics Be When the Sludge Hits the Fan? on Wednesday panelists include David L. Ferguson, SUNY, Stonybrook; Kay S. King, Theta Technologies; Rollie Lamphere, Humboldt State College; Chris Schaufele, Kennesaw State College; and Nancy Zumoff, Kennesaw State College. The moderator is Ben Fusaro, Florida State University. Panel members will address two contentions: 1) Society at large will be more inclined to support mathematics if it perceives that our field is engaged in solving crucial problems; and 2) Students will be more inclined to take the road to more mathematics if they see the environmental modeling potential of our discipline.

In the Roundtable Discussion with the Client Disciplines on Friday panelists include Ron Oaxaca, University of Arizona; John Prados, NSF/University of Tennessee; Wayne Roberge, Rensselaer Polytechnic Institute; and Michael Ruane, Boston University. Cosponsored by the MAA CUPM Subcommittee on Mathematics Across the Disciplines.

MAA's Newsletter Functions: Friday, 7:00 p.m. to 9:00 p.m. In May 1996 MAA President Ken Ross appointed an ad hoc committee, the Committee on the MAA's Newsletter Functions, and gave it the following charge: to study the newsletter needs of the Association and recommend ways of best meeting those needs through coordinated use of print and electronic media. Perhaps the overriding policy question raised by this charge is: Should the role and scope of FOCUS, hitherto the MAA's principal medium for the dissemination of news to its membership, be restructured in the interest of greater cost effectiveness and some of its traditional content shifted to MAA Online, the Association's site on the World Wide Web? There are also a
number of important satellite issues surrounding this question (e.g., How broadly is the term "MAA news" to be construed?). This panel discussion, organized by Bruce Palka, University of Texas, is intended to stimulate debate on these issues.

**Shaping the Future: New Expectations in Undergraduate Science, Mathematics, Engineering, and Technology Education:** Friday, 7:00 p.m. to 9:00 p.m. Panelists include Mel George, University of Minnesota; David Sanchez, Texas A&M University; and Alan Tucker, SUNY-Stony Brook. An advisory group to NSF has completed a national review of undergraduate science, mathematics, engineering, and technology education. The report identifies advances which have been made in undergraduate SME&T education and barriers to improvement. The report also includes recommendations to the NSF and the community at large. This session will provide a forum to discuss the report and recommendations, focusing on implications for the mathematics community. Copies of report will be available.

**The Diaries of a Victorian Mathematician:** Friday, 5:30 p.m. to 6:20 p.m. In this 50-minute presentation, Thomas Archer Hirst (1830–1892) in full Victorian costume talks about his life and work and the people (Gauss, Dirichlet, Darwin, Faraday, Cayley, Klein, Chebyshev,...) that he met. Illustrated with seventy slides, this presentation involves some audience involvement and is based on articles in the American Mathematical Monthly, May–December, 1993, vol. 100. This dramatic presentation will be made by Robin Wilson and John Fauvel.

In the College Algebra Reform on Friday, additional panelists are Benny Evans, Oklahoma State University; and Raymond Hicks, Grambling State University.

**Other MAA Events**

**Life After Retirement:** Wednesday, 2:15 p.m. to 5:15 p.m. This three-hour seminar will explore options and activities of interest to retirees and those considering retirement. A panel of retired mathematics professors, organized by Andy Sterrett, MAA, will discuss how they have kept themselves active both professionally and personally.

Retirement financial planning may involve a change of investment strategy. A certified financial planner will talk about the best approaches to various investment opportunities at this time of life. Plus, a member of the Estate Planning Attorneys Association will present ways to approach estate planning along with your investment strategy.

**Concert:** Saturday, 9:30 p.m. This delightful event will feature Leonard Gillman, University of Texas, Austin, and Louis Rowen, Bar-Ilan University, playing the Chopin sonata for piano and cello.

**Other Organizations**

**Board on Mathematical Sciences (BMS)**

**Actions for the Mathematical Sciences: Preserving Strength While Meeting Challenges:** Wednesday, 10 a.m. to 10:55 a.m. John R. Tucker, Board on Mathematical Sciences, will conduct this session based on the May 17–19, 1996, BMS workshop and its soon-to-be-released report. The workshop's goal was to lead the mathematical sciences community in productive directions that reflect and respond to the new imperatives facing the scientific community at large and all of society as a result of recent changes in the national and international economic and political arenas. Based on information provided by invited workshop speakers and participants' own considerable experience, forty-three representatives from within and outside of the mathematical sciences community agreed at the workshop on fourteen actions the community should consider taking in response to recent and continuing changes in the education, research, technology, and policy environment.

