

Notices

of the American Mathematical Society

November 1999

Volume 46, Number 10

Analysis on Fractals

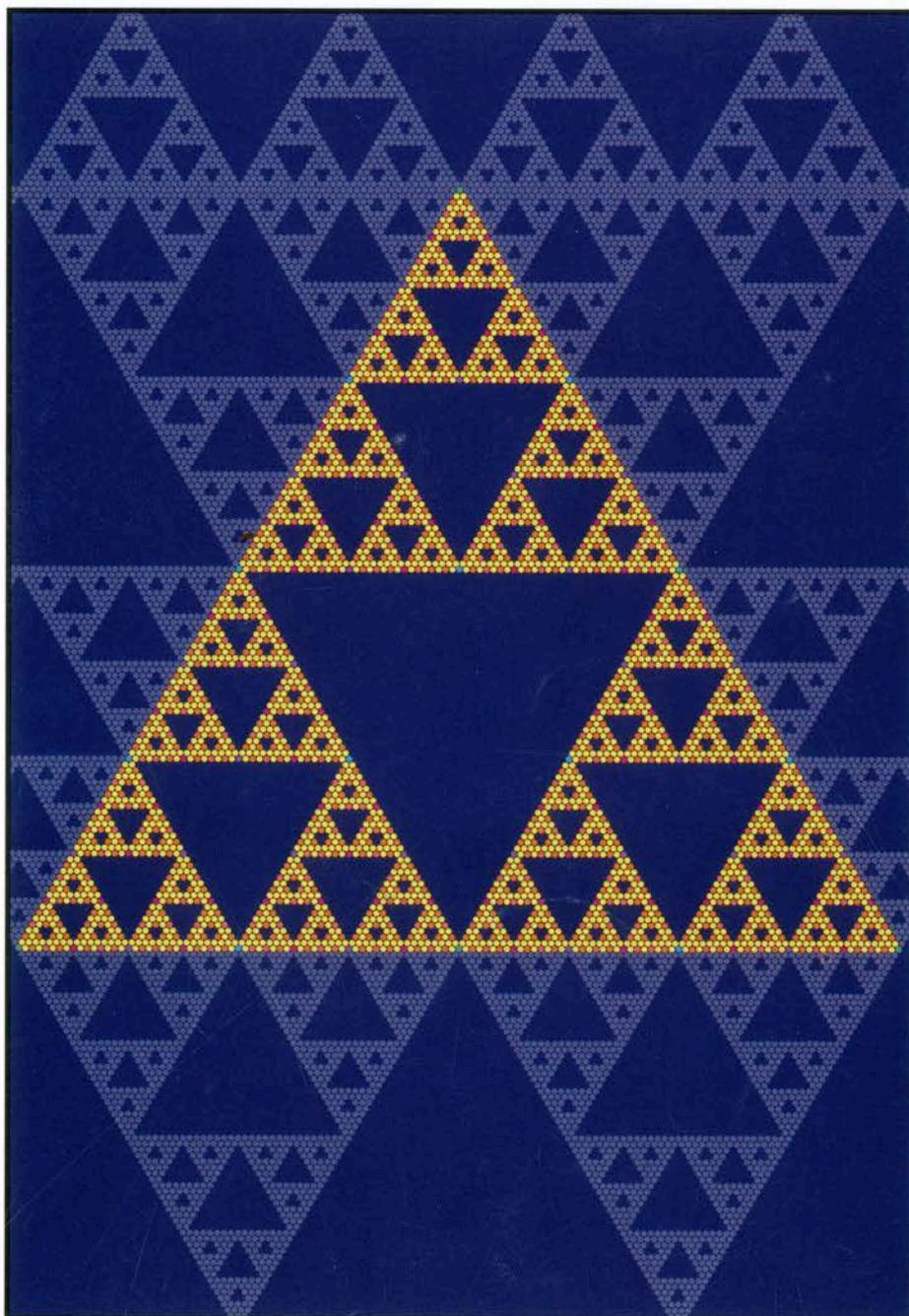
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The Sierpinski Gasket (see page 1208)

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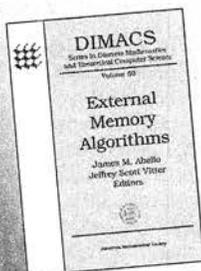
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New Titles from the AMS



External Memory Algorithms

James M. Abello, *AT&T Bell Labs-Research, Florham Park, NJ*, and **Jeffrey Scott Vitter**, *Duke University, Durham, NC*, Editors

Techniques from computer science and mathematics are used to solve combinatorial problems in designing memory algorithms when associated data require a hierarchy of storage devices. These solutions employ "extended memory algorithms". The input/output (I/O) communication between the levels of the hierarchy is often a significant bottleneck in applications that process massive amounts of data. Gains in performance may be possible by incorporating locality directly into the algorithms and managing the contents of each storage level.

The relative difference in data access speeds is most apparent between random access memory and magnetic disks. Therefore, much research has been devoted to algorithms that focus on the I/O bottleneck. These algorithms are usually called "external memory", "out-of-core", or "I/O algorithms".

This volume presents new research results and current techniques for the design and analysis of external memory algorithms. The articles grew out of the workshop, "External Memory Algorithms and Visualization" held at DIMACS. Leading researchers were invited to give lectures and to contribute their work. Topics presented include problems in computational geometry, graph theory, data compression, disk scheduling, linear algebra, statistics, software libraries, text and string processing, visualization, wavelets, and industrial applications.

The vitality of the research and the interdisciplinary nature of the event produced fruitful ground for the compelling fusion of ideas and methods. This volume comprises the rich results that grew out of that process.

DIMACS: Series in Discrete Mathematics and Theoretical Computer Science, Volume 50; 1999; approximately 297 pages; Hardcover; ISBN 0-8218-1184-3; List \$75; Individual member \$45; Order code DIMACS/50NT911

Recommended Text

Foliations I

Alberto Candel, *California Institute of Technology, Pasadena*, and **Lawrence Conlon**, *Washington University, St. Louis, MO*

This is the first of two volumes on the qualitative theory of foliations. This volume is divided into three parts. The book is extensively illustrated throughout and provides a large number of examples.

Part 1 is intended as a "primer" in foliation theory. Part 2 considers foliations of codimension one. Presented here is the first and only full treatment of the theory of levels in a textbook. Part 3 is devoted to foliations of higher codimension, including abstract laminations (foliated spaces).

This comprehensive volume has something to offer a broad spectrum of readers: from beginners to advanced students to professional researchers. Packed with a wealth of illustrations and copious examples at varying degrees of difficulty, this highly-accessible text offers the first full treatment in the literature of the theory of levels for foliated manifolds of codimension one. It would make an elegant supplementary text for a topics course at the advanced graduate level.

Graduate Studies in Mathematics; 2000; 394 pages; Hardcover; ISBN 0-8218-0809-5; List \$54; All AMS members \$43; Order code GSM-CONLONNT911

Recommended Text

A Course in Operator Theory

John B. Conway, *University of Tennessee, Knoxville*

Operator theory is a significant part of many important areas of modern mathematics: functional analysis, differential equations, index theory, representation theory, mathematical physics, and more. This text covers

the central themes of operator theory, presented with the excellent clarity and style that readers have come to associate with Conway's writing.

Professor Conway's authoritative treatment makes this a compelling and rigorous course text, suitable for graduate students who have had a standard course in functional analysis.

Graduate Studies in Mathematics; Volume 21; 2000; 372 pages; Hardcover; ISBN 0-8218-2065-6; List \$49; All AMS members \$39; Order code GSM/21NT911

Recommended Text

Growth of Algebras and Gelfand-Kirillov Dimension

Revised Edition

Günter R. Krause, *University of Manitoba, Winnipeg, Canada*, and **Thomas H. Lenagan**, *University of Edinburgh, Scotland*

During the two decades that preceded the publication of the first edition of this book, the Gelfand-Kirillov dimension had emerged as a very useful and powerful tool for investigating non-commutative algebras. At that time, the basic ideas and results were scattered throughout various journal articles. The first edition of this book provided a much-needed reliable and coherent single source of information. Since that time, the book has become the standard reference source for researchers.

For this edition, the authors incorporated the original text with only minor modifications. The newly added Chapter 12 provides broad overviews of the new developments that have surfaced in the last few years, updated and accordingly, almost double the size of the original one.

The faithful revision and contemporary design of this work offers time-honored expertise with modern functionality. A keenly appealing combination. So, whether for the classroom, the well-tended mathematical books collection, or the research desk, this book holds unprecedented relevance.

Graduate Studies in Mathematics; Volume 22; 2000; 212 pages; Hardcover; ISBN 0-8218-0859-1; List \$39; All AMS members \$31; Order code GSM/22NT911

Supplementary Reading

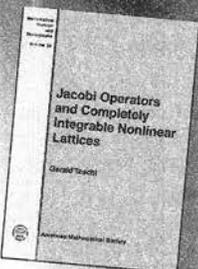
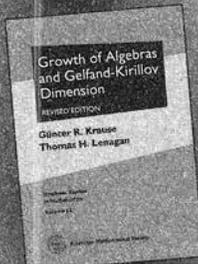
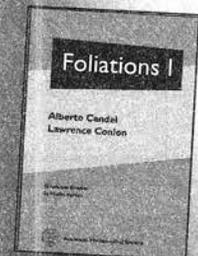
Jacobi Operators and Completely Integrable Nonlinear Lattices

Gerald Teschl, *Institut für Mathematik, Universität Wien, Vienna, Austria*

This volume can serve as an introduction and a reference source on spectral and inverse spectral theory of Jacobi operators (i.e., second order symmetric difference operators) and applications of those theories to the Toda and Kac-van Moerbeke hierarchy.

Beginning with second order difference equations, the author develops discrete Weyl-Titchmarsh-Kodaira theory, covering all classical aspects, such as Weyl m -functions, spectral functions, the moment problem, inverse spectral theory, and uniqueness results. This text covers all basic topics of Jacobi operators and includes recent advances. It is suitable for use as a text at the advanced graduate level.

Mathematical Surveys and Monographs, Volume 72; 1999; 344 pages; Hardcover; ISBN 0-8218-1940-2; List \$65; All AMS members \$52; Order code SURV/72NT911



AMS

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MATHEMATICS

from Birkhäuser

The Gelfand Mathematical Seminars: 1997-1999

I.M. Gelfand & V. Retakh, both, Rutgers University, New Brunswick, NJ (Eds.)

This volume continues a tradition of one of the most influential mathematical seminars in this century, reflecting a variety of different areas, approaches, and connections. One of the main topics in the seminar in recent years has been noncommutative algebra and geometry, and its relation to modern physics. Different groups are working in this direction with different methods. This volume contains two articles devoted to the subject, "Noncommutative Smooth Spaces" by M. Kontsevich and A. Rosenberg approaching it on a modern theory of categories, and a paper by A. Rosenberg, "The Existence of a Fiber Functor".

The volume is dedicated to the memory of Chih-Han Sah, and contains a review of his work with J. Dupont "Three Questions about Simplices in Spherical and Hyperbolic 3-Space". A paper by T. Alekseevskaya, A. Borovik, I. Gelfand, and N. White, "Matroid Homology" is devoted to another type of combinatorial geometry, and the paper by G. Cherlin, "Sporadic Homogeneous Structures" is a bridge between logic and geometry. The papers by Victor Kac and Andrey Radul, "Poisson Structure for Restricted Lie Algebras", and by A. Kozarnovskiy-Krol, "A Cycle for Integration Yielding the Zonal Spherical Function of Type A_n " deal with Lie groups, algebras, and their representations.

Gelfand Mathematical Seminar Series

November 1999 Approx. 168 pp. Hardcover ISBN 0-8176-4013-4
\$69.95 (tent.)

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Third Edition

G. Grätzer, University of Manitoba, Winnipeg, Canada

"Recommended both as a very good introductory text for beginners as well as a handy up-to-date LaTeX reference for experienced users."

—SIAM Review (on the second edition)

This successful introduction and reference to LaTeX presents a systematic, simple and direct approach, featuring a formula gallery, sample files and templates as well as useful appendices containing symbol tables. The text covers special topics such as the use of PostScript fonts and where to find TeXware, and—new in this edition—includes an introduction to web development from LaTeX as well as a section devoted to book publishing.

December 1999 Approx. 520 pp., 20 illus. Softcover
ISBN 0-8176-4131-9

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Time-Dependent Partial Differential Equations and Their Numerical Solution

H.-O. Kreiss, University of California at Los Angeles

This book studies time-dependent pdes and their numerical solution, developing the analytic and the numerical theory in parallel, and placing special emphasis on the discretization of boundary conditions. The theoretical results are then applied to Newtonian and non-Newtonian flows, two-phase flows and geophysical problems.

Lectures in Mathematics

1999 Approx. 150 pp. Softcover ISBN 3-7643-6125-5

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Spatial Branching Processes, Random Snakes and Partial Differential Equations

J.-F. LeGall, ENS, Paris, France

This book introduces several new probabilistic objects that combine spatial motion with a continuous branching phenomenon and are closely related to certain semilinear pdes. The Brownian snake approach is used to give a concrete and powerful presentation of superprocesses and to investigate their connections to pdes. The presentation is essentially self-contained and complete proofs are given.

Lectures in Mathematics

1999 172 pp. Softcover ISBN 3-7643-6126-3

\$29.95

Canonical Metrics in Kähler Geometry

G. Tian, M.I.T., Cambridge, MA

The uniformization theory of canonical Kähler metrics has played an important role in the fundamental progress in complex differential geometry that has happened in the last two decades, and many applications have been found, including the use of Calabi-Yau spaces in superstring theory. This book gives a self-contained introduction to the theory of canonical Kähler metrics on complex manifolds, and also presents some advanced topics in complex differential geometry not easily found elsewhere.

Lectures in Mathematics

1999 112 pp. Softcover ISBN 3-7643-6194-8

\$24.50 (tent.)

Singular Loci of Schubert Varieties

S. Billey, M.I.T., Cambridge, MA & V. Lakshmibai, Northeastern University, Boston, MA

The study of singular loci lies at the crossroads of representation theory, algebraic geometry, and combinatorics. This is the first book to present the various theories and approaches previously only published in journal articles in a coherent manner, giving a systematic presentation of a wide range of topics and presenting new results with sufficient examples to emphasize key points. The book also includes an excellent introduction giving background material, a comprehensive bibliography, an index, and tables—the latter not to be found elsewhere in the mathematics literature.

Progress in Mathematics, Vol. 182

December 1999 Approx. 240 pp. Hardcover ISBN 0-8176-4092-4

\$49.95

JOURNAL

Transformation Groups

Edited by E.B. Vinberg, Moscow State University & V.L. Popov, Moscow State Technical University

Special double issue dedicated to Claude Chevalley (Vol. 4 / 1999, Nos. 2 & 3) featuring:

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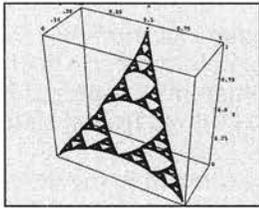
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Analysis on Fractals

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Robert S. Strichartz

The Laplacian operator, harmonic functions, and eigenfunctions of the Laplacian all have a meaning on certain fractals in Euclidean space. This article concentrates on the Sierpinski gasket in the plane and describes the resulting theory.

Pseudorandomness

1209

Oded Goldreich

Pseudorandomness refers to the efficient generation of long strings of random-looking zeroes and ones from shorter random strings. Generating perfectly random bits by hardware is expensive, and the theory in this article allows computer programs to make an economical use of randomness.



Kerosinka: An Episode in the History of Soviet Mathematics

1217

Mark Saul

The Kerosinka story illustrates the subtle interplay between passion and politics in the former Soviet Union, where individuals and institutions went out of their way to pursue mathematics in the face of anti-Semitism.

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of the American Mathematical Society

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AMS in the Twentieth Century

The Start of the *Notices*

In his book on the history of the AMS from 1938 to 1988, Everett Pitcher writes, "From the beginning of the Society through 1953, preliminary announcements and programs of meetings were issued as separate.... In 1954 the *Notices* began as a periodical. One purpose was to take advantage of the favorable postal rates allowed to periodical publications...."

"In addition to preliminary announcements and programs of meetings, the *Notices* contained notes on appointments and news about publications in mathematics. Announcements of fellowships, grants, and conferences appeared in increasing numbers. Abstracts of contributed papers were moved from the *Bulletin* to the *Notices* effective in 1958.