**Center for Discrete Mathematics and Theoretical Computer Science (DIMACS)**

**Mathematical, Statistical, and Algorithmic Problems of Very Large Data Sets:** Wednesday, 2:15 p.m. to 6:00 p.m., jointly sponsored by DIMACS, and DMS (Division of Mathematical Sciences at the National Science Foundation). The emergence of the computer as an essential tool in scientific research and as an essential ingredient in commercial systems has led to the emergence of massive amounts of data of critical importance for a broad variety of applications, including (but certainly not limited to) astrophysical models, genetic sequencing, geographic information systems, ecological monitoring, weather prediction, telecommunications applications, commercial digital video and audio, digital libraries, government information systems, and biological models for medical applications. Researchers in all of these applications areas currently face daunting computational problems in organizing and extracting useful information from these massive data sets. This session will describe some of the challenging mathematical, statistical, and algorithmic problems inherent in organizing and using enormous amounts of data. The emphasis will be on basic issues that transcend particular applications. Speakers will explain why existing mathematical, statistical, and algorithmic methods break down on the enormous data sets that scientists and technologists now encounter regularly, and will attempt to delineate the boundaries at which these breakdowns occur. The session will include a discussion of specific DIMACS and DMS programs that focus on huge data sets.

**Conference Board on Mathematical Sciences (CBMS)**

**Fall 1995 CBMS Survey Results Including Data on Reform Calculus:** Saturday, 1:00 p.m. to 2:20 p.m. Recently compiled data from the 1995 CBMS Survey of undergraduate mathematics programs in two-year, four-year, and university institutions will be presented by Donald C. Rung, director of the 1995 CBMS survey. In addition to overall data on enrollment, detailed information on faculty composition will be presented. Also, the presentation will include a complete description of first-year calculus enrollments, including the number of students enrolled in large lecture versus small sections as well as the number of students enrolled in courses using "reform" calculus, along with other relevant data. Information on advising procedures for undergraduate majors will also be given.

**National Association of Mathematicians**

**Granville-Brown Session of Presentations by Recent Doctoral Recipients in the Mathematical Sciences:** Friday,
2:15 p.m. to 4:00 p.m., moderated by Stella Ashford, Southern University.

Cox-Talbot Address: Following the banquet on Friday evening. Charles Bell, San Diego State University, Some of my favorite mathematicians.

Calculus Reform—Where Are We Now?: Saturday, 10:00 a.m. to 10:50 a.m. Panelists include Della Bell, Texas Southern University; Yewande Olubummo-Lanier, Spelman College; Donald B. Small, U.S. Military Academy; and Lawrence Woodard, Grambling University. This panel will be moderated by Jacqueline B. Giles, Houston Community College System.

William W. S. Claytor Lecture: Saturday, 1:00 p.m. to 1:50 p.m. Carolyn R. Mahoney, California State University at San Marcos/MSRI, On calculating the log concavity of matroids.

Dynamical Systems and Fractal Geometry (Code: AMS SS C1), Fernanda Botelho, University of Memphis.

Graph Theory (Code: AMS SS M1), Ralph J. Faudree Jr. and Richard H. Schelp, University of Memphis.

Harmonic Analysis and Convexity (Code: AMS SS G1), Eric A. Carlen, Georgia Institute of Technology, Erwin Lutwak, Polytechnic University, and Elisabeth Werner, Case Western Reserve University.

Invariants of 3-manifolds (Code: AMS SS H1), Stavros Garoufalidis, Brown University, and Richard Martin Hain and Jun Yang, Duke University.

Mathematical Methods in Computer Vision (Code: AMS SS J1), Benjamin B. Kimia, Brown University.

Numerical Solutions for Partial Differential Equations (Code: AMS SS D1), Xiaobing Feng and Ohannes Karakashian, University of Tennessee.

Partial Differential Equations (Code: AMS SS P1), Gisele Ruiz Goldstein and Jerome A. Goldstein, University of Memphis.

Random Graphs (Code: AMS SS N1), Bela Bollobas and Cecil C. Rousseau, University of Memphis.

Symbolic Dynamics (Code: AMS SS B1), Paul B. Trow, University of Memphis.

Topology of Manifolds and Singular Spaces (Code: AMS SS L1), Bruce Hughes, Vanderbilt University, and Andrew A. Ranicki, Edinburgh University.

Memphis, Tennessee

University of Memphis

March 21–22, 1997

Meeting #919
Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of Notices: January 1997
Program issue of Notices: March 1997
Issue of Abstracts: Volume 18, Issue 2

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: December 14, 1996

Invited Addresses
Keith Ball, Texas A & M University, Title to be announced.
Nikolai I. Chernov, University of Alabama at Birmingham, Title to be announced.
Richard Martin Hain, Duke University, Title to be announced.
Allen R. Tannenbaum, University of Minnesota, Title to be announced.

Special Sessions
Approximation in Mathematics (Code: AMS SS A1), George A. Anastassiou, University of Memphis.
Chaotic Dynamics (Code: AMS SS I1), Nikolai I. Chernov and Sergei Troubetzkoy, University of Alabama at Birmingham.
Complex Analysis in One and Several Variables (Code: AMS SS F1), Dmitry Khavinson, University of Arkansas.
Convergence and Recurrence in Ergodic Theory (Code: AMS SS E1), James T. Campbell and Mate Wierdl, University of Memphis.

College Park, Maryland

University of Maryland, College Park

April 12–13, 1997

Meeting #920
Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: February 1997
Program issue of Notices: April 1997
Issue of Abstracts: Volume 18, Issue 2

Deadlines
For organizers: Expired
For consideration of contributed papers in Special Sessions: November 18, 1996
For abstracts: January 13, 1997

Invited Addresses
Lisa Claire Jeffrey, McGill University, Title to be announced.
Alexandre Kirillov, University of Pennsylvania, Merits and demerits of the orbit method.

Jian-Shu Li, University of Maryland, College Park, Title to be announced.

Richard Pollack, Courant Institute of Mathematical Sciences, New York University, Algorithms in real algebraic geometry.

Special Sessions


Analysis of Spatial Stochastic Models (Code: AMS SS E1), A. M. Kagan and Eric V. Slud, University of Maryland.

Automorphism Groups of Geometric Structures (Code: AMS SS J1), Alessandra Iozzi and Garrett James Stuck, University of Maryland.

Groupoids and their Applications (Code: AMS SS F1), Alan T. Paterson, University of Mississippi.

Harmonic Analysis and Applications (Code: AMS SS N1), Stephen D. Casey, American University, and David F. Walnut, George Mason University.

Hyperbolic Equations (Code: AMS SS L1), Manoussos Grillakis and Matei Machedon, University of Maryland.


Lie Groups and Automorphic Forms (Code: AMS SS C1), Jian-shu Li, University of Maryland, and Gordan Savin, University of Utah.


Numerical Solution of Differential Equations (Code: AMS SS M1), Ricardo H. Nochetto and John E. Osborn, University of Maryland.

Partial Differential Equations (Code: AMS SS K1), Jonathan Adam Poritz, University of Maryland.

Symplectic Geometry, Moduli Spaces and Integrable Systems (Code: AMS SS B1), Lisa Claire Jeffrey, McGill University, and Eyal Markman, University of Michigan.


Detroit, Michigan

Wayne State University

May 2-4, 1997

Meeting #922

Central Section

Associate secretary: Susan J. Friedlander

Announcement issue of Notices: March 1997

Program issue of Notices: May 1997

Issue of Abstracts: Volume 18, Issue 2

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions: December 9, 1996

For abstracts: February 3, 1997

Invited Addresses

Harold P. Boas, Texas A&M University, Title to be announced.

Carlos E. Kenig, University of Chicago, Title to be announced.

Ernest E. Shult, Kansas State University, Title to be announced.

A. L. Volberg, Michigan State University, Title to be announced.

Special Sessions

Algebraic Combinatorics (Code: AMS SS K1), Devadatta M. Kulkarni, Oakland University.

Algebraic Topology (Code: AMS SS D1), Robert R. Bruner and David Handel, Wayne State University.

Analysis and Geometry (Code: AMS SS J1), Carlos E. Kenig, University of Chicago, and Tatiana Toro, University of Washington.

C* Algebras (Code: AMS SS H1), Jerry Kaminker, Indiana University-Purdue University at Indianapolis, and Claude L. Schochet, Wayne State University.

Differential Geometry and Its Applications (Code: AMS SS C1), Daniel S. Drucker and Chorng-Shi Houh, Wayne State University.