"Letters to the Editor were a frequent subject of disagreement in the development of the *Notices*.... Not until 1958 did Letters to the Editor become a feature.... The [first] letter was followed by this note:

The purpose of this new department is to provide a forum for discussions of the programs of the Society, and a method for communicating information of interest to the membership. Questions concerning matters of scholarship, such as those relating to the location of primary references, will be welcomed.

The Council has instructed the Editor of the *Notices* not to allow the new department to be used for quick publication of mathematical results, and not to accept criticism of *specific individual papers* or of *specific individual reviews in Mathematical Reviews* or elsewhere....

"The last paragraph of the note corresponds to the fact that the editor [who was then the executive director, J. H. Curtiss] was solely responsible for the acceptance of letters."

Letters were a controversial subject both for the range of the allowable content and for the power to decide which particular letters were acceptable. A "forum for discussions of the programs of the Society" offered the potential for a conflict of interest on the part of the person deciding about letters, and various schemes were tried over a period of time to get around this problem.

Pitcher continues, "Abstracts of papers presented at meetings or offered by title were printed in the *Bulletin* after the fact for many years. The system was changed so that abstracts appeared currently in the *Notices*, effective with [1958]. This arrangement continued through 1979, at which point the journal *Abstracts of the American Mathematical Society* was started.

"From its beginning [in 1891], the *Bulletin* was the journal of record of the Society. It contained reports of Council and Business Meetings, elections, reports of the treasurer, bylaws, and other items of Society business affecting its membership. The Council of 26 January 1977, in the course of considering the redirection of the *Bulletin*, ordered that the *Notices* become the journal of record of the Society...."

"Abstracts were only the beginning of the appearance of substantive mathematics in the *Notices*. It had always been regarded as a 'throwaway' journal, of little value after the occurrence of the programs listed in it. Already in 1972... a column called 'Queries' was instituted...."

"When the journal became one of record, it was realistic to put articles with mathematical content of more permanent value in it. In 1982, Ronald L. Graham was named associate editor for special articles and the first such article... appeared in the February issue. The new direction was a source of discontent among those readers whose concept was still that of a throwaway."

Twenty-three "special articles" appeared in the *Notices* between 1982 and 1993. By the early 1990s the relative roles of the *Notices* and the *Bulletin* had become a more and more frequent subject of discussion. A Committee to Review Member Publications was established to make recommendations, and it did so in 1993. Those recommendations and their aftermath will be the subject of a later column.

—Anthony W. Knapp

Impact of the Government Performance and Results Act

Phillip A. Griffiths

In 1993 Congress passed a law known as the Government Performance and Results Act, whose stated goal is to encourage efficiency, effectiveness, and accountability throughout the federal government. The “Results Act”, or GPRA, affects all federal agencies, including those that fund research. The act takes full effect in less than a year, but many mathematicians have heard little about its existence or its likely impact on the research community. I would like to take this opportunity to review the act’s brief history and to suggest what the research community might expect from it.

The Committee on Science, Engineering, and Public Policy (COSEPUP) of the National Academies has undertaken a study of the application of GPRA to federal agencies that support science and engineering research. Our report, “Evaluating Federal Research Programs”, concludes that the research community, contrary to the opinion of some observers, can conform with both the spirit and letter of the law in ways that are likely to strengthen the nation’s research effort.

GPRA applies to all programs funded by the federal government. The focus of the act is on “outcomes”, rather than “output”. For example, when policymakers evaluate federal funding for an unemployment program, they are interested less in output—such as the number of people who are part of a training program—than in outcome—the number of people who obtain employment as a result of that training program.

From the point of view of the research community, a central challenge of the act is to devise a meaningful way to

apply this principle to the evaluation of research programs. It is not easy to measure the outcomes of research every year, especially basic research, and an attempt to do so by purely mechanistic means would fail to carry out the intent of the act. Such an attempt might even distort the research process or produce meaningless data (such as an agency’s “Top 100” discoveries of the preceding year). In the field of mathematics it is often difficult to quantify “outcomes” of a long-term line of research on an annual basis. For example, building on the work of a number of mathematicians over a number of years, Wiles’s solution of Fermat’s Last Theorem required more than seven years of concentrated work, whose success could only be known and described at its conclusion.

After extensive discussions, however, the committee concluded that both basic and applied research programs can be usefully assessed on a regular basis. At the risk of oversimplifying, let me describe how this can be done in two areas. Many of the applied research programs of the mission agencies can be assessed in terms of expected outcomes; in other words, progress toward expected outcomes can be measured annually. For example, if the Department of Energy adopted the goal of producing cheaper solar energy, every year it could measure the results of research directed toward decreasing the cost of solar cells, which is an expected outcome.

For basic research programs, on the other hand, we found that progress also can be documented—by using a different method of assessment. That method needs to be different because of the well-known fact that the ultimate outcomes of basic research are seldom identifiable while the research is in progress.

Let me reinforce this point. History tells us that the benefits to the nation of our investments in basic research are extremely high. History also shows us that basic research often leads to outcomes that were unexpected or took many years to emerge. For example, pre-World War II basic research on atomic structure contributed to the Global Positioning System that now supports navigation systems worldwide and is spreading through the private sector. But attempts to assess a year’s worth of that early research would have contained no hint of this particular outcome.

Since we cannot predict ultimate practical outcomes, the committee suggested other means to ensure that research programs generate useful knowledge. We believe that the most effective means of evaluation is a three-pronged process we call “expert review”, as follows:

Phillip A. Griffiths is professor of mathematics and director of the Institute for Advanced Study in Princeton, NJ. He is the chair of the committee of the National Academy of Sciences that studied the likely impact of the Government Performance and Results Act on agencies that fund research. His e-mail address is pg@math.ias.edu.

- A quality review looks at the quality of the research being performed. It is best undertaken by reviewers who are expert in the field, an approach traditionally called peer review.

- A relevance review examines whether a research program focuses on the subjects most relevant to an agency's mission. This type of review is undertaken not only by experts in the field but also by potential users and experts in related fields.

- International benchmarking determines whether the research is being performed at the forefront of scientific and technological knowledge. This type of review is best done by national and international experts with sufficient stature and perspective to assess the overall, relative quality of a program.

Expert review involving these elements is already in wide use, both within and outside science. For example, when a congressional committee or a corporate board investigates an issue, it traditionally invites both experts on the issue and a broad representation of people from related fields and the concerned public.

A second concern addressed by COSEPUP is the overlap among agencies of research topics. Our committee concluded that the principle of pluralism in the U.S. research enterprise, by which programs approach important questions from different perspectives, is in fact a major strength. But improvements are still needed. In particular, better communication among agencies is necessary to enhance collaboration, to help keep important questions from being overlooked, and to reduce duplication of effort. The committee recommended the establishment of a formal process to identify and coordinate areas of research that are supported by multiple agencies.

Federal agencies also have a major stake in the production of human resources, and yet not all agencies include human resources as a goal in their strategic plans. The integration of research and education at advanced levels is extremely important to the nation. The committee strongly urges that agencies explicitly adopt the objective of developing and maintaining adequate human capital in science and engineering fields critical to their missions.

A final concern heard by the committee is that the prospect of regular evaluations could be detrimental to the research enterprise. The committee believes that more objective assessments of research programs can only benefit the national research effort, both by focusing resources on the most vital fields and by allocating those resources more effectively. Many researchers already contribute much time and effort to parts of this process by reviewing grant applications, program proposals, and papers submitted for publication, but few of them have heard of GPRA. We believe that the law can become a valuable tool if working scientists and engineers involved in research understand its intention, help educate more people about their work, and lend their expertise to the development of more accurate evaluations.

On behalf of the committee, I would say that this exercise has been a valuable one. The committee has conducted a series of workshops to discuss the act and its implica-

tions with the agencies themselves. We believe the act can provide better opportunities for dialog between researchers and funders of research and for demonstrating to the public the enormous value of scientific, engineering, and medical research.

Information Resources on GPRA

There has been extensive discussion of the Government Performance and Results Act (GPRA) within the scientific community, professional societies, and federal agencies. Below are some Web resources that may be useful to readers wishing to learn more.

The Law: The text of the Government Performance and Results Act of 1993 may be found at <http://www.nsf.gov/od/gpra/law.htm>.

NAS Report: In his Forum article, Phillip Griffiths discusses the report about GPRA issued by the Committee on Science, Engineering, and Public Policy (COSEPUP) of the National Academies. The report, *Evaluating Federal Research Programs*, is available through the COSEPUP Web site <http://www2.nas.edu/cosepup/>. See also "National Academy Report on Evaluating Research", *Notices*, June/July 1999, pages 691-692.

NSF: Information about the response of the National Science Foundation (NSF) to GPRA may be found at <http://www.nsf.gov/od/gpraplan/gpraplan.htm> and at <http://www.nsf.gov/od/gpra/start.htm>.

NSF has also issued two reports addressing GPRA and mathematics. In February 1998, the Committee of Visitors of the NSF's Division of Mathematical Sciences (DMS) (Morton Lowengrub, chair) submitted its report, which provides a GPRA assessment for the Division. The report is available at <http://www.nsf.gov/mps/dms/cov98findings.htm>. The DMS response to the report is at <http://www.nsf.gov/mps/dms/cov98reply.htm>. In addition, *Report of the Senior Assessment Panel of the International Assessment of the U.S. Mathematical Sciences*, issued by the DMS in March 1998, came in part as a response to GPRA. The report may be found at <http://www.nsf.gov/pubs/1998/nsf9895/>. See also "Reports Assess U.S. Standing in Mathematics," *Notices*, August 1998, p. 880.

AAAS: The Science and Public Policy Programs of the American Association for the Advancement of Science (AAAS) have monitored developments surrounding GPRA. The AAAS report *1999 AAAS Science and Technology Policy Yearbook* has a number of chapters on GPRA. The report is available online at <http://www.aaas.org/spp/yearbook/>.

GAO Report: A General Accounting Office report on GPRA, entitled *Agencies' Strategic Plans Under GPRA: Key Questions to Facilitate Congressional Review*, is available at <http://www.house.gov/science/gao.html>.

For Taxpayers: The House of Representatives Web page <http://www.house.gov/science/taxpayer.html> discusses what the average taxpayer might want to know about GPRA.

—Allyn Jackson

Analysis on Fractals

Robert S. Strichartz

From Manifolds to Fractals

Analysis on manifolds has been one of the central areas of mathematical research in the twentieth century. Rooted in the foundational work of the nineteenth century, with its rigorous theory of multidimensional calculus and the visionary ideas of Riemann, it has flowered into a richly layered mathematical tapestry. It has attracted mathematicians with diverse expertise and points of view, including topology, differential equations, differential geometry, functional and harmonic analysis, and probability theory. This heady mix of ideas has produced a vast body of work and a seemingly endless supply of challenging problems that should keep mathematicians busy well into the next century.

At the same time it has become apparent that many phenomena in the real world are best modeled by geometric structures that are much more irregular. The theory of fractals, as B. Mandelbrot [Ma] has so forcefully argued, seeks to provide the mathematical framework for such development. A theory of analysis on fractals is now emerging and is perhaps poised for the kind of explosive and multilayered expansion that has characterized analysis on manifolds. This article will explain some of what has been accomplished and where it might lead.

The central character in the theory of analysis on manifolds is the Laplacian. Thus the starting

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Figures 3 and 5 were prepared using Mathematica. Figure 6 was produced by Kyallee Dalrymple.

point for analysis on fractals will be the construction of an analogous operator on a class of fractals. This will not be a genuine differential operator, of course, but it will have quite a few of the features we have come to expect from anything labeled "Laplacian". It will be a local operator, and in fact $\Delta f(x)$ will be a limit in a suitable renormalized sense of the difference between an average value of f in a neighborhood of x and $f(x)$. We will be imitating the weak formulation of the Laplacian, so that $\Delta u = f$ will be interpreted to mean

$$(1) \quad \mathcal{E}(u, v) = - \int f v \, d\mu$$

for a suitable test class of functions v , vanishing on the boundary, where μ is a measure and $\mathcal{E}(u, v)$ is a bilinear form called a *Dirichlet form*. In the manifold case,

$$(2) \quad \mathcal{E}(u, v) = \int \nabla u \cdot \nabla v \, d\mu = \int g^{jk}(x) \frac{\partial u}{\partial x^j} \frac{\partial v}{\partial x^k} \sqrt{g(x)} \, dx$$

and $d\mu(x) = \sqrt{g(x)} \, dx$ in local coordinates, where $\{g_{jk}(x)\}$ is a given Riemannian metric, $g(x) = \det\{g_{jk}(x)\}$, and $\{g^{jk}(x)\}$ is the inverse of the matrix $\{g_{jk}(x)\}$. In the fractal case the Dirichlet form will come to play the leading role. There does not seem to be any canonical measure, and the measure on the right side of (1) may be different from the one on the right side of (2). There is certainly no analog of the Riemannian metric. It is interesting to ask in the manifold case whether or not the Dirichlet form determines the metric. The

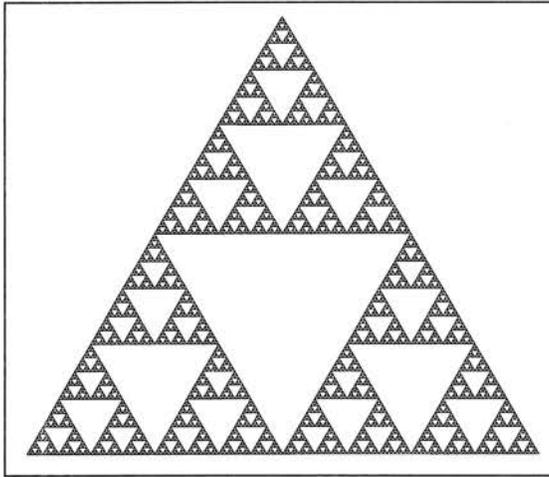


Figure 1. The Sierpinski gasket.

duced by J. Kigami, which is direct, constructive, and easy to explain. It is also possible to use probabilistic methods that will indirectly yield the same Laplacians. For this approach see M. Barlow [Ba], which is also a good source for references in this area. Later references to the probabilistic literature are found in [HK]. The forthcoming book [Ki3] will have an extensive bibliography. Other mathematical developments that might also be described as “analysis on fractals” are not described here; for example, the function spaces of A. Jonsson and H. Wallin [JW] and the work of J. Harrison [H] and U. Mosco [Mo].

Laplacian on the Sierpinski Gasket

In order to keep the discussion on a concrete level, I will concentrate on the construction of the fully symmetric Laplacian on the *Sierpinski gasket* SG (Figure 1), the familiar self-similar fractal generated by three contractions F_i in the plane with contraction ratio $1/2$ and fixed points at the vertices of an equilateral triangle. Its construction will be described in more detail below. This was the first example considered by J. Kigami [Ki1], who later extended the method to a class of fractals called “p.c.f.” (post-critically finite) [Ki2]. The SG is typical for p.c.f. fractals, but this class is certainly very special, and other methods (nonconstructive) for producing Laplacians have been presented for other fractals.

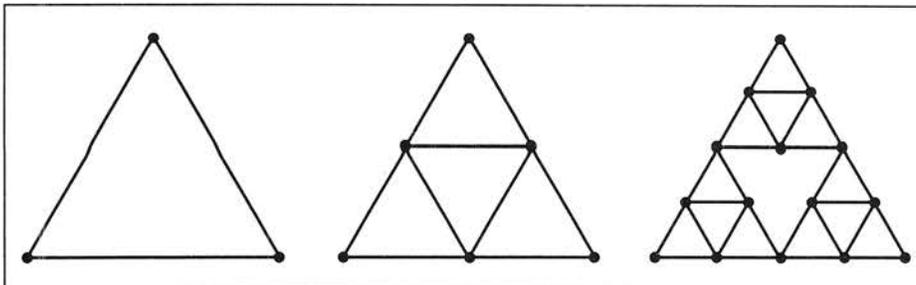


Figure 2. The first three graphs $\Gamma_0, \Gamma_1, \Gamma_2$ approximating the Sierpinski gasket.

answer is yes when the dimension $n \neq 2$. When $n = 2$, conformal metrics yield the same Dirichlet form, and there is an obstruction in passing from a positive definite form in the gradient to a Riemannian metric, not present when $n \neq 2$.

This article will describe the approach intro-

Kigami’s idea is to approximate the fractal from within by a sequence of finite graphs. The Laplacian on the fractal is then the renormalized limit of graph Laplacians. The same method works on the unit interval or the unit square, but we will see that there are features of the construction on SG that are more reminiscent of the interval than the square. In particular, points will have positive capacity.