Corvallis, Oregon

Oregon State University

April 19-20, 1997

Meeting #921

Western Section

Associate secretary: William A. Harris Jr

Announcement issue of Notices: February 1997

Program issue of Notices: April 1997

Issue of Abstracts: Volume 18, Issue 2

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions: November 18, 1996

For abstracts: January 13, 1997
Optimization and Variational Analysis (Code: AMS SS I1), Boris S. Mordukhovich, Wayne State University, and Jay S. Treiman and Qi Ji Zhu, Western Michigan University.


Recent Advances in Noncommutative Ring Theory (Code: AMS SS F1), Peter Malcolmson and Frank Okoh, Wayne State University.

Representation Theory of Finite Groups and Related Topics (Code: AMS SS B1), David Howard Gluck, Wayne State University.

Stochastic Processes in Finance and Control (Code: AMS SS G1), Raoul LePage, Michigan State University, and Bert M. Schreiber, Wayne State University.

VOA's Monstrous Moonshine and Related Topics (Code: AMS SS I1), Chongying Dong, University of California Santa Cruz, and Robert L. Griess Jr., University of Michigan.

Wavelets and Applications (Code: AMS SS M1), Gregory F. Bachelis and Tze-Chien Sun, Wayne State University, and Grant Gerhart, Tardec, Tacoma, Army.

Robert Mackay, University of Cambridge, United Kingdom, Title to be announced.

Peter Sarnak, Princeton University, Title to be announced.

Special Sessions

Algebraic K-Theory (Code: AMS SS F1), Eric M. Friedlander, Northwestern University, and Remi Kuku, ICTP, Trieste, Italy.

Dynamical Systems and Ergodic Theory (Code: AMS SS B1), Harvey B. Keynes, University of Minnesota, and Michael Sears, University of Witwatersrand, South Africa.

Fluid Dynamics (Code: AMS SS D1), Susan J. Friedlander, University of Illinois at Chicago, Andrew Gilbert, University of Exeter, United Kingdom, and David Mason, University of Witwatersrand, South Africa.

Geometry, Topology, and Physics (Code: AMS SS A1), Steven B. Bradlow, University of Illinois-Urbana, George Ellis, University of Cape Town, South Africa, Nigel J. Hitchin, University of Cambridge, England, and Joao Rodrigues, University of Witwatersrand, South Africa.

Invariant Subspaces and Collections of Operators (Code: AMS SS G1), Peter Rosenthal, University of Toronto, and Graeme Philip West, University of Witwatersrand.

Number Theory (Code: AMS SS E1), John Knopfmacher, University of Witwatersrand, South Africa, and Peter Sarnak, Princeton University.

Secondary and Postsecondary Curriculum Reform (Code: AMS SS C1), Johann Engelbrecht, University of Pretoria, South Africa, Deborah Hughes Hallet, Harvard University, and Harvey B. Keynes, University of Minnesota.

Pretoria, Republic of South Africa

University of Pretoria

June 26–28, 1997

Meeting #923


Associate secretary: Susan J. Friedlander

Announcement issue of Notices: To be announced

Program issue of Notices: To be announced

Issue of Abstracts: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses

Hyman Bass, Columbia University, Title to be announced.
Percy Deift, Courant Institute of Mathematical Sciences, New York University, Title to be announced.
David Epstein, University of Warwick, United Kingdom, Title to be announced.
Doron Lubinsky, University of Witwatersrand, South Africa, Title to be announced.

Montreal, Quebec, Canada

University of Montreal

September 26–28, 1997

Meeting #924

Eastern Section

Associate secretary: Lesley M. Sibner

Announcement issue of Notices: August 1997

Program issue of Notices: October 1997

Issue of Abstracts: To be announced

Deadlines

For organizers: December 20, 1996
For consideration of contributed papers in Special Sessions: May 1, 1997
For abstracts: June 26, 1997

Invited Addresses

J. E. Goodman, City University of New York, Title to be announced.
Meetings & Conferences

Dieter Kotschick, University of Basel, Title to be announced.
Francois Lalonde, University of Quebec at Montreal, Title to be announced.
I. Moerdijk, University of Utrecht, Netherlands, Title to be announced.

Special Sessions
Potential Theory (Code: AMS SS A1), Kohur Gowri Sankaran, McGill University, and David H. Singman, George Mason University.