In order to figure out the correct renormalization for the limit, we will construct the Dirichlet form first. The sequence of graphs $\{\Gamma_m\}$ is easy to describe inductively (see Figure 2). Γ_0 is just the complete graph on the three vertices V_0 of the triangle, and Γ_m with vertices V_m is obtained from Γ_{m-1} by applying the contractions F_i to the vertices V_{m-1} , with the edge relation $x \sim_m y$ holding if and only if x and y are vertices of the same cell $F_{i_1} \cdots F_{i_m}(SG)$ of order m . It is clear that the union of the vertices V_m is dense in SG, so a continuous function is determined by its restriction to vertex points. It turns out that we can work entirely within the class of continuous functions on SG.

The unit interval can also be obtained as a limit of graphs by taking V_m to be the dyadic points $\{j2^{-m} : 0 \leq j \leq 2^m\}$ with edges between consecutive points. The constructions that follow are closely modeled on this example.

On each graph Γ_m there is a naive Dirichlet form

$$E_m(f, g) = \sum_{x \sim_m y} (f(x) - f(y))(g(x) - g(y))$$

but these forms are not related to each other unless we multiply by the appropriate constants. That is, for

$$(3) \quad E_m(f, g) = c_m \sum_{x \sim_m y} (f(x) - f(y))(g(x) - g(y)),$$

we would like the following consistency condition to hold: given a real-valued function f defined on V_{m-1} , we want

$$(4) \quad E_{m-1}(f, f) = E_m(\tilde{f}, \tilde{f}),$$

where \tilde{f} is the extension of f to V_m that minimizes E_m . We call \tilde{f} the *harmonic extension*. If we work this out for $m = 1$, we find that $c_1 = (5/3)c_0$, and the harmonic extension \tilde{f} is given by the $(2/5, 1/5)$ law: the value of f at a vertex of $V_1 \setminus V_0$ is the weighted average of f at the vertices of V_0 with weights $2/5$ for the adjacent vertices and $1/5$ for the opposite vertex. In the general case the harmonic extension problem is seen to be local, so the same $(2/5, 1/5)$ law applies on each cell of order $m - 1$, and the same relationship $c_m = (5/3)c_{m-1}$ holds for the renormalization constants. Thus we must have $c_m = (5/3)^m c_0$, and for simplicity we

take $c_0 = 1$. Note that the local harmonic extension law is the analog of the fact that a linear function on an interval takes on the average value of its endpoint values at the midpoint; no such result holds for harmonic functions on a square.

The consistency condition (4) means that for any continuous function f on SG, $\mathcal{E}_m(f, f)$ is a monotone increasing function of m , so

$$(5) \quad \mathcal{E}(f, f) = \lim_{m \rightarrow \infty} \mathcal{E}_m(f, f)$$

is always defined (in $[0, \infty]$). We let $\text{dom } \mathcal{E}$ be the set of functions f for which $\mathcal{E}(f, f)$ is finite. The constants, and only the constants, have zero energy, and it is not hard to see that $\text{dom } \mathcal{E}$ modulo constants is a Hilbert space with inner product $\mathcal{E}(f, g)$ defined by the same sort of limit as in (5). The energy form satisfies the self-similar identity

$$(6) \quad \mathcal{E}(f, g) = \sum_{i=1}^3 (5/3) \mathcal{E}(f \circ F_i, g \circ F_i)$$

and is symmetric under the 6-element symmetry group of the equilateral triangle.

The three vertices in V_0 are, by definition, the *boundary* of SG. Note that every nonboundary vertex in V_m has exactly four neighbors in V_m . We define a *harmonic function* on Γ_m to be one that assumes the value at a nonboundary vertex x equal to the average of the values at the neighboring vertices. A *harmonic function* on SG is just a continuous function whose restrictions to Γ_m are all harmonic. It is uniquely determined by its values on the boundary, and its values on V_m are obtained from its values on V_{m-1} by the harmonic extension $(2/5, 1/5)$ law. Thus the space of harmonic functions is 3-dimensional. Figure 3 shows the graph of a harmonic function.

To define a Laplacian from the Dirichlet form via the weak formulation (1) requires that we choose a measure μ for the right side of (1). There is certainly a natural measure on SG, namely the self-similar probability measure satisfying

$$(7) \quad \mu = \sum_{i=1}^3 \frac{1}{3} \mu \circ F_i^{-1},$$

or equivalently

$$(8) \quad \int_{\text{SG}} f d\mu = \sum_{i=1}^3 \frac{1}{3} \int_{\text{SG}} f \circ F_i d\mu.$$

In fact, such an identity determines μ , and μ is the normalized Hausdorff measure of dimension $\log 3 / \log 2$ restricted to SG. The measure of each of the 3^m cells of order m is just 3^{-m} . The identity (8) makes it possible to evaluate many integrals exactly (for example, inner products of harmonic functions). With this choice of μ we define $u \in \text{dom } \Delta$ and $\Delta u = f$ if $u \in \text{dom } \mathcal{E}$, f is continuous, and (1) holds for all $v \in \text{dom } \mathcal{E}$ with v vanishing on the boundary V_0 . This is in fact a useful

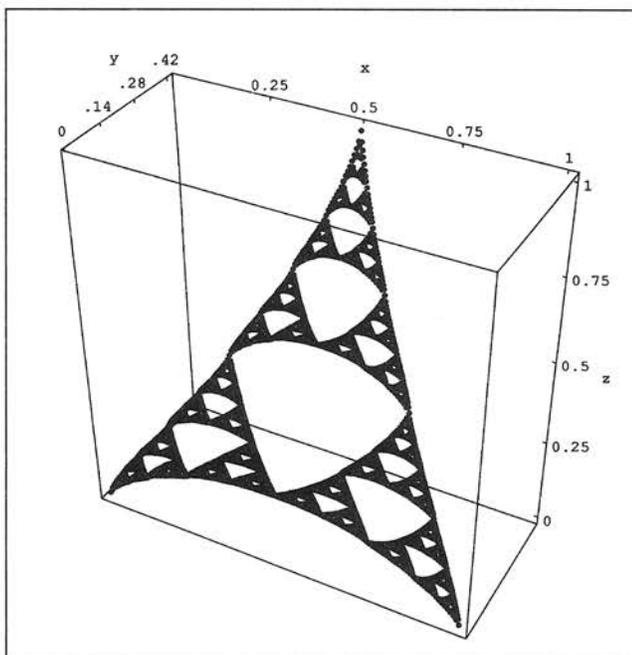


Figure 3. The graph of a harmonic function on the Sierpinski gasket, with boundary values 0, 0, 1 at the vertices $(0, 0)$, $(1, 0)$, $(1/2, \sqrt{3}/4)$. The function was actually plotted just at the points of V_7 .

definition for proving theorems, but a more explicit definition is the pointwise formula

$$(9) \quad \Delta u(x) = \lim_{m \rightarrow \infty} (3/2) 5^m \sum_{y \sim_m x} (u(y) - u(x))$$

for any nonboundary vertex point x . The renormalization factor 5^m in (9) is just the product of $(5/3)^m$ in (3) divided by the factor $(1/3)^m$ from the measure μ . The relatively unimportant constant $3/2$ arises because vertices in V_m do not correspond exactly to sets of measure $(1/3)^m$. The exact theorem [Kil] is that $u \in \text{dom } \Delta$ if and only if the limit in (9) exists uniformly. Note that (9) is, as promised, a renormalized limit of graph Laplacians, but the renormalization constant 5^m cannot be explained by any superficial dimension arguments. Of course (9) exhibits Δu as a limit of difference quotients and shows the local nature of this Laplacian: $\Delta u(x)$ depends only on the values of u in any neighborhood of x . But (9) is valid only for vertex points, and although these points are dense in SG, they are a set of measure zero for μ and are far from being typical points. From (9) it is not hard to show that a function h is harmonic if and only if $\Delta h = 0$.

There is a version of the Gauss-Green formula valid for this Laplacian. Not only is this an interesting result in itself, but also it is an important technical tool. To state the result we need to define normal derivatives at the boundary points $x \in V_0$:

$$(10) \quad \partial_n f(x) = \lim_{m \rightarrow \infty} (5/3)^m \sum_{y \sim_m x} (f(y) - f(x)).$$

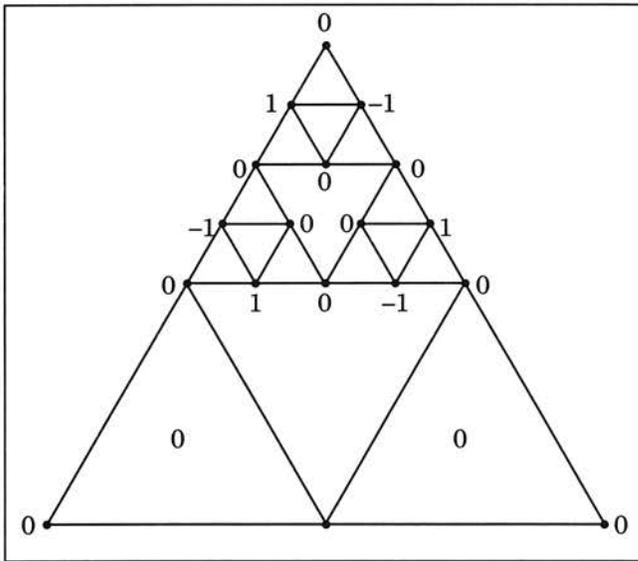


Figure 4. The values of an eigenfunction on Γ_3 with eigenvalue $\lambda_3 = 5$, identically zero on two of the three cells of order 1.

Note that there are exactly two neighboring points when $x \in V_0$. The limit exists when f is in $\text{dom } \Delta$.

Theorem 1. (Gauss-Green Formula). If u and v are in $\text{dom } \Delta$,

$$(11) \quad \int_{SG} (u \Delta v - v \Delta u) d\mu = \sum_{x \in V_0} (u(x) \partial_n v(x) - v(x) \partial_n u(x)).$$

There is also a Green's function $G(x, y)$ for solving

$$(12) \quad \Delta u = f, \quad u|_{V_0} = 0$$

uniquely via

$$(13) \quad u(x) = \int_{SG} G(x, y) f(y) d\mu(y).$$

The Green's function is continuous, symptomatic of the fact that points have positive capacity. There is an explicit formula for G that we omit here.

Eigenfunctions and Spectral Decimation

With the definition of the Laplacian in place, it is possible to consider analogs of the classical equations involving the Laplacian. We have already mentioned harmonic functions, for which there exists a simple and effective local extension algorithm. The harmonic functions are the analogs of linear functions on an interval. Similarly, the eigenfunctions of the Laplacian

$$(14) \quad -\Delta f = \lambda f$$

are the analogs of sines, cosines, and exponentials. By imposing either Dirichlet ($f|_{V_0} = 0$) or Neumann ($\partial_n f|_{V_0} = 0$) boundary conditions on solutions of (14), we obtain a discrete family of *Dirichlet* (or *Neumann*) *eigenfunctions*, with eigenvalues forming a

discrete *Dirichlet* (or *Neumann*) *spectrum*. Moreover, arbitrary functions may be expanded in infinite series of either type of eigenfunctions, giving the analog of Fourier sine and cosine series. The spectrum was first studied by the physicists R. Rammal and G. Toulouse in 1983 and 1984. In 1992 M. Fukushima and T. Shima gave a mathematical description of eigenvalues and eigenfunctions. Many illustrations can be found in [DSV].

The eigenfunctions may in fact be computed via an effective local extension algorithm. To see what this should be like, we observe that the function $\sin \pi k x$ on the unit interval is an eigenfunction not only of the differential operator d^2/dx^2 but also of the symmetric second difference operator

$$(15) \quad \Delta_h^2 f(x) = h^{-2}(f(x+h) + f(x-h) - 2f(x)),$$

with eigenvalue $2h^{-2}(\cos \pi k h - 1)$ that tends to $-(\pi k)^2$ as $h \rightarrow 0$. Thus, if we let V_m denote the dyadic points $j2^{-m}$ in the unit interval, the eigenfunctions of Δ_h^2 with $h = 2^{-m}$ on V_m are restrictions to V_m of eigenfunctions of d^2/dx^2 , and we obtain the whole Dirichlet spectrum (with the correct eigenvalues) in the limit as $m \rightarrow \infty$. Moreover, there is a bifurcation of eigenfunctions as we extend from V_m to V_{m+1} . If we start with $f(x) = \sin \pi k x$ on V_m with $1 \leq k < 2^m - 1$, we can extend f to V_{m+1} as either $\sin \pi k x$ or $\sin \pi(k + 2^m)x$, giving different eigenfunctions with different eigenvalues. Here we can begin the whole process with the single Dirichlet eigenfunction $\sin \pi x$ on V_1 .

The story is quite similar on SG. Aside from a few complications, every eigenfunction

$$(16) \quad -\Delta_m f_m = \lambda_m f_m$$

of the graph Laplacian

$$(17) \quad \Delta_m f_m(x) = \sum_{y \sim x} (f(y) - f(x))$$

on Γ_m can be extended by an explicit local algorithm in two distinct ways to an eigenfunction f_{m+1} on Γ_{m+1} with eigenvalue λ_{m+1} , where the eigenvalues are related by the quadratic equation

$$(18) \quad \lambda_m = \lambda_{m+1}(5 - \lambda_{m+1}).$$

Furthermore, eigenfunctions of Δ on SG arise by taking limits as $m \rightarrow \infty$. What is new is that the process needs to be started at different levels. Eigenvalues can have high multiplicity (much higher than is suggested by the 6-element symmetry group), and the eigenfunctions can be completely localized. For example, Figure 4 shows the values of an eigenfunction on Γ_3 with eigenvalue $\lambda_3 = 5$. By extending this function and passing to the limit, we obtain a Dirichlet eigenfunction on SG that vanishes identically on two of the three cells of order 1. This means that there are solutions to the heat equation or wave equation on SG for which the heat

(or vibration) never escapes from a small cell. This is perhaps not so surprising in view of the topological structure of SG, where single junction points (the vertices in V_m) control the connection between neighboring cells, and any signal with an odd symmetry in a neighborhood of such a junction point will not get past. Another peculiar feature of the eigenfunctions on SG is that they may assume a constant value along a line segment. For example, the ground state Dirichlet eigenfunction (Figure 5) assumes its maximum value along the whole inverted triangle connecting the nonboundary vertices in V_1 .

As a consequence of this description of eigenvalues called the *spectral decimation method*, the spectrum (Dirichlet or Neumann) satisfies a Weyl asymptotic law with a dimension $d_S = 2 \log 3 / \log 5$ known as the *spectral dimension*. The example of SG is a bit special, since the spectral decimation method works only for a very limited class of fractals. J. Kigami and M. Lapidus established the Weyl asymptotic law in full generality using different methods in 1993.

Heat and Wave Equation

Using the Laplacian Δ on SG for the space part, we can consider space-time heat and wave equations $u_t = \Delta u$ and $u_{tt} = \Delta u$ for $u(x, t)$ a function on $SG \times [0, \infty)$. The heat equation may also be considered as the diffusion equation for a stochastic process that may be described as Brownian motion on SG, with Δ as its infinitesimal generator. It is possible to give an independent description of this Brownian motion, and in fact this predates the explicit construction of the Laplacian we have described. The heat kernel then describes the transition probabilities for the process.

Estimates for the heat kernel of the expected Gaussian type have been obtained by B. Hambly and T. Kumagai [HK], and there are some interesting features. The dimension that appears in the on-diagonal estimates is the spectral dimension d_S . The distance that appears in the off-diagonal estimates is not the Euclidean distance. This should not be too surprising, since the geometry that comes from the embedding of SG in the plane plays no role in the construction of the Laplacian. The distance that is relevant is the *intrinsic resistance metric*. If we regard the graphs Γ_m as electric circuits, with the edges consisting of resistors whose resistance is the reciprocal of the conductance constant c_m , then the effective resistance between vertices is independent of m and by continuity yields a metric on SG. Another way to describe this metric $d_R(x, y)$ is as the infimum of the energy of a function f that satisfies $f(x) = 0$ and $f(y) = 1$. The intrinsic resistance metric is not exactly self-similar, but asymptotically it scales by a ratio of $3/5$ with each contraction. Thus cells of order m have diameter approximately $(3/5)^m$.

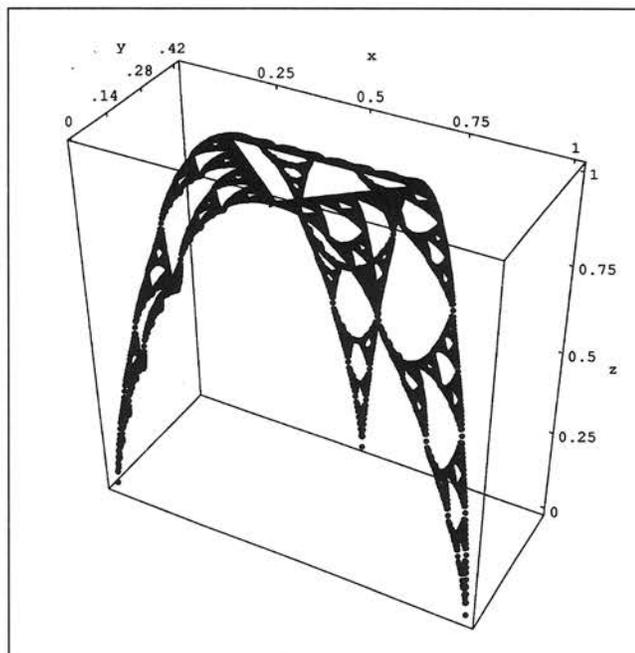


Figure 5. The graph of the ground-state Dirichlet eigenfunction on the Sierpinski gasket. This function is strictly positive on the interior and achieves its maximum value of 1 everywhere on the principal interior triangle. The function has $\lambda_1 = 2$. For $m \geq 1$, λ_{m+1} is $(1/2)(5 - \sqrt{25 - 4\lambda_m})$, the negative square root being chosen at each stage.

An interesting connection between the intrinsic resistance metric and the spectral dimension is the formula

$$d_S = 2d_H / (d_H + 1),$$

where d_H denotes the Hausdorff dimension in this metric.

The wave equation presents another surprise: there is no finite propagation speed. This can be explained in terms of a mismatch between the scaling properties of the second time derivative (factor of 4) and the Laplacian (factor of 5). If we were to construct a “Sierpinski harp” by wiring strings along the edges of Γ_m and coupling the strings appropriately at the vertices in V_m , we would need to increase the tension on the strings as m increases in order to obtain in the limit a model for wave propagation on SG. As every musician knows, increasing tension increases pitch, but the reason behind the increase in pitch is that the speed of propagation increases. Thus, for large m a vibration can travel along the edge of the harp at high speed. However, most of the energy of the vibration will not discover this potential superhighway but instead will get snarled in the local traffic of the convoluted connections in the graph Γ_m . In the limit, small amounts of energy can travel at arbitrarily large speed. From a scaling perspective, vibrations appear to travel faster on a smaller scale.

The unbounded propagation speed seems to defy basic physical principles, but the resolution of this problem is simply that true fractals do not exist in nature. Once one gets to the molecular level, a different model is needed. Nevertheless, objects that have a fractal structure at several scales may often still be profitably modeled by fractals.

Numerical Analysis

Where exact solutions to fractal differential equations are unavailable, a number of techniques for finding approximate solutions are known. One rather obvious method, the analog of the finite-difference method, is to use $5^m \Delta_m$ on Γ_m as an approximation to Δ on SG. This method was used for the space components in the heat and wave equations in [DSV]. It is also possible to develop an analog of the finite-element method by constructing spline spaces [SU]. The analog of the space of polynomials of degree at most $2j + 1$ on an interval is the space \mathcal{H}_j of multiharmonic functions satisfying $\Delta^{j+1}u = 0$. By using the Green's function representation (13) it is possible to give effective local algorithms for computing multiharmonic functions, starting from the boundary data

$$(19) \quad \begin{cases} \Delta^k f|_{V_0} & k \leq j/2, \\ \partial_n \Delta^k f|_{V_0} & k < j/2. \end{cases}$$

We then define spline spaces $S_m \mathcal{H}_j$ of functions that are piecewise in \mathcal{H}_j on each of the 3^m cells of order m and that satisfy matching conditions at the nonboundary vertices in V_m corresponding to the data (19). The spline space $S_m \mathcal{H}_0$ is just the space of continuous piecewise harmonic functions at level m . By taking higher values of j we allow the splines to be "smoother".

To find the finite-element approximation to the solution of (12), for example, we choose values for j and m and take the subspace of $S_m \mathcal{H}_j$ satisfying the boundary condition $u|_{V_0} = 0$. The approximate solution is the function in this space satisfying the integrated equation (1) for all v in this space. By choosing a natural basis for this space we obtain a sparse system of linear equations. The values of $\mathcal{E}(u, v)$ can be computed theoretically, but the right side of (1) requires numerical integration. The spline spaces may be used also to develop efficient numerical integration methods analogous to Simpson's method. They are also useful for cutting and pasting operations on functions. A version of the finite-element method implemented by M. Gibbons and A. Raj may be found at <http://mathlab.cit.cornell.edu/~gibbons/>.

Taylor Approximations

It would be difficult to convince a calculus student that the second derivative is the more basic concept and the first derivative is a subordinate no-

tion. Yet that is the situation we are in at this stage of the development of calculus on SG. In fact, there is no completely satisfactory analog of the gradient, although I will describe two distinct approaches to the problem. On an interval the tangent line is defined by the local approximation of a differentiable function by linear functions. This is the first of the sequence of Taylor polynomial approximations, involving higher derivatives, for functions with greater smoothness. The first derivative and also the higher derivatives appear as coefficients of the Taylor polynomials. On SG the analogs of linear functions are harmonic functions, and the analogs of polynomials are the multiharmonic functions. These are the functions that should serve as local approximations to a general "differentiable" function, and the coefficients identifying the approximation should serve as components of various derivatives of the function. With some luck, one may also compute the derivatives as limits of difference quotients.

The situation turns out to be more complicated for three reasons. First, the results are different at the special vertex points in V_m and at generic points, where the theory is somewhat incomplete. Second, at a vertex point the approximation rate that characterizes the Taylor approximation must be described by two different estimates, a faster rate for the odd part and a slower rate for the even part (hence overall). Third, the region where the approximation takes place is limited by the geometry of the point regardless of the function.

To describe the situation in more detail, we begin by defining a tangential derivative $\partial_T f(x)$ at boundary points $x \in V_0$ to go along with the normal derivative defined by (10):

$$(20) \quad \partial_T f(x) = \lim_{m \rightarrow \infty} 5^m (f(a_m) - f(b_m)),$$

where a_m and b_m are the two neighbors of x in V_m . The limit exists if f is in $\text{dom } \Delta$. Next we localize both derivatives to the cells of order m whose boundary points are the vertices in V_m . Each nonboundary vertex x_0 is a boundary point for two such cells, and so there are four derivatives defined at x_0 . However, under reasonable assumptions, such as $f \in \text{dom } \Delta$, the two normal derivatives are related: in fact, they sum to 0. The two tangential derivatives are independent however. So we can define a gradient of f at x_0 consisting of three component derivatives. This leads to an embarrassing dimensional miscount, since we have four numbers (the value of the function at x_0 plus the three derivatives) to match a harmonic function, and the space of harmonic functions is only 3-dimensional. The resolution of this paradox is that we should try to match only a local harmonic function, not a global harmonic function. The point x_0 has a natural system of neighborhoods $U_m(x_0)$ consisting of pairs of adjacent cells of order m meeting at x_0 .

Here we must require that m be sufficiently large so that $x_0 \in V_m$. Each of these neighborhoods has exactly four boundary points, and there is a 4-dimensional space of local harmonic functions on $U_m(x_0)$. The first Taylor approximation to f at x_0 is defined to be the local harmonic function h that matches the values of f and its three derivatives at x_0 . Note that the domain of definition of h is limited by the geometry of x_0 alone.

Next we describe the local approximation properties of h . We define a reflection symmetry R in $U_m(x_0)$ that fixes x_0 and reflects each cell to itself through the angle bisector of x_0 . (Here R does not permute the two cells.) The overall estimate takes the form

$$(21) \quad |f(x) - h(x)| = o((3/5)^m) \quad \text{for } x \in U_m(x_0),$$

while the estimate for the odd part is

$$(22) \quad |(f(x) - f(Rx)) - (h(x) - h(Rx))| = o((1/5)^m)$$

for $x \in U_m(x_0)$. It is not hard to show that at most one local harmonic function can satisfy (21) and (22) and that if such a local harmonic function exists, then its derivatives at x_0 must match the corresponding derivatives of f at x_0 . In addition, $f(x_0) = h(x_0)$. The following existence theorem is proved in [S]:

Theorem 2. *Suppose f is in $\text{dom}(\Delta)$ and Δf satisfies a Hölder condition of any positive order. Then for each vertex point x_0 there exists a local harmonic function h satisfying (21) and (22).*

There are analogous statements involving higher-order Taylor approximations by local multiharmonic functions with better estimates, under assumptions that f belongs to the domain of a power of Δ . The occurrence of a power of $3/5$ in (21) and (10) is a consequence of the fact that $c_m = (5/3)^m$ in (3). However, the power of 5 that appears in (22) and (20) is just coincidentally the same as the power of 5 that appears in (9). This coincidence is related to the additional hypothesis of Hölder continuity required in Theorem 2.

The story for local approximation at a generic point x_0 is quite different. If we specifically assume that x_0 does not belong to any V_m , then x_0 belongs to a unique cell $U'_m(x_0)$ of order m , and this gives a natural system of neighborhoods of x_0 . Each cell has three boundary points, and local harmonic functions on the cell are determined by the values at these boundary points. In fact, each local harmonic function is the restriction of a unique global harmonic function, and the extension and restriction are easily described in terms of three matrices M_i and their inverses M_i^{-1} . The restriction from SG to $F_i(SG)$ of a harmonic h is given by

$$(23) \quad h \circ F_i \Big|_{V_0} = M_i h \Big|_{V_0},$$

where

$$(24) \quad M_1 = \begin{pmatrix} 1 & 0 & 0 \\ 2/5 & 2/5 & 1/5 \\ 2/5 & 1/5 & 2/5 \end{pmatrix}$$

and M_2 and M_3 are obtained from M_1 by cyclic permutations of indices. The restriction to the cell $F_{i_1} \cdots F_{i_m}(SG)$ is then given by

$$(25) \quad h \circ (F_{i_1} \cdots F_{i_m}) \Big|_{V_0} = M_{i_m} \cdots M_{i_1} h \Big|_{V_0},$$

and the extension is the inverse relation

$$(26) \quad h \Big|_{V_0} = M_{i_1}^{-1} \cdots M_{i_m}^{-1} h \circ (F_{i_1} \cdots F_{i_m}) \Big|_{V_0}.$$

Now if a nonvertex point x_0 is given, the neighborhood system $U'_m(x_0)$ corresponds to a unique sequence $\{i_j\}$. We let h_m denote the harmonic function that matches f at the three boundary points of $U'_m(x_0)$. By (26) this means

$$(27) \quad h_m \Big|_{V_0} = M_{i_1}^{-1} \cdots M_{i_m}^{-1} f \circ (F_{i_1} \cdots F_{i_m}) \Big|_{V_0}.$$

If the limit exists as $m \rightarrow \infty$, we call the harmonic function $h = \lim_{m \rightarrow \infty} h_m$ the first-order Taylor approximation to f at x_0 . Using H. Furstenberg's 1963 theory of products of random matrices, [S] shows that for μ -almost every point x_0 , the first-order Taylor approximations at x_0 exist for every $f \in \text{dom} \Delta$, and the estimate

$$(28) \quad |f(x) - h(x)| = O(\beta^m) \quad \text{for } x \in U'_m(x_0)$$

holds for $\beta > \beta_0$. Moreover, the estimate (28) uniquely characterizes the harmonic function h . The value of the constant β_0 in (28) can only be estimated.

Energy Measures

Since the Dirichlet form $\mathcal{E}(u, v)$ is the analog of $\int \nabla u \cdot \nabla v \, d\mu$, it is tempting to look for the analogs of both $\nabla u \cdot \nabla v$ and dx within it. In fact, there is a standard procedure for associating a measure $\nu_{u,v}$ to every $u, v \in \text{dom} \mathcal{E}$ (positive when $u = v$) such that

$$(29) \quad \mathcal{E}(u, v) = \int d\nu_{u,v}.$$

In this case the simplest way to describe $\nu_{u,v}$ is to take for $\nu_{u,v}(A)$, when A is any simple set, the same limit that defines $\mathcal{E}(u, v)$, but restricting the sums in $\mathcal{E}_m(u, v)$ to points in A . If we can find a positive measure ν with the property that $\nu_{u,v}$ is absolutely continuous with respect to ν for all $u, v \in \text{dom} \mathcal{E}$, then we can write

$$(30) \quad \nu_{u,v} = \Gamma(u, v) \, d\nu$$

for the appropriate Radon-Nikodym derivative $\Gamma(u, v)$. Here Γ is called the *carré du champs* operator. S. Kusuoka in 1989 showed that (30) holds

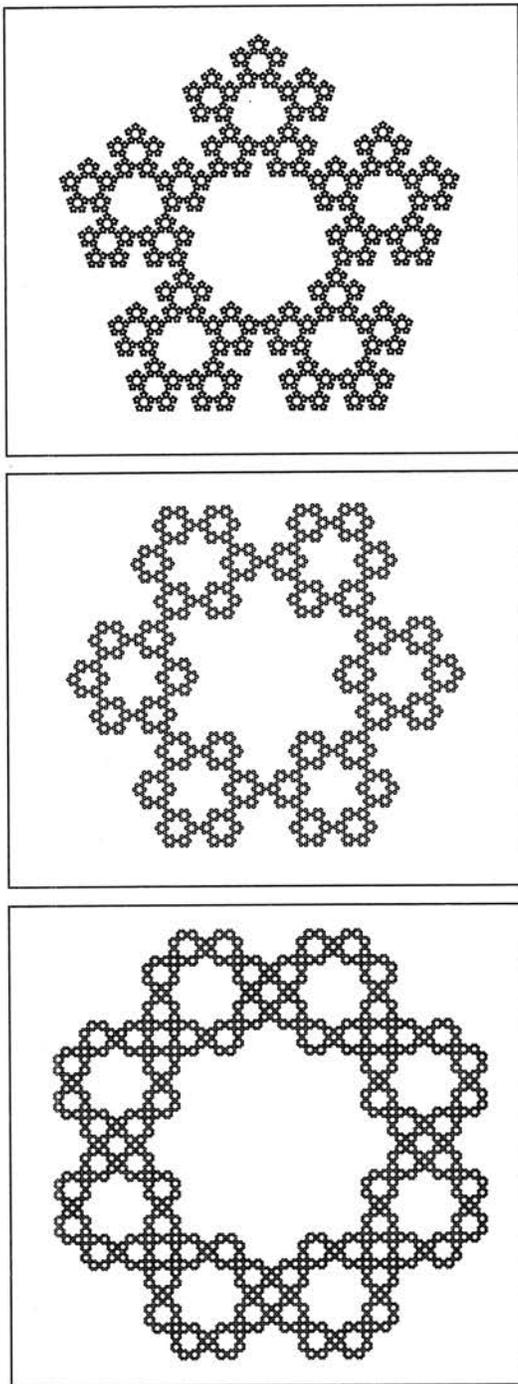


Figure 6. The pentagasket (top), hexagasket (middle), and octagasket (bottom).

with the choice of $\nu = \nu_{h_1, h_1} + \nu_{h_2, h_2}$, where $\{h_1, h_2\}$ is an orthonormal basis for the harmonic functions mod constants in the energy inner product. We refer to $\nu_{f, g}$ as *energy measures* and ν as the *Kusuoka measure*. A perhaps surprising observation is that the Kusuoka measure and hence all the energy measures are singular with respect to the self-similar measure μ defined by (7) and (8) that we used in the construction of the Laplacian! We can think of $\Gamma(u, \nu)$ as the analog of $\nabla u \cdot \nabla \nu$, but we must keep in mind that $\Gamma(u, \nu)$ is defined only almost everywhere with respect to ν . It is not clear whether there is any meaningful way to define ∇u so that $\Gamma(u, \nu) = \nabla u \cdot \nabla \nu$.

The singularity of the Kusuoka measure has another disquieting consequence: multiplication is forbidden in $\text{dom}(\Delta)$. Specifically, if $u \in \text{dom}(\Delta)$ is not constant, then u^2 is not in $\text{dom}(\Delta)$. This can be explained by the putative identity

$$(31) \quad \Delta u^2 = 2u\Delta u + \nabla u \cdot \nabla u,$$

which can be interpreted correctly only in terms of measures [BST]. A different explanation can be based on the incommensurability of the different approximation rates in the local Taylor approximation. If f is in $\text{dom}(\Delta)$ and x_0 is a vertex point where $\partial_n f(x_0) \neq 0$, then the rate of convergence of $f(x)$ to $f(x_0)$ is bounded above and below by a multiple of $(3/5)^m$ on $U_m(x_0) \setminus U_{m+1}(x_0)$. Then

$(f(x) - f(x_0))^2$ converges to 0 too rapidly to have nonzero normal derivative. But it also converges to 0 too slowly to have normal derivative equal to 0, for that implies a rate of at least $m(1/5)^m$.