Atlanta, Georgia
Georgia Institute of Technology
October 10–12, 1997

Meeting #926
Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of Notices: August 1997
Program issue of Notices: October 1997
Issue of Abstracts: To be announced

Deadlines
For organizers: January 10, 1997
For consideration of contributed papers in Special Sessions: May 14, 1997
For abstracts: July 9, 1997

Special Sessions
Computability Theory (Code: AMS SS A1), Steffen Lempp, University of Wisconsin, Madison, and Robert I. Soare, University of Chicago.
Concentration Phenomena in Differential Equations (Code: AMS SS E1), Lia Bronsard, McMaster University, and Wei-Ming Ni, University of Minnesota.
Eigenvalue Problems for Differential Equations (Code: AMS SS K1), Paul A. Binding, University of Calgary, and Hans W. Volkmer, University of Wisconsin-Milwaukee.
Enveloping Algebras and Quantum Groups (Code: AMS SS J1), Ian M. Musson and Yi Ming Zou, University of Wisconsin-Milwaukee.
Geometric Topology and Geometric Group Theory (Code: AMS SS H1), Fredric Davis Ancel and Craig R. Guilbault, University of Wisconsin-Milwaukee.
Harmonic Analysis and Its Applications (Code: AMS SS F1), Lung-Kee Chen, Oregon State University, Dushan Fan, University of Wisconsin-Milwaukee, and Yi-Biao Pan, University of Pittsburgh.
Low-Dimensional Dynamics (Code: AMS SS C1), Karen M. Brucks, University of Wisconsin-Milwaukee, and Beverly E. J. Diamond, University of Charleston.
Number Theory and Cryptography (Code: AMS SS D1), Eric Bach and Rene Peralta, University of Wisconsin-Milwaukee.
Operator Theory and Function Spaces (Code: AMS SS G1), Zeljko Cuckovic, University of Toledo.
Rings and Modules (Code: AMS SS I1), Karl Andrew Kosler and Shubhangi S. Stalder, University of Wisconsin Centers-Waukesha.

Milwaukee, Wisconsin
University of Wisconsin
October 24–26, 1997

Meeting #927
Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of Notices: August 1997
Program issue of Notices: October 1997
Albuquerque, New Mexico
University of New Mexico
November 8-9, 1997
Meeting #928
Western Section
Associate secretary: William A. Harris Jr.
Announcement issue of Notices: September 1997
Program issue of Notices: November 1997
Issue of Abstracts: To be announced

Deadlines
For organizers: January 4, 1997
For consideration of contributed papers in Special Sessions: June 12, 1997
For abstracts: August 7, 1997

Oaxaca, Mexico
Oaxaca, Mexico
December 4-7, 1997
3rd Joint Meeting of the American Mathematical Society and the Sociedad Matemática Mexicana.
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: To be announced

Deadlines
For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Baltimore, Maryland
Baltimore Convention Center
January 7-10, 1998
Joint Mathematics Meetings, including the 104th Annual Meeting of the AMS, 81st Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL).
Associate secretary: Robert J. Daverman
Announcement issue of Notices: October 1997
Program issue of Notices: January 1998
Issue of Abstracts: To be announced

Deadlines
For organizers: April 10, 1997
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Invited Addresses
Edward Witten, Institute for Advanced Study. (AMS Josiah Willard Gibbs Lecture).

Louisville, Kentucky
University of Louisville
March 20-21, 1998
Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: To be announced

Deadlines
For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Special Sessions
Combinatorics and Enumerative Geometry (Code: AMS SS A1), Kequan Ding, University of Illinois, Urbana-Champaign, and Chi Wang, University of Louisville.
Combinatorics and Graph Theory (Code: AMS SS B1), Andre E. Kezdy, Grzegorz Kubicki, and Jenoe Lehel, University of Louisville.
Discrete Mathematics, Classification Theory and Consensus (Code: AMS SS C1), Robert C. Powers, University of Louisville.
Fractal Geometry and Related Topics (Code: AMS SS D1), Ka-Sing Lau, University of Pittsburgh, and Weibin Zeng, University of Louisville.
Functional Equations and Inequalities (Code: AMS SS E1), Thomas Riedel and Prasanna Sahoo, University of Louisville.
Real Analysis (Code: AMS SS G1), Udayan B. Darji and Lee Larson, University of Louisville.
Semigroups, Algorithms, and Universal Algebra (Code: AMS SS H1), Ralph N. McKenzie, Vanderbilt University, and Steven Seif, University of Louisville.
The Use of the History of Mathematics and Science in the University and School Classroom (Code: AMS SS I1), Richard M. Davitt, University of Louisville.
Manhattan, Kansas
Kansas State University
March 27-28, 1998
Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of Notices: January 1998
Program issue of Notices: March 1998
Issue of Abstracts: To be announced