The impossibility of multiplication is a serious obstacle to the interpretation of the domains of Δ and powers of Δ as spaces of smooth functions. Perhaps that is just the nature of things. Another possible response is to study a different Laplacian, constructed by taking the Kusuoka measure on the right side of (1). This eliminates the problem of multiplication and enables us to make perfect sense out of (31). But it has the disadvantage that ν is not self-similar, so computations with this Laplacian will not be independent of scale. Certainly when dealing with physical models, one will not have the luxury of choosing a measure at will if the measure is to have the interpretation of mass distribution.

Here is an entertaining diversion concerning the Kusuoka measure. Suppose we carry out the same procedure for the standard Dirichlet form $\int |\nabla u|^2 dx$ on the unit disc. In this case there is an infinite orthonormal basis $\{h_i\}$ of harmonic functions modulo constants in this inner product, and we would take

$$(32) \quad \nu = \sum_{i=1}^{\infty} |\nabla h_i(x)|^2 dx,$$

the sum being independent of the choice of orthonormal basis. The computation of ν is straightforward but lengthy, and the result is a multiple of the Riemannian measure associated to the hyperbolic metric on the disc. This should come as no surprise, since we have already observed that the Dirichlet form in two dimensions is a conformal invariant, so we might as well start out by working in the hyperbolic metric. Then the Möbius transformations of the disc are isometries, and ν must be Möbius invariant (because composing the orthonormal basis with a Möbius transform produces another orthonormal basis). Up to a constant multiple, there is a unique σ -finite Möbius invariant measure.

P.C.F. Self-Similar Fractals

Kigami [Ki2] has described a class of fractals called *post-critically finite* (p.c.f.), for which a similar theory of Dirichlet forms and Laplacians may be constructed, provided a certain algebraic problem can be solved. In the interest of simplicity I will describe a more limited class of fractals that seems to contain all the interesting examples. The key property of SG that we want to maintain is that it is connected, but just barely: the removal of a finite number of points makes it disconnected, so these junction points control all access from one point of the set to another. These fractals are often referred to as *finitely ramified*.

We will work within the class of self-similar sets in \mathbb{R}^n . A self-similar set is defined to be the unique nonempty compact set K satisfying

$$(33) \quad K = \bigcup_{i=1}^N F_i K$$

for a family $\{F_i\}$ of contractive similarities. The *critical set* C is defined to be the set of all intersection points $F_i K \cap F_j K$ for $i \neq j$, and the *post-critical set* P is defined to be the pre-images of C under the mappings F_i and their iterates. The p.c.f. assumption we make is that P is a finite set, and by definition it is the *boundary* of K .

To get a feeling for what is and is not in a p.c.f. fractal, consider the class of polygaskets, which are constructed from a regular N -gon in the same way that SG is constructed from a triangle. We adjust the contraction ratio for F_i (with fixed points the vertices of the N -gon) so that the images just touch. When N is not divisible by 4, the image N -gons touch at single vertices, and we obtain a p.c.f. fractal with P equal to the N vertices of the original N -gon. But when 4 divides N , the intersections are infinite (for $N = 4$ we obtain a square). Figure 6 shows the pentagasket and hexagasket, which are p.c.f., and the octagasket, which is not.

For a p.c.f. fractal K we define cells of order m to be images $F_{i_1} \cdots F_{i_m} K$, and we define graphs Γ_m by taking $V_0 = P$,

$$V_m = \bigcup_{i=1}^N F_i V_{m-1},$$

and the edge relation $x \sim_m y$ if x and y belong to the same cell. The intersections of distinct cells consist of vertices in V_m , but not all nonboundary vertices are such junction points (see the pentagasket and hexagasket, for example). We want to construct a Dirichlet form \mathcal{E} on K that is again the limit of Dirichlet forms \mathcal{E}_m on Γ_m , but we can no longer rely on the simple formula (3). For \mathcal{E}_m , the expression

$$(34) \quad \mathcal{E}_m(f, f) = \sum_{x \sim_m y} c(x, y)(f(x) - f(y))^2$$

with rather arbitrary positive coefficients $c(x, y)$ would be allowable, but this is too general. What we want is a self-similarity condition on the sequence $\{\mathcal{E}_m\}$,

$$(35) \quad \mathcal{E}_m(f, f) = \sum_{i=1}^N r_i^{-1} \mathcal{E}_{m-1}(f \circ F_i, f \circ F_i)$$

for certain positive coefficients $\{r_i\}$, that will translate into the self-similarity identity

$$(36) \quad \mathcal{E}(f, f) = \sum_{i=1}^N r_i^{-1} \mathcal{E}(f \circ F_i, f \circ F_i)$$

in the limit. We will continue to require the consistency condition (4) as well. The following theorem is proved in [Ki2].

Theorem 3. *Suppose there exist \mathcal{E}_0 on Γ_0 of the form (34) and coefficients $\{r_i\}$ such that if we use (35) to define \mathcal{E}_1 , then (4) holds for $m = 1$. Then if we use (35) to define \mathcal{E}_m inductively, the consistency condition (4) holds for all m . In the case that $r_i < 1$ for all i , the limit \mathcal{E} defines a local Dirichlet form whose domain is contained in the continuous functions on K , and (36) holds.*

In other words, the whole construction succeeds provided it succeeds at the first step. Of course, the algebraic problem of finding the coefficients for \mathcal{E}_0 and the coefficients $\{r_i\}$ is nontrivial, and there is still no general existence theorem, although C. Sabot in 1997 and T. Lindström in 1989 have resolved the problem in some cases. Generally speaking, one expects that there is a continuum of solutions.

For the construction of a Laplacian from the Dirichlet form via (1), it is not necessary to choose a self-similar measure for μ . It is enough to have a finite measure that gives positive values to all nonempty open sets. Many of the results discussed above for SG extend to p.c.f. fractals, with appropriate modifications and hypotheses. One new feature that does not show up in the SG example is that the matrices M_i that occur in the analog of (23) for restricting harmonic functions are not always invertible, so that the extension of harmonic functions given by (27) is not always possible. In particular, harmonic functions may be locally constant but not globally constant.

Challenges for the Future

This article has described some of the developments that have taken us quite far for a relatively narrow class of fractals, and further progress can be expected. There are some hints that these fractals have something in common with manifolds of positive curvature, although there is no obvious candidate for curvature in this context. A Liouville theorem holds for certain noncompact “blow-ups” of these fractals, and in the manifold case this requires a nonnegative curvature assumption.

However, an important challenge for the future is to extend the theory beyond the finitely ramified context. There are Brownian-motion-type processes on other fractals, notably some “Sierpinski carpets”, and the infinitesimal generators give, indirectly, Laplacians. It is not clear what the natural class of fractals is for which this approach will succeed, and it is also not clear how much further information can be obtained in this mainly nonconstructive setting.

It should also be possible to go beyond the self-similar context. Of course, it is easier to work with structures obtained by iterating the same

construction, but it is the hierarchical structure on different scales that seems to be essential to the current theory. Perhaps what is needed is a concept of *fractafold*, the fractal analog of the concept of manifold.

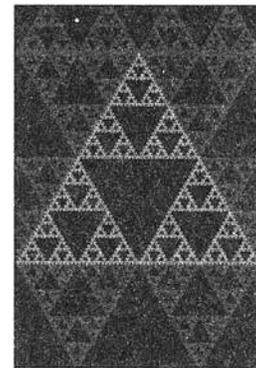
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About the Cover

The Sierpinski gasket is the connected subset of the plane obtained from an equilateral triangle by removing the open middle inscribed equilateral triangle of $1/4$ the area, removing the corresponding open triangle from each of the three constituent triangles, and continuing this way. The gasket can also be obtained as the closure of the set of vertices arising in this construction. The cover shows the vertices of the constituent triangles through seven iterations of constructing midpoints. The vertices are color coded according to the stage at which they first appear, the last three stages being red, orange, and yellow. The vertices have been increased in size from points to small disks to give the illusion of connectedness for the displayed finite set of vertices.

—Peter Sykes



Pseudorandomness

Oded Goldreich

This essay considers finite objects, encoded by binary finite sequences called strings. When we talk of distributions we mean discrete probability distributions having a finite support that is a set of strings. Of special interest is the uniform distribution, which for a length parameter n (explicit or implicit in the discussion), assigns each n -bit string $x \in \{0, 1\}^n$ equal probability (i.e., probability 2^{-n}). We will colloquially speak of “perfectly random strings”, meaning strings selected according to such a uniform distribution.

The second half of this century has witnessed the development of three theories of randomness, a notion that has been puzzling thinkers over the ages. The first theory (cf. [3]), initiated by Shannon, is rooted in probability theory and is focused on distributions that are not perfectly random. Shannon’s information theory characterizes perfect randomness as the extreme case in which the *information content* is maximized (and there is no redundancy at all).¹ Thus, perfect randomness is

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¹In general, the amount of information in a distribution D is defined as $-\sum_x D(x) \log_2 D(x)$. Thus, the uniform distribution over strings of length n has information measure n , and any other distribution over n -bit strings has lower information measure. Also, for any function $f: \{0, 1\}^n \rightarrow \{0, 1\}^m$ with $n < m$, the distribution obtained by applying f to a uniformly distributed n -bit string has information measure at most n , which is strictly lower than the length of the output.

associated with a unique distribution—the uniform one. In particular, by definition, one cannot generate such perfect random strings from shorter random strings.

The second theory (cf. [11, 12]), due to Solomonov, Kolmogorov, and Chaitin, is rooted in computability theory and specifically in the notion of a universal language (equivalently, universal machine or computing device). It measures the complexity of objects in terms of the shortest program (for a fixed universal machine) that generates the object.² Like Shannon’s theory, Kolmogorov complexity is quantitative, and perfect random objects appear as an extreme case. Interestingly, in this approach one may say that a single object, rather than a distribution over objects, is perfectly random. Still, Kolmogorov’s approach is inherently intractable (i.e., Kolmogorov complexity is uncomputable), and, by definition, one cannot generate strings of high Kolmogorov complexity from short random strings.

The third theory, initiated by Blum, Goldwasser, Micali, and Yao [8, 2, 13], is rooted in complexity theory and is the focus of this essay. This approach is explicitly aimed at providing a theory of perfect randomness that nevertheless allows for the efficient generation of perfect random strings from shorter random strings. The heart of this approach is the suggestion to view objects as equal if they cannot be told apart by any efficient

²For example, the string 1^n has Kolmogorov complexity $O(1) + \log_2 n$ (by virtue of the program “print n ones”, which has length dominated by the encoding of n (say, in binary)). In contrast, a simple counting argument shows that most n -bit strings have Kolmogorov complexity at least n .

procedure. Consequently a distribution that cannot be efficiently distinguished from the uniform distribution will be considered as being random (or rather “random for all practical purposes”, which we call “pseudorandom”). Thus, randomness is not an “inherent” property of objects (or distributions) but rather is relative to an observer (and its computational abilities). To demonstrate this approach, let us consider the following mental experiment.

Alice and Bob play HEAD OR TAIL in one of the following four ways. In all of them Alice flips a coin high in the air, and Bob is asked to guess its outcome *before* the coin hits the floor. The alternative ways differ by the knowledge Bob has before making his guess. In the first alternative, Bob has to announce his guess before Alice flips the coin. Clearly, in this case Bob wins with probability $1/2$. In the second alternative, Bob has to announce his guess while the coin is spinning in the air. Although the outcome is *determined in principle* by the motion of the coin, Bob does not have accurate information on the motion and thus we believe that also in this case Bob wins with probability $1/2$. The third alternative is similar to the second, except that Bob has at his disposal sophisticated equipment capable of providing accurate information on the coin’s motion as well as on the environment affecting the outcome. However, Bob cannot process this information in time to improve his guess. In the fourth alternative, Bob’s recording equipment is directly connected to a powerful computer programmed to solve the motion equations and output a prediction. It is conceivable that in such a case Bob can improve substantially his guess of the outcome of the coin.

We conclude that the randomness of an event is relative to the information and computing resources at our disposal. Thus, a natural concept of pseudorandomness arises: a distribution is pseudorandom if no efficient procedure can distinguish it from the uniform distribution, where efficient procedures are associated with (probabilistic) polynomial-time algorithms.

An algorithm is called polynomial-time if there exists a polynomial p so that for any possible input x , the algorithm runs in time bounded by $p(|x|)$, where $|x|$ denotes the length of the string x . Thus, the running time of such an algorithm grows moderately as a function of the length of its input. A probabilistic algorithm is one that can

take random steps, where, without loss of generality, a random step consists of selecting which of two predetermined steps to take next so that each possible step is taken with probability $1/2$. These choices are called the algorithm’s internal coin tosses.

The Definition of Pseudorandom Generators

Loosely speaking, a pseudorandom generator is an *efficient* program (or algorithm) that *stretches* short random strings into long *pseudorandom* sequences. We emphasize three fundamental aspects in the notion of a pseudorandom generator:

1. **Efficiency.** The generator has to be efficient. As we associate efficient computations with polynomial-time ones, we postulate that the generator has to be implementable by a deterministic polynomial-time algorithm. This algorithm takes as input a string, called its seed. The seed captures a bounded amount of randomness used by a device that “generates pseudorandom sequences”. The formulation views any such device as consisting of a deterministic procedure applied to a random seed.
2. **Stretching.** The generator is required to stretch its input seed to a longer output sequence. Specifically, it stretches n -bit long seeds into $\ell(n)$ -bit long outputs, where $\ell(n) > n$. The function ℓ is called the stretching measure (or stretching function) of the generator.
3. **Pseudorandomness.** The generator’s output has to look random to any efficient observer. That is, any efficient procedure should fail to distinguish the output of a generator (on a random seed) from a truly random sequence of the same length. The formulation of the last sentence refers to a general notion of computational indistinguishability that is the heart of the entire approach.

To demonstrate the above, consider the following suggestion for a pseudorandom generator. The seed consists of a pair of 32-bit integers, x and N , and the 100,000-bit output is obtained by repeatedly squaring the current x modulo N and emitting the least significant bit of each intermediate result (i.e., let $x_i \leftarrow x_{i-1}^2 \bmod N$, for $i = 1, \dots, 10^5$, and output $b_1, b_2, \dots, b_{10^5}$, where $x_0 \stackrel{\text{def}}{=} x$ and b_i is the least significant bit of x_i). This process may be generalized to seeds of length n (here we used $n = 64$) and outputs of length $\ell(n)$ (here $\ell(n) = 10^5$). Such a process certainly satisfies items (1) and (2) above, whereas the question whether item (3) holds is debatable (once a rigorous definition is provided). Anticipating some of the discussion below, we mention that, under the assumption that it is difficult to factor large integers, a slight variant of the above process is indeed a pseudorandom generator.

Computational Indistinguishability

Intuitively, two objects are called computationally indistinguishable if no efficient procedure can tell them apart. As usual in complexity theory, an elegant formulation requires asymptotic analysis (or rather a functional treatment of the running time of algorithms in terms of the length of their input).³ Thus, the objects in question are infinite sequences of distributions, where each distribution has a finite support. Such a sequence will be called a distribution ensemble. Typically, we consider distribution ensembles of the form $\{D_n\}_{n \in \mathbb{N}}$, where for some function $\ell: \mathbb{N} \rightarrow \mathbb{N}$, the support of each D_n is a subset of $\{0, 1\}^{\ell(n)}$. Furthermore, typically ℓ will be a positive polynomial. For such D_n , we denote by $e \sim D_n$ the process of selecting e according to distribution D_n . Consequently, for a predicate P , we denote by $\Pr_{e \sim D_n}[P(e)]$ the probability that $P(e)$ holds when e is distributed (or selected) according to D_n .

Definition 1. (computational indistinguishability [8, 13]). *Two probability ensembles, $\{X_n\}_{n \in \mathbb{N}}$ and $\{Y_n\}_{n \in \mathbb{N}}$, are called computationally indistinguishable if for any probabilistic polynomial-time algorithm A , any positive polynomial p , and all sufficiently large n*

$$\left| \Pr_{x \sim X_n}[A(x) = 1] - \Pr_{y \sim Y_n}[A(y) = 1] \right| < \frac{1}{p(n)}.$$

The probability is taken over X_n (resp., Y_n) as well as over the coin tosses of algorithm A .

A few comments are in order. First, we have allowed algorithm A , which is called a distinguisher, to be probabilistic. This makes the requirement only stronger, and seems essential to several important aspects of our approach. Second, we view events occurring with probability that is upper bounded by the reciprocal of polynomials as negligible. This is well coupled with our notion of efficiency (i.e., polynomial-time computations): an event that occurs with negligible probability (as a function of a parameter n) will also occur with negligible probability when the experiment is repeated for $\text{poly}(n)$ -many times. Third, when allowing A in the above definition to be an arbitrary function (rather than a probabilistic polynomial-time algorithm), one obtains a notion of statistical indistinguishability. The latter is equivalent to requiring that the variation distance between X_n and Y_n (i.e., $\sum_z |X_n(z) - Y_n(z)|$) is negligible (in n).

We note that computational indistinguishability is a strictly more liberal notion than statistical indistinguishability (cf. [13]). An important case is the one of distributions generated by a pseudo-

random generator (as defined next): such distributions are computationally indistinguishable from uniform but are not statistically indistinguishable from uniform.

Definition 2. (pseudorandom generators [2, 13]). *A deterministic polynomial-time algorithm G is called a pseudorandom generator if there exists a stretching function, $\ell: \mathbb{N} \rightarrow \mathbb{N}$, so that the following two probability ensembles, denoted $\{G_n\}_{n \in \mathbb{N}}$ and $\{R_n\}_{n \in \mathbb{N}}$, are computationally indistinguishable:*

1. *Distribution G_n is defined as the output of G on a uniformly selected seed in $\{0, 1\}^n$.*
2. *Distribution R_n is defined as the uniform distribution on $\{0, 1\}^{\ell(n)}$.*

That is, letting U_m denote the uniform distribution over $\{0, 1\}^m$, we require that for any probabilistic polynomial-time algorithm A , any positive polynomial p , and all sufficiently large n

$$\left| \Pr_{s \sim U_n}[A(G(s)) = 1] - \Pr_{r \sim U_{\ell(n)}}[A(r) = 1] \right| < \frac{1}{p(n)}.$$

Thus, pseudorandom generators are efficient (i.e., polynomial-time) deterministic programs that expand short randomly selected seeds into longer pseudorandom bit sequences, where the latter are defined as computationally indistinguishable from truly random sequences by efficient (i.e., polynomial-time) algorithms. It follows that any efficient randomized algorithm maintains its performance when its internal coin tosses are substituted by a sequence generated by a pseudorandom generator. That is,

Construction 3. (typical application of pseudorandom generators). *Let A be a probabilistic polynomial-time algorithm, and let $\rho(n)$ denote an upper bound on its randomness complexity (i.e., number of coins that A tosses on n -bit inputs). Let $A(x, r)$ denote the output of A on input x and coin tossing sequence $r \in \{0, 1\}^{\rho(|x|)}$. Let G be a pseudorandom generator with stretching function $\ell: \mathbb{N} \rightarrow \mathbb{N}$. Then A_G is a randomized algorithm that on input x proceeds as follows. It sets $k = k(|x|)$ to be the smallest integer such that $\ell(k) \geq \rho(|x|)$, uniformly selects $s \in \{0, 1\}^k$, and outputs $A(x, r)$, where r is the $\rho(|x|)$ -bit long prefix of $G(s)$.*

It can be shown that it is infeasible to find long x 's on which the input-output behavior of A_G is noticeably different from the one of A , although A_G may use much fewer coin tosses than A . This is formulated in the proposition below, where F represents an algorithm trying to find x 's so that $A(x)$ and $A_G(x)$ are distinguishable (by an algorithm D).

Proposition 4. *Let A and G be as above. For any algorithm D , let $\Delta_{A,D}(x)$ denote the discrepancy, as judged by D , in the behavior of A and A_G on input x , i.e., $\Delta_{A,D}(x)$ is defined as*

³The asymptotic (or functional) treatment is not essential to this approach. One may develop the entire approach in terms of inputs of fixed lengths and an adequate notion of complexity of algorithms. However, such an alternative treatment is more cumbersome.

$$\left| \Pr_{r \sim U_{p(n)}}[D(x, A(x, r)) = 1] - \Pr_{s \sim U_{k(n)}}[D(x, A_G(x, s)) = 1] \right|,$$

where the probabilities are taken over the U_m 's as well as over the coin tosses of D . Then for every pair of probabilistic polynomial-time algorithms F and D , every positive polynomial p , and all sufficiently long n

$$\Pr \left[\Delta_{A,D}(F(1^n)) > \frac{1}{p(n)} \right] < \frac{1}{p(n)},$$

where the probability is taken over the coin tosses of F .

The proposition is proven by showing that a triplet (A, F, D) violating the claim can be converted into an algorithm D' that distinguishes the output of G from the uniform distribution, in contradiction to the hypothesis. Analogous arguments are applied whenever one wishes to prove that an efficient randomized process (be it an algorithm as above or a multiparty computation) preserves its behavior when one replaces true randomness by pseudorandomness as defined above. Thus, given pseudorandom generators with large stretch function, one can considerably reduce the randomness complexity in any efficient application.

Amplifying the Stretch Function

Pseudorandom generators as defined above are required only to stretch their input a bit; for example, stretching n -bit long inputs to $(n+1)$ -bit long outputs will do. Clearly, generators with such moderate stretch functions are of little use in practice. In contrast, we want to have pseudorandom generators with an arbitrarily long stretch function. By the efficiency requirement, the stretch function can be at most polynomial. It turns out that pseudorandom generators with the smallest possible stretch function can be used to construct pseudorandom generators with any desirable polynomial stretch function. (Thus, when talking about the existence of pseudorandom generators, we may ignore the specific stretch function.)

Theorem 5. [5, Sec. 3.3.2]. *Let G be a pseudorandom generator with stretch function $\ell(n) = n + 1$, and let ℓ' be any stretch function such that $\ell'(n)$ is computable in poly(n)-time from n . Let $G_1(x)$ denote the $|x|$ -bit long prefix of $G(x)$, and let $G_2(x)$ denote the last bit of $G(x)$ (i.e., $G(x) = G_1(x)G_2(x)$). Then*

$$G'(s) \stackrel{\text{def}}{=} \sigma_1 \sigma_2 \cdots \sigma_{\ell'(|s|)},$$

where $x_0 = s$, $\sigma_i = G_2(x_{i-1})$, and $x_i = G_1(x_{i-1})$, for $i = 1, \dots, \ell'(|s|)$

is a pseudorandom generator with stretch function ℓ' .

How to Construct Pseudorandom Generators

The known constructions transform computational difficulty, in the form of one-way functions (defined below), into pseudorandomness generators. Loosely speaking, a polynomial-time computable function is called one-way if any efficient algorithm can invert it only with negligible success probability. For simplicity, we consider only length-preserving one-way functions.

Definition 6. (one-way function). *A one-way function, f , is a polynomial-time computable function such that for every probabilistic polynomial-time algorithm A' , every positive polynomial $p(\cdot)$, and all sufficiently large n*

$$\Pr_{x \sim U_n} [A'(f(x)) \in f^{-1}(f(x))] < \frac{1}{p(n)},$$

where U_n is the uniform distribution over $\{0, 1\}^n$.

Popular candidates for one-way functions are based on the conjectured intractability of integer factorization, the discrete logarithm problem, and decoding of random linear code. The infeasibility of inverting f yields a weak notion of unpredictability: Let $b_i(x)$ denote the i^{th} bit of x . Then, for every probabilistic polynomial-time algorithm A (and sufficiently large n), it must be the case that $\Pr_{i,x} [A(i, f(x)) \neq b_i(x)] > 1/2n$, where the probability is taken uniformly over $i \in \{1, \dots, n\}$ and $x \in \{0, 1\}^n$. A stronger (and in fact the strongest possible) notion of unpredictability is that of a hard-core predicate. Loosely speaking, a polynomial-time computable predicate b is called a hard-core of a function f if any efficient algorithm, given $f(x)$, can guess $b(x)$ with probability of success that is only negligibly better than one half.

Definition 7. (hard-core predicate [2]). *A polynomial-time computable predicate $b : \{0, 1\}^* \rightarrow \{0, 1\}$ is called a hard-core of a function f if for every probabilistic polynomial-time algorithm A' , every positive polynomial $p(\cdot)$, and all sufficiently large n*

$$\Pr_{x \sim U_n} [A'(f(x)) = b(x)] < \frac{1}{2} + \frac{1}{p(n)}.$$

Clearly, if b is a hard-core of a 1-1 polynomial-time computable function f , then f must be one-way.⁴ It turns out that any one-way function can be slightly modified so that it has a hard-core predicate.

⁴Functions that are not 1-1 may have hard-core predicates of an information-theoretic nature, but these are of no use to us here. For example, functions of the form $f(\sigma, x) = 0f'(x)$ (for $\sigma \in \{0, 1\}$) have an "information theoretic" hard-core predicate $b(\sigma, x) = \sigma$.

Theorem 8. (a generic hard-core [7]). Let f be an arbitrary one-way function, and let g be defined by $g(x, r) \stackrel{\text{def}}{=} (f(x), r)$, where $|x| = |r|$. Let $b(x, r)$ denote the inner-product mod 2 of the binary vectors x and r . Then the predicate b is a hard-core of the function g .

A proof may be found in [5, Appen. C.2]. Finally, we get to the construction of pseudorandom generators.

Proposition 9. (a simple construction of pseudorandom generators). Let b be a hard-core predicate of a polynomial-time computable 1-1 function f . Then, $G(s) \stackrel{\text{def}}{=} f(s)b(s)$ (i.e., $f(s)$ followed by $b(s)$) is a pseudorandom generator.

In a sense, the key point in the proof of the above proposition is showing that the (obvious by definition) unpredictability of the output of G implies its pseudorandomness. The fact that (next-bit) unpredictability and pseudorandomness are equivalent in general is proven explicitly in the alternative presentation below.

An Alternative Presentation

Our presentation of the construction of pseudorandom generators, via Theorem 5 and Proposition 9, is different but analogous to the original construction of pseudorandom generators suggested by Blum and Micali [2]: Given an arbitrary stretch function $\ell: \mathbb{N} \rightarrow \mathbb{N}$ and a 1-1 one-way function f with a hard-core b , one defines

$$G(s) \stackrel{\text{def}}{=} b(x_0)b(x_1) \cdots b(x_{\ell(|s|)-1}),$$

where $x_0 = s$ and $x_i = f(x_{i-1})$ for $i = 1, \dots, \ell(|s|) - 1$. A concrete instantiation, based on the assumption that it is difficult to factor large integers, is depicted in Figure 1. The pseudorandomness of G is established in two steps using the notion of (next-bit) unpredictability. An ensemble $\{Z_n\}_{n \in \mathbb{N}}$ is called unpredictable if any probabilistic polynomial-time machine obtaining a prefix of Z_n fails to predict the next bit of Z_n with probability nonnegligibly higher than $1/2$.

Step 1. One first proves that the ensemble $\{G(U_n)\}_{n \in \mathbb{N}}$, where U_n is uniform over $\{0, 1\}^n$, is (next-bit) unpredictable (from right to left) [2]. Loosely speaking, if one can predict $b(x_i)$ from $b(x_{i+1}) \cdots b(x_{\ell(|s|)-1})$, then one can predict $b(x_i)$ given $f(x_i)$ (namely, by computing $x_{i+1}, \dots, x_{\ell(|s|)-1}$ and so obtaining $b(x_{i+1}) \cdots b(x_{\ell(|s|)-1})$). But this contradicts the hard-core hypothesis.

Step 2. Next one uses Yao's observation by which an ensemble is pseudorandom if and only if it is (next-bit) unpredictable (cf. [4, Sec. 3.3.4]).

Clearly, if one can predict the next bit in an ensemble, then one can distinguish this ensemble from the uniform ensemble (which is unpredictable regardless of computing power). However, here

we need the other, less obvious direction. One can show that (next-bit) unpredictability implies indistinguishability from the uniform ensemble. Specifically, consider the "hybrid" distributions in which the i^{th} hybrid takes the first i bits from the ensemble in question and the rest from the uniform one. Thus, distinguishing the extreme hybrids implies distinguishing some neighboring hybrids, which in turn implies next-bit predictability (of the ensemble in question).

A General Condition for the Existence of Pseudorandom Generators

Recall that given any one-way 1-1 function, we can easily construct a pseudorandom generator. Actually, the 1-1 requirement may be dropped, but the currently known construction—for the general case—is quite complex. Still, we do have

Theorem 10. (on the existence of pseudorandom generators [9]). Pseudorandom generators exist if and only if one-way functions exist.

To show that the existence of pseudorandom generators implies the existence of one-way functions, consider a pseudorandom generator G with stretch function $\ell(n) = 2n$. For $x, y \in \{0, 1\}^n$, define $f(x, y) \stackrel{\text{def}}{=} G(x)$ so that f is polynomial-time computable (and length-preserving). It must be that f is one-way, or else one can distinguish $G(U_n)$ from U_{2n} by trying to invert and checking the result: Inverting f on its range distribution refers to the distribution $G(U_n)$, whereas the probability that U_{2n} has inverse under f is negligible.

We assume that it is infeasible to factor integers that are the product of two large primes (each congruent to 3 mod 4). Under this assumption, squaring modulo such integers is a one-way function. Furthermore, squaring modulo such N is 1-1 over the quadratic residues mod N , and the least significant bit of the argument is a corresponding hard-core [1].

The following pseudorandom generator uses a polynomial-time algorithm that when fed with $4m$ bits generates an m -bit number so that when the input $4m$ bits are uniformly distributed, the output is essentially an m -bit random prime (congruent to 3 mod 4).

Input: An n -bit seed $s = abc$, where $|a| = |b| = 4n/10$.

Initialization Steps:

1. Use a to produce an $n/10$ -bit prime $p \equiv 3 \pmod{4}$.
2. Similarly, use b to produce $q \equiv 3 \pmod{4}$.
3. Multiply p and q , obtaining N .
4. Let $x_0 \leftarrow c^2 \pmod{N}$.

Iterations: For $i = 0, \dots, \ell(n) - 1$

5. Let b_i be the least significant bit of x_i .
6. Let $x_{i+1} \leftarrow x_i^2 \pmod{N}$.

Output: $b_0, b_1, \dots, b_{\ell(n)-1}$

Figure 1. A pseudorandom generator based on the intractability of factoring.

The interesting direction is the construction of pseudorandom generators based on any one-way function. In general (when f may not be 1-1), the ensemble $f(U_n)$ may not be pseudorandom, and so Construction 9 (i.e., $G(s) = f(s)b(s)$, where b is a hard-core of f) cannot be used *directly*. Instead, this construction is used together with a couple of other ideas (cf. [9]). Unfortunately, these ideas and more so the details of implementing them are far too complex to be described here. Indeed, an alternative construction of pseudorandom generators based on any one-way function would be most appreciated.

Pseudorandom Functions

Pseudorandom generators allow one to efficiently generate long pseudorandom sequences from short random seeds. Pseudorandom functions (defined below) are even more powerful: they allow efficient direct access to a huge pseudorandom sequence (which is infeasible to scan bit by bit). In other words, pseudorandom functions can replace truly random functions in any efficient application (e.g., most notably in cryptography). That is, pseudorandom functions are indistinguishable from random functions by efficient machines that may obtain the function values at arguments of their choice. Such machines are called oracle machines; and if M is such a machine and f is a function, then $M^f(x)$ denotes the computation of M on input x when M 's queries are answered by the function f .

Definition 11. (pseudorandom functions [6]). A pseudorandom function (ensemble), with length parameters $\ell_D, \ell_R: \mathbb{N} \rightarrow \mathbb{N}$, is a collection of functions

$$F \stackrel{\text{def}}{=} \{f_s: \{0, 1\}^{\ell_D(|s|)} \rightarrow \{0, 1\}^{\ell_R(|s|)}\}_{s \in \{0, 1\}^*}$$

satisfying

- (efficient evaluation). *There exists an efficient (deterministic) algorithm that when given a seed, s , and an $\ell_D(|s|)$ -bit argument, x , returns the $\ell_R(|s|)$ -bit long value $f_s(x)$.*

(Thus, the seed s is an “effective description” of the function f_s .)