Deadlines
For organizers: June 26, 1997
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Special Sessions

New Orleans, Louisiana
New Orleans Marriott and ITT Sheraton New Orleans Hotel
January 10–13, 2001
Joint Mathematics Meetings, including the 107th Annual Meeting of the AMS, 84th Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM).
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: To be announced

Deadlines
For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Philadelphia, Pennsylvania
Temple University
April 4–5, 1998
Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of Notices: To be announced
Program issue of Notices: To be announced
Issue of Abstracts: To be announced

Deadlines
For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Washington, District of Columbia
Sheraton Washington Hotel and Omni Shoreham Hotel
January 19–22, 2000
Joint Mathematics Meetings, including the 106th Annual Meeting of the AMS, 83rd Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM).
Associate secretary: William A. Harris Jr.
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Meetings and Conferences of the AMS

Associate Secretaries of the AMS

Western Section: William A. Harris Jr., Department of Mathematics, University of Southern California, Los Angeles, CA 90089-1113; e-mail: g_harris@ams.org; telephone: 213-740-3794.

Central Section: Susan J. Friedlander, Department of Mathematics, University of Illinois at Chicago, 851 S. Morgan (M/C 249), Chicago, IL 60607-7045; e-mail: g_friedlander@ams.org; telephone: 312-996-3041.

Eastern Section: Lesley M. Sibner, Department of Mathematics, Polytechnic University, Brooklyn, NY 11201-2990; e-mail: g_sibner@ams.org; telephone: 718-260-3505.

Southeastern Section: Robert J. Daverman, Department of Mathematics, University of Tennessee, Knoxville, TN 37996-1300; e-mail: g_daverman@ams.org; telephone: 423-974-6577.

The Meetings and Conferences section of the Notices gives information on all AMS meetings and conferences approved by press time for this issue. Please refer to the page numbers cited in the table of contents on this page for more detailed information on each event. Invited Speakers and Special Sessions are listed as soon as they are approved by the cognizant program committee; the codes listed are needed for electronic abstract submission. For some meetings the list may be incomplete. Up-to-date meeting and conference information is available on the World Wide Web via the Internet at URL http://www.ams.org/.

Meetings:

1996
November 16-17 Pasadena, California p. 1421
1997
January 8-11 San Diego, California p. 1613
Annual Meeting
March 21-22 Memphis, Tennessee p. 1615
April 12-13 College Park, Maryland p. 1615
April 19-20 Corvallis, Oregon p. 1616
May 2-4 Detroit, Michigan p. 1616
June 26-28 Republic of South Africa p. 1617
September 26-28 Montreal, Canada p. 1617
October 10-12 Atlanta, Georgia p. 1618
October 24-26 Milwaukee, Wisconsin p. 1618
November 8-9 Albuquerque, New Mexico p. 1619
December 4-7 Oaxaca, Mexico p. 1619
1998
January 7-10 Baltimore, Maryland p. 1619
Annual Meeting
March 20-21 Louisville, Kentucky p. 1619
March 27-28 Manhattan, Kansas p. 1620
April 4-5 Philadelphia, Pennsylvania p. 1620

2000
January 19-22 Washington, DC p. 1620
Annual Meeting
2001
January 10-13 New Orleans, LA p. 1620
Annual Meeting

Important Information Regarding AMS Meetings

Potential organizers and speakers should refer to the January issue of the Notices for guidelines on participation.

Should your university be interested in hosting an AMS meeting, see the January issue for details.

Abstracts

Several options are available for speakers submitting abstracts, including an easy-to-use interactive Web form. No knowledge of TeX is necessary to submit an electronic form, although those who use plain TeX, AMS-TeX, LaTeX, or AMS-LaTeX may submit abstracts with TeX coding. To see descriptions of the forms available, visit http://www.ams.org/abstracts/instructions.html or send mail to abs-submit@ams.org, typing help as the subject line, and descriptions and instructions on how to get the template of your choice will be e-mailed to you.

Completed abstracts should be sent to abs-submit@ams.org, typing submission as the subject line. Questions about abstracts may be sent to abs-info@ams.org.