- (pseudorandomness). *For every probabilistic polynomial-time oracle machine M , every positive polynomial p , and all sufficiently large n*

$$\left| \Pr_{f \sim F_n}[M^f(1^n) = 1] - \Pr_{\rho \sim R_n}[M^\rho(1^n) = 1] \right| < \frac{1}{p(n)},$$

where F_n denotes the distribution on $f_s \in F$ obtained by selecting s uniformly in $\{0, 1\}^n$ and R_n denotes the uniform distribution over all functions mapping $\{0, 1\}^{\ell_D(n)}$ to $\{0, 1\}^{\ell_R(n)}$.

Suppose, for simplicity, that $\ell_D(n) = n$ and $\ell_R(n) = 1$. Then a function uniformly selected among 2^n functions (of a pseudorandom ensemble) presents an input-output behavior indistinguishable in $\text{poly}(n)$ -time from the one of a function selected

at random among all the 2^{2^n} Boolean functions. Contrast this with a distribution over 2^n sequences, produced by a pseudorandom generator applied to a random n -bit seed, that is computationally indistinguishable from a sequence selected uniformly among all the $2^{\text{poly}(n)}$ -many sequences. Still, pseudorandom functions can be constructed from any pseudorandom generator.

Theorem 12. (how to construct pseudorandom functions [6]). *Let G be a pseudorandom generator with stretching function $\ell(n) = 2n$. Let $G_0(s)$ (resp., $G_1(s)$) denote the first (resp., last) $|s|$ bits in $G(s)$, and let*

$$G_{\sigma_1 \dots \sigma_k}(s) \stackrel{\text{def}}{=} G_{\sigma_1}(\dots G_{\sigma_k}(G_{\sigma_1}(s)) \dots).$$

Then the function ensemble $\{f_s: \{0, 1\}^{|s|} \rightarrow \{0, 1\}^{|s|}\}_{s \in \{0, 1\}^}$, where $f_s(x) \stackrel{\text{def}}{=} G_x(s)$, is pseudorandom with length parameters $\ell_D(n) = \ell_R(n) = n$.*

The above construction can be easily adapted to any (polynomially bounded) length parameters $\ell_D, \ell_R: \mathbb{N} \rightarrow \mathbb{N}$.

We mention that pseudorandom functions have been used to derive negative results in computational learning theory and in complexity theory.

The Applicability of Pseudorandom Generators

Randomness is playing an increasingly important role in computation: it is frequently used in the design of sequential, parallel, and distributed algorithms and is of course central to cryptography. Whereas it is convenient to design such algorithms making free use of randomness, it is also desirable to minimize the use of randomness in real implementations, since generating perfectly random bits via special hardware is quite expensive. Thus, pseudorandom generators (as defined above) are a key ingredient in an “algorithmic tool-box”: they provide an automatic compiler of programs written with free use of randomness into programs that make an economical use of randomness.

Indeed, “pseudo-random number generators” appeared with the first computers. However, typical implementations use generators that are not pseudorandom according to the above definition. Instead, at best, these generators are shown to pass *some* ad hoc statistical test (cf. [10]). However, the fact that a “pseudo-random number generator” passes some statistical tests does not mean that it will pass a new test and that it is good for a future (untested) application. Furthermore, the approach of subjecting the generator to some ad hoc tests fails to provide general results of the type stated above (i.e., of the form “for all practical purposes using the output of the generator is as good as using truly unbiased coin tosses”). In contrast, the approach encompassed in Definition 2 aims at such generality and in fact is tailored to

obtain it: the notion of computational indistinguishability, which underlines Definition 2, covers all possible efficient applications, postulating that for all of them pseudorandom sequences are as good as truly random ones.

Pseudorandom generators and functions are of key importance in cryptography. They are typically used to establish private-key encryption and authentication schemes (cf. [5, Sec. 1.5.2 & 1.6.2]). For example, suppose that two parties share a random n -bit string, s , specifying a pseudorandom function (as in Definition 11 with $\ell_D(n) = \ell_R(n) = n$), and that s is unknown to the adversary. Then these parties may send encrypted messages to one another by XORing the message with the value of f_s at a random point. That is, to encrypt $m \in \{0, 1\}^n$, the sender uniformly selects $r \in \{0, 1\}^n$ and sends $(r, m \oplus f_s(r))$ to the receiver. The security of this encryption scheme relies on the fact that for every computationally feasible adversary (not only to adversary strategies that were envisioned and tested) the values of the function f_s on such r 's look random.

The Intellectual Contents of Pseudorandom Generators

We shortly discuss some intellectual aspects of pseudorandom generators as defined above.

Behavioristic versus Ontological

Our definition of pseudorandom generators is based on the notion of computational indistinguishability. The behavioristic nature of the latter notion is best demonstrated by confronting it with the Kolmogorov-Chaitin approach to randomness. Loosely speaking, a string is *Kolmogorov-random* if its length equals the length of the shortest program producing it. This shortest program may be considered the "true explanation" to the phenomenon described by the string. A Kolmogorov-random string is thus a string that does not have a substantially simpler (i.e., shorter) explanation than itself. Considering the simplest explanation of a phenomenon may be viewed as an ontological approach. In contrast, considering the effect of phenomena (on an observer) as underlying the definition of pseudorandomness is a behavioristic approach. Furthermore, there exist probability distributions that are not uniform (and are not even statistically close to a uniform distribution) but nevertheless are indistinguishable from a uniform distribution by any efficient procedure. Thus, distributions that are ontologically very different are considered equivalent by the behavioristic point of view taken in the definitions above.

A Relativistic View of Randomness

Pseudorandomness is defined above in terms of its observer. It is a distribution that cannot be told apart from a uniform distribution by any efficient (i.e., polynomial-time) observer. However, pseudorandom sequences may be distinguished from

random ones by infinitely powerful computers (not at our disposal!). Specifically, an exponential-time machine can easily distinguish the output of a pseudorandom generator from a uniformly selected string of the same length (e.g., just by trying all possible seeds). Thus, pseudorandomness is subjective, dependent on the abilities of the observer.

Randomness and Computational Difficulty

Pseudorandomness and computational difficulty play dual roles: The definition of pseudorandomness relies on the fact that putting computational restrictions on the observer gives rise to distributions that are not uniform and still cannot be distinguished from uniform. Furthermore, the construction of pseudorandom generators relies on conjectures regarding computational difficulty (i.e., the existence of one-way functions), and this is inevitable: given a pseudorandom generator, we can construct one-way functions. Thus, nontrivial pseudorandomness and computational difficulty can be converted back and forth.

Generalization

Pseudorandomness as surveyed above can be viewed as an important special case of a general paradigm. A generic formulation of pseudorandom generators consists of specifying three fundamental aspects—the *stretching measure* of the generators, the class of distinguishers that the generators are supposed to fool (i.e., the algorithms with respect to which the *computational indistinguishability* requirement should hold), and the resources that the generators are allowed to use (i.e., their own *computational complexity*). In the above presentation we focused on polynomial-time generators (thus having polynomial stretching measure) that fool any probabilistic polynomial-time observers. A variety of other cases are of interest too, and we briefly discuss some of them. For more details see [5].

Weaker Notions of Computational Indistinguishability

Whenever the aim is to replace random sequences utilized by an algorithm with pseudorandom ones, one may try to capitalize on knowledge of the target algorithm. Above we have merely used the fact that the target algorithm runs in polynomial-time. However, if we know for example, that the algorithm uses very little workspace, then we may be able to do better. Similarly we may be able to do better if we know that the analysis of the algorithm depends only on some specific properties of the random sequence it uses (e.g., pairwise independence of its elements). In general, weaker notions of computational indistinguishability such as fooling space-bounded algorithms, constant-depth circuits, and even specific tests (e.g., testing pairwise independence of the sequence) arise naturally. Generators producing sequences that fool such

tests are useful in a variety of applications; if the application utilizes randomness in a restricted way, then feeding it with sequences of low randomness quality may do. Needless to say, the author advocates a rigorous formulation of the characteristics of such applications and rigorous constructions of generators that fool the type of tests that emerge.

Alternative Notions of Generator Efficiency

The previous paragraph has focused on one aspect of the pseudorandomness question: the resources or type of the observer (or potential distinguisher). Another important question is whether such pseudorandom sequences can be generated from much shorter ones and at what cost (or complexity). Throughout this essay we have required the generation process to be at least as efficient as the efficiency limitations of the distinguisher.⁵ This seems indeed “fair” and natural. Allowing the generator to be more complex (i.e., use more time or space resources) than the distinguisher seems unfair but still yields interesting consequences in the context of trying to “de-randomize” randomized complexity classes. For example, one may consider generators working in time exponential in the length of the seed. In some cases we lose nothing by using such a relaxation (i.e., allowing exponential-time generators). To see why, we consider a typical derandomization argument, proceeding in two steps: First one replaces the true randomness of the algorithm by pseudorandom sequences generated from much shorter seeds, and next one goes deterministically over all possible seeds and looks for the most frequent behavior of the modified algorithm. In such a case the deterministic complexity is anyhow exponential in the seed length. The benefit is that constructing exponential-time generators may be easier than constructing polynomial-time ones.

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⁵In fact, we have required the generator to be more efficient than the distinguisher: the former was required to be a fixed polynomial-time algorithm, whereas the latter was allowed to be any algorithm with polynomial running time.

Kerosinka: An Episode in the History of Soviet Mathematics

Mark Saul

*"It gathers to a greatness, like the ooze of oil
Crushed..."*

—Gerard Manley Hopkins

In the Western world, access to a mathematical education is not difficult for an eager and talented student. This was not the case in the former Soviet Union. Young people pursuing mathematical careers faced numerous obstacles. The market was particularly glutted with mathematicians from Jewish families, and these young men and women were routinely denied access to certain institutes and departments where they might have done fine work.

Consider the case of Edik, a young man who showed great mathematical promise very early. He had followed the course of study of the correspondence school established by I. M. Gelfand and had sought out a local mathematician to tutor him on topics such as p -adic numbers, Hilbert spaces, and topology. Because he lived in a provincial city, Edik did not have the opportunity to take advantage of two landmarks of Soviet mathematical life: the special mathematics school¹ and the mathematical study circle.² When he finished high school at the age of sixteen, he traveled from his home in Kolomna to Moscow to present himself to the examiners of the department of mathematics at Moscow State University (MGU), the most prestigious in the USSR. The year was 1984.

"What is the definition of a circle?" asked the examiner.

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¹See A. Shen, *Mathematical high schools: What are they?*, Notices Amer. Math. Soc. **40** (September 1993).

²Dmitri Fomin, Sergey Genkin, and Ilia Itenberg, *Mathematical Circles* (Russian Experience), Amer. Math. Soc., Providence, RI, 1996.

"It is the set of points in a plane, equidistant from a fixed point," Edik replied.

"Wrong," said the examiner. "It is the set of *all* points in a plane, equidistant from a fixed point." The examiner continued, in the fashion of the Red Queen interrogating Alice. He then passed to more serious questions, involving topics such as inversion in a circle, which ordinary high school students could not have been expected to know.

The story is a familiar one: students from Jewish backgrounds were asked questions significantly more difficult than those asked of other candidates, and reasons were found not to admit them.³ In Edik's case, because of his strong background and ability, this process took more than four hours.

How did the examiners know that a given candidate was Jewish? This was a finely cultivated art in the former Soviet Union, where anti-Semitism was officially illegal but officially practiced. Every Soviet citizen was assigned a nationality, recorded on the internal passport that each carried. If one's parents were Jewish, then one's nationality was Jewish. But what of the descendants of mixed marriages? Late Soviet anti-Semitism proceeded under unwritten racial laws easily as strict as those of the antebellum South.

There were many ways to identify "Jewish" candidates. The simplest was the origin of the family name. (This method caught many ethnic Russians with foreign-sounding names as well as Jews.) Readers of Russian novels are familiar with another

³See A. Shen, *Entrance examinations to the Mekh-mat*, Math. Intelligencer **16** (1994); or A. Vershik, *Admission to the mathematics faculty in Russia in the 1970s and 1980s*, Math. Intelligencer **16** (1994).



The Institute for Petrochemical and Natural Gas Industry or *Kerosinka*.

method. A Russian middle name is derived, by law and custom, from one's father's given name. These patronymics are used in formal address and are very much part of Russian life. So it was quite routine to ask the full names of one's parents and thus to learn given names of a candidate's grandfathers. If one of these names sounded Jewish, the candidate was doomed.

In any case, it was decided that Edik was Jewish (in fact, his father was Jewish, but not his mother), and his examination results were graded accordingly. Not one answer was accepted as correct. He and his family chose not to go through the tedious and usually fatuous appeals process after his rejection from MGU.

Upon leaving the interview, Edik met his interrogator in the elevator. While some faculty members at MGU harbored anti-Semitic feelings, others were forced, by political circumstance, to go along with the exclusion of Jews from the university's departments. (Many Russian mathematicians to this day have troubled feelings about their actions at the time.) This faculty member may have been of the latter sort, or he may simply have been glad that Edik was not appealing the examination results.

Oddly, having just failed Edik on every question, the examiner now turned to him and said, "I was really impressed by your knowledge. I advise you to apply to the Institute for Petrochemical and Natural Gas Industry. They take people *like you* there."

Edik had not heard of this institute. It was founded in the early Soviet period⁴ and, along with several other such schools, had done fine work preparing technicians for a particular industry. But such a place was hardly the object of the as-

⁴Bol'shaia Sovetskaia Entsiklopediia, vol. 17, 1974, p. 38.

pirations of a gifted young mathematician. Why this institute?

After 1968 political circumstances started an avalanche of anti-Semitism in the mathematics and physics departments of Soviet universities. The reverence with which scholarship was held in traditional Jewish culture often translated, in modern times, into an interest in mathematics, and there were many Jewish students of the subject. This factor, combined with the exclusion of Jewish students from particular academic departments, created a market for placements in mathematics for these students. Certain technical institutes of Moscow and other cities began to cater to these markets, benefiting from the anti-Semitic policies of other universities to get highly qualified students. A talented Jewish mathematician sometimes found an

education at the Institute of Metallurgy or the Pedagogical Institute. Others would enroll in the Institute of Railway Engineers, whose Russian abbreviation sounded like MEED. This led to the saying, "*Esl'i zheed, idi v MEED*"—"If you're a Jew [the rhyme scheme requires a pejorative term here], then go to MEED." The slogan was typical of the mixture of pride and cynicism that was the Jewish student's only defense against a hostile environment.

The Institute for Petrochemical and Natural Gas Industry was another of those institutions that benefited from the prejudice against Jews at MGU. Its nickname, *Kerosinka*, reflected this same pride and cynicism. A *kerosinka* is a kerosene-burning space heater, a low-tech but effective response to adversity. The students and graduates of the institute quickly became known as "kerosine-shchiks", and the school became a haven for Jewish students with a passion for mathematics.

The shared enthusiasm for their subject that is characteristic of the Russian mathematical community has been described elsewhere,⁵ and by now the Soviet diaspora has allowed many Americans to experience this atmosphere firsthand. The *Kerosinka* story is but one example of the subtle interplay between passion and politics, a story of how individuals and institutions reacted to adversity in order to pursue mathematics.

How did fate choose *Kerosinka* as the repository of so much talent? This question is not easy to answer. We know that there were other institutions that benefited from the exclusion of Jews from MGU. We also know that the establishment of this exclusionary policy was a conscious act, which

⁵For example, see M. Saul, *Love among the ruins: The education of high-ability mathematics students in the USSR*, Focus 12 (February 1992).

probably met with some resistance at first. It may have been easier for some institutions to continue accepting Jewish students than for them to institute a new policy. But once the phenomenon grew and there was a cadre of Jewish students at Kerosinka, why was it tolerated? There are dark whispers of a plot by the secret police (KGB) to keep the Jewish students under surveillance in one or two places. But some of the motivation may have been more positive: the administration of the institute may have seen a good department developing and done what it could to preserve the phenomenon.

Once enrolled at Kerosinka, Edik studied pure mathematics at a high level, but not nearly so thoroughly as students at MGU. The course of study was designed, after all, for specific application to the petrochemical industries. So while Edik learned analysis, linear algebra, and differential equations quite well, his program also included significant work in applied mathematics and computer science. There were many areas of pure mathematics that Edik could not learn about in Kerosinka.

He and his fellow students found a way out. They would “climb the fence” (literally: the building was well guarded) to get into MGU and audit courses and seminars unofficially. Mathematicians such as Gelfand, Kolmogorov, and Kirillov often tolerated or even invited to their classes students who were not legally enrolled at MGU. Edik was the particular beneficiary of the kindness of Dmitri Fuchs and Boris Feigin, who spent much of their own time working with the young man. These avenues allowed Edik and his friends to explore such advanced topics as differentiable manifolds, Lie groups, representation theory, and topology.