Paper abstract forms may be sent to Abstracts Coordinator, AMS, F.O. Box 6887, Providence, RI 02940. Note that all abstract deadlines are strictly enforced. Close attention should be paid to specified deadlines in this issue. Unfortunately, late abstracts cannot be accommodated.

See http://www.ams.org/committee/meetings/ for the most up-to-date information on these conferences.

1997:

January 6-7: AMS Short Courses on Applications of Computational Algebraic Geometry and Mathematical Finance, San Diego, CA. See October 1996, pp. 1296-1304, for details.


June 29-July 19: Summer Research Institute, Differential geometry and control, University of Colorado at Boulder. See October 1996, p. 1304, for details.
Hotel Reservations

To ensure accurate assignments, please rank hotels in order of preference by writing 1, 2, 3, etc., in the spaces at the left of the form and by circling the requested room type and rate. If the rate or the hotel requested is no longer available, you will be assigned a room at a ranked or unranked hotel at a comparable rate. Participants are urged to call the hotels directly for details on suite configurations, sizes, etc. Reservations at the following hotels must be made through the MMSB to receive the convention rates listed. All rates are subject to a 10.5% sales occupancy tax. **Guarantee requirements:** First night deposit by check (add to payment on reverse of form) or a credit card guarantee.

<table>
<thead>
<tr>
<th>Opportunity</th>
<th>Marriott Hotel &amp; Marina (Hqtrs)</th>
<th>Cityview</th>
<th>Bayview</th>
<th>Students</th>
<th>Embassy Suites (1 bedroom suites)</th>
<th>Students (1 bedroom suites)</th>
<th>Wyndham Emerald Plaza</th>
<th>Students</th>
<th>Doubletree</th>
<th>Students</th>
<th>Clarion Hotel Bay View</th>
<th>Students</th>
<th>Horton Grand</th>
<th>Bristol Court</th>
<th>Students</th>
<th>Holiday Inn on the Bay</th>
<th>Cityview</th>
<th>Bayview</th>
<th>Best Western Bayside Inn</th>
<th>Students</th>
<th>Radisson Hotel Harborview</th>
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<th>Howard Johnson Hotel Harborview</th>
<th>Comfort Inn</th>
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If you are not making a reservation, please check off one of the following:
- I plan to make a reservation at a later date.
- I will be making my own reservations at a hotel not listed. Name of hotel:
- I live in the area or will be staying privately with family or friends.
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Priority consideration will be given to all participants with special needs and they will be assigned to properties that are in compliance with the ADA.
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Registration Fees

Joint Meetings by Dec 20 at mtg
□ Member AMS, ASL, CMS, MAA, SMM $140 $182
□ Nonmember $217 $282
□ Graduate Student $ 35 $ 45
□ Undergraduate $ 20 $ 26
□ High School Student $ 2 $ 5
□ Unemployed $ 35 $ 45
□ Temporarily Employed $100 $125
□ Third World Fee $ 35 $ 45
□ Emeritus Member of AMS or MAA $ 35 $ 45
□ High School Teacher $ 35 $ 45
□ Librarian $ 35 $ 45
□ One-day Member — $109
□ One-day Nonmember — $154
□ Exhibitor — $ 0
□ Guest $ 5 $ 5

AMS Short Course on Algebraic Geometry
□ Member, Nonmember $ 75 $ 90
□ Student, Unemployed, Emeritus $ 35 $ 45

AMS Short Course on Mathematical Finance
□ Member, Nonmember $ 75 $ 90
□ Student, Unemployed, Emeritus $ 35 $ 45

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(Registration for the Joint Meetings is required for participation. Applicant resume forms and employer job listing forms will be on e-MATH in September and in the October issue.)
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□ Employer—Second Table $ 80 $110
□ Employer—Posting Only $ 50 $ 50
□ Applicant $ 40 $ 75

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MAA Minicourses: See separate form in October issue.

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□ Vegetarian ___________________________ $27 ___________________________
□ Kosher ___________________________ $27 ___________________________

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Statistical Information:
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Total Payment

Category Total
□ Registration fee(s) __________
□ Employment Register __________
□ Event tickets __________
□ Hotel deposit (only if paying by check) __________
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Deadlines

Room lottery October 31, 1996
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Reservation changes/cancellations through MMSB December 9, 1996
Advance registration, Employment Register December 20, 1996
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