In a development peculiar to Soviet life, this unofficial educational system had earlier spawned a complete institution: an evening “university” within MGU. Using space from university buildings, but without any official sanction, professors and students began to meet after hours, holding classes and seminars that extended and complemented the classes at Kerosinka and other institutions. Since many of the students in these classes were Jewish, the institution soon received the name “Jewish People’s University” (*Evreyskiy Narodniy Universitet*). Well-known mathematicians such as D. Fuchs, A. Sosinsky, A. Onitschik, B. Feigin, V. Ginzburg, A. Zelevinsky, and A. Shen were among the professors in this unofficial institution. The Jewish People’s University suffered a calamitous setback with

the death of one of its chief organizers, Bella Muchnik Subbotovskaya, who was killed in a suspicious auto accident just after being interviewed by the KGB about her educational and mathematical activities.

It took a certain amount of courage to pursue mathematics under these circumstances. What impelled Edik and others to continue, like so many salmon swimming upstream? There was every indication that the discrimination they faced at the university level would continue into their professional lives. Why then should they prepare themselves so intensively and against such odds for a career in mathematics?

The answer strikes at the heart of Soviet mathematical culture and contributes significantly to the explanation of many phenomena in this period of the history of mathematics. In the totalitarian atmosphere of the former Soviet Union, most intellectual fields were put at the service, and the mercy, of the state. Mathematics was a significant exception. Because mathematicians were not dependent on laboratories or equipment but only on colleagues, they were relatively free from government control. For this reason many young people with active minds pursued this field rather than others. In the United States many young people look at the job market, then choose

a career. In the former Soviet Union it was more likely that a young person would follow his or her personal inclinations in choosing a subject to study, then seek employment using his or her skills. This often worked. Kerosinka graduates found work in a number of technical institutions and also in high schools with special mathematics programs. Some room in the job market was made for them by yet another Soviet institution, the secret research facilities called “boxes” (*yashchiki*). Known only by their post office box address, these were laboratories and academic departments serving the military or sensitive industries. Employees of these departments had ready access to classified materials, and so anyone with less than a “spotless application” (*chistaya anketa*), including most Jews, was excluded.

But we know that political events overtook the plans of these students. The Russian academies are now more open, if less opulent, places to work, and the bursting of the Soviet Union has spilled its mathematicians all over the world. A Web page of Kerosinshchiks⁶ provides a partial list of alumni. More than half of those listed work in technical

⁶<http://www.mng.com/yuri/KYP.html>.

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fields in the U.S., another quarter or so in Israel, and a few more in other Western countries. Less than one-quarter of the listed alumni work in the former Soviet Union (although this statistic is probably influenced by difficulties in Web or e-mail access). The Kerosinshchiks' education has stood them in good stead.

And Edik? His real name is Edward Frenkel, and the examination in Moscow failed to reveal his abilities. Like many Kerosinshchiks, he has already made significant contributions to mathematics. After graduating from Kerosinka he was selected as one of only three Russian mathematicians to study at Harvard. He received his Ph.D. there in 1991, after one year of study, and became a full professor on the faculty of the University of California at Berkeley at the age of twenty-nine.

While Frenkel did not have the opportunity to attend the famous Moscow Math Circles, he provides support and inspiration for his wife, Zvezdelina Stankova-Frenkel (also a gifted mathematician), who founded the San Francisco Bay Area Mathematics Circles for talented youth. Among the regular lecturers at these Circles is at least one other graduate of Kerosinka, Alexander Givental of Berkeley, as well as Dmitri Fuchs himself.

What can we learn from this story? Is it more than a footnote with a very strange name in the history of mathematics? We must be careful in taking lessons from experiences in other countries. The creative process seems to be highly sensitive to culture in ways that we do not understand.⁷

One thing we can note is that the development of Soviet mathematics was driven by forces quite different from those in U.S. American mathematics, like most American scholarship, is largely driven by publication. Certainly the university tenure and promotion processes are dominated by the need to publish. In the Soviet Union, however, a delicate set of cultural and political circumstances allowed for the flowering of a mathematical culture based largely on fellowship through mathematics. I have traced elsewhere its effect on talented students of the subject.⁸ The Kerosinka story gives another view of this scene.

The pleasure of doing mathematics together was a powerful driving force in the former Soviet Union. Knowing of this force, perhaps we can harness it, for example, to include students of mathematics from populations heretofore underrepresented in our profession. It may also be that we can use it to attract gifted high school and undergraduate students, from whatever background, into mathematics. (Perhaps then we would be able to encourage more undergraduates in American

schools to go on to graduate work in mathematics.) And some compassion for younger faculty members might go far towards ameliorating the rather difficult circumstances of their lives.

In the lines quoted at the beginning of this article, the poet Gerard Manley Hopkins is writing about "God's Grandeur", a rather broader topic than the joy of mathematics. And yet the mathematical community might learn from his words. If the creative urge found outlets in the harsh circumstances of Soviet life, we should be able to find ways for it to contribute to American mathematics as well.

Author's Note: It is a pleasure to acknowledge the following people for their contributions to the research that resulted in this article:

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⁷For more on this point, see Raymond Wilder, *Mathematics As a Cultural System*, Pergamon, 1981.

⁸See footnote 5.

Kenkichi Iwasawa

(1917–1998)

John Coates

Kenkichi Iwasawa, whose ideas have deeply influenced the course of algebraic number theory in the second half of the twentieth century, died in Tokyo on October 26, 1998. He spent much of his mathematical career in the United States, but he remained quintessentially Japanese and incarnated many of the finest qualities of the traditional Japanese scholar. Iwasawa was born on September 11, 1917, in Shinshuku-mura near Kiryu in Gumma prefecture. After elementary school he was educated in Tokyo, where he first attended Musashi High School and then did his undergraduate studies at Tokyo University from 1937 to 1940. In 1940 he entered the graduate school of Tokyo University and became an Assistant in the Department of Mathematics, being awarded the degree of Doctor of Science in 1945. However, the war years were difficult for him. He became seriously ill with pleurisy in 1945 and was only well enough to return to his post at the university in April 1947. He was appointed Assistant Professor at Tokyo University from 1949 to 1955.

He travelled to the United States in 1950 to give an invited lecture at the International Congress of Mathematicians in Cambridge, Massachusetts, and then spent the two academic years 1950–52 at The Institute for Advanced Study in Princeton. While preparing to return to Japan in the spring of 1952, he received the offer of a post at the Massachusetts Institute of Technology and ended up staying there until 1967. In 1967 he moved to Princeton University as Henry Burchard Fine Professor of Math-

ematics and remained at Princeton until his retirement in 1986. In 1987 he and his wife returned to live in Tokyo.

He was awarded the Asahi Prize in 1959, the Prize of the Japan Academy in 1962, the American Mathematical Society Cole Prize in 1962, and the Fujiwara Prize in 1979. His principal mathematical legacy is a general method in arithmetical algebraic geometry, known today as *Iwasawa theory*, whose central goal is to seek analogues for algebraic varieties defined over number fields of the techniques which have been so successfully applied to varieties defined over finite fields by H. Hasse, A. Weil, B. Dwork, A. Grothendieck, P. Deligne, and others.

Cyclotomic Fields

Until about 1950, most of Iwasawa's papers were on questions of group theory, and we shall briefly discuss this aspect of his work later. However, he himself stated that he was interested in number theory from his student days, and all of his published papers from the early 1950s onwards are devoted to algebraic number theory. The dominant theme of his work in number theory is his revolutionary idea that deep and previously inaccessible information about the arithmetic of a finite extension F of \mathbb{Q} can be obtained by studying coarser questions about the arithmetic of certain infinite Galois towers of number fields lying above F . This idea, whose power lies in subtly mixing p -adic analytic methods with Galois cohomology, has subsequently been applied to a much wider circle of problems in arithmetic algebraic geometry. But the origin and archetypical example of Iwasawa's

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Left to right: Kenkichi Iwasawa with John Coates, John Tate, and Ichiro Satake at the 1976 Symposium on Algebraic Number Theory in Kyoto.

theory is in the classical theory of cyclotomic fields when F is the field generated over \mathbb{Q} by the p -th roots of unity, where p is a prime number, and the infinite tower above F is given by the fields generated by all p -power roots of unity. We shall now discuss it in some detail, emphasizing the new ideas introduced by Iwasawa.

We say that an odd prime number p is *irregular* if p divides the class number of the field $\mathbb{Q}(\mu_p)$, where μ_p denotes the group of p -th roots of unity. The first few irregular primes are given by 37, 59, 67, 101, . . . This notion was introduced by Kummer in his work on Fermat's Last Theorem. The fact that it is at all feasible to determine whether a prime p is irregular is because of a mysterious and unexpected connexion between irregularity and the values of the Riemann zeta function $\zeta(s)$. For $k = 2, 4, 6, \dots$, we have $\zeta(1 - k) = -B_k/k$, where the B_k are the Bernoulli numbers defined by the expansion

$$\frac{t}{e^t - 1} = \sum_{n=0}^{\infty} B_n t^n / n!.$$

Kummer proved the remarkable result that p is irregular if and only if p divides the numerator of at least one of the rational numbers

$$\zeta(-1), \dots, \zeta(4 - p).$$

Iwasawa was the first to realize, in a series of papers published in the 1960s, that the key to a deeper understanding of this result was to study a natural arithmetic representation of the Galois group of the cyclotomic field generated by all the p -power roots of unity over \mathbb{Q} . To explain his idea, we begin by defining the *Iwasawa algebra* of an arbitrary profinite abelian group G by

$$\Lambda(G) = \varprojlim_U \mathbb{Z}_p[G/U],$$

where U runs over all open subgroups of G , \mathbb{Z}_p denotes the ring of p -adic integers, and $\mathbb{Z}_p[G/U]$ denotes the ordinary group ring of the finite abelian group G/U with coefficients in \mathbb{Z}_p . The Iwasawa algebra is particularly useful because it has both an

analytic and an algebraic interpretation. The analytic interpretation of $\Lambda(G)$ is as the algebra of measures on G with values in \mathbb{Z}_p , allowing us to define the integral $\int_G f d\mu$ for all μ in $\Lambda(G)$ and all continuous functions f from G to \mathbb{Q}_p , the field of p -adic numbers. The algebraic interpretation is that we can naturally extend the continuous action of G on any compact \mathbb{Z}_p -module X to an action of the whole Iwasawa algebra $\Lambda(G)$.

To apply these notions to cyclotomic fields, we write μ_{p^∞} for the group of all p -power roots of unity; we define F_∞ to be the maximal real subfield of $\mathbb{Q}(\mu_{p^\infty})$, that is,

$$F_\infty = \mathbb{Q}(\mu_{p^\infty}) \cap \mathbb{R};$$

and we take G to be the Galois group of F_∞ over \mathbb{Q} . The principal analytic ingredient for Iwasawa's theory of cyclotomic fields is the p -adic analogue of the Riemann zeta function, whose existence was already known from the work of Kummer and T. Kubota, and H. Leopoldt, but for which Iwasawa gave a new construction in his 1969 paper [1] by an ingenious use of the classical Stickelberger elements.

We say that an element φ of the ring of fractions of $\Lambda(G)$ is a *pseudo-measure* if $(\sigma - 1)\varphi$ belongs to $\Lambda(G)$ for all σ in G (intuitively, one should think of such a φ as possibly having a simple pole at the trivial character of G). Let $G_{\mathbb{Q}}$ be the Galois group of a fixed algebraic closure of \mathbb{Q} , and write $\psi : G_{\mathbb{Q}} \rightarrow \mathbb{Z}_p^\times$ for the homomorphism giving the action of $G_{\mathbb{Q}}$ on μ_{p^∞} , that is, $\sigma(\zeta) = \zeta^{\psi(\sigma)}$ for all σ in $G_{\mathbb{Q}}$ and ζ in μ_{p^∞} . By Galois theory G is a quotient of $G_{\mathbb{Q}}$, and the characters ψ^k , where k is any even integer, factor through G . Modulo a slight change of language and normalisation, Iwasawa proved that there exists a unique pseudo-measure ζ_p on G such that

$$(1) \quad \int_G \psi^k d\zeta_p = (1 - p^{k-1})\zeta(1 - k) \quad (k = 2, 4, 6, \dots);$$

this makes sense, since one can integrate any non-trivial p -adic homomorphism of G against any pseudo-measure.

The principal algebraic and arithmetic ingredient is a compact G -module X_∞ , which Iwasawa had introduced in his papers in the 1950s. Let M_∞ be the maximal abelian extension of F_∞ with the properties that it is unramified outside p and that its Galois group over F_∞ is a pro- p -group. Put $X_\infty = G(M_\infty/F_\infty)$ for the Galois group of M_∞ over F_∞ . Clearly X_∞ is a compact \mathbb{Z}_p -module. In addition, X_∞ has a natural action of G given by

$$\sigma \cdot x = \bar{\sigma} x \bar{\sigma}^{-1}$$

for σ in G and x in X_∞ , where $\bar{\sigma}$ denotes any lifting of σ to the Galois group of M_∞ over \mathbb{Q} (the maximality of M_∞ guarantees that it is Galois over \mathbb{Q}).

By our general remarks above, X_∞ then has a natural structure as a module over the Iwasawa algebra $\Lambda(G)$. It can easily be shown that X_∞ is finitely generated over $\Lambda(G)$. Moreover, as G is a p -adic Lie group of dimension 1 with no element of order p , a simple structure theory is known for finitely generated $\Lambda(G)$ -modules. By combining arithmetic arguments with this structure theory, Iwasawa proved that there exist an integer $\tau_p \geq 1$ and elements f_1, \dots, f_{τ_p} of $\Lambda(G)$ that are not divisors of zero, such that we have an exact sequence of $\Lambda(G)$ -modules

$$(2) \quad 0 \rightarrow X_\infty \rightarrow \bigoplus_{i=1}^{\tau_p} \Lambda(G) / f_i \Lambda(G) \rightarrow D \rightarrow 0,$$

where D is a $\Lambda(G)$ -module of finite cardinality. Via a remarkable series of papers in the 1960s, Iwasawa was led to the startling idea that there should be a simple relation between the analytic object given by (1) and the algebraic object defined by (2). The precise statement, which became known as *the main conjecture on cyclotomic fields*, is the assertion that

$$(3) \quad \zeta_p \Lambda(G)_0 = f_1 \cdots f_{\tau_p} \Lambda(G),$$

where $\Lambda(G)_0 = \ker(\Lambda(G) \rightarrow \mathbb{Z}_p)$ is the augmentation ideal of $\Lambda(G)$. Although it is not obvious, Kummer's criterion mentioned above is a consequence of (3) (the starting point for proving this is the classical argument showing that p is irregular if and only if the maximal real subfield of $\mathbb{Q}(\mu_p)$ possesses a cyclic extension of degree p that is unramified outside p and that is distinct from the maximal real subfield of the field generated by the p^2 roots of unity). Much deeper results due to J. Herbrand and K. Ribet about the eigenspaces for the action of the Galois group of $\mathbb{Q}(\mu_p)$ over \mathbb{Q} on the p -primary subgroup of the ideal class group of $\mathbb{Q}(\mu_p)$ are also corollaries of (3).

The honour of giving the first proof of (3) for all primes p fell in 1984 to B. Mazur and A. Wiles using modular curves, but there is still great interest in studying the evolution of Iwasawa's ideas leading to (3), especially in his wonderful paper published in 1964 in [2]. In this paper Iwasawa used cyclotomic units to construct a compact $\Lambda(G)$ -module Y_∞ together with a natural $\Lambda(G)$ -homomorphism

$$(4) \quad \varphi : Y_\infty \rightarrow X_\infty.$$

He then proved, by a very ingenious use of an explicit reciprocity law going back to E. Artin and H. Hasse, that we have an isomorphism

$$(5) \quad Y_\infty \simeq \Lambda(G) / \zeta_p \Lambda(G)_0;$$

here we are implicitly using the construction of ζ_p given in the later paper [1].

For the sake of completeness, the precise definition of Y_∞ is as follows. Let F_n be the maximal real subfield of the field generated over \mathbb{Q} by the p^{n+1} -th roots of unity ($n = 0, 1, \dots$). The group of cyclotomic units C_n of F_n is defined to be the intersection with the unit group of the ring of integers of F_n of the multiplicative group generated by all conjugates of $1 - \zeta_n$, where ζ_n is a primitive p^{n+1} -th root of unity. There is a unique prime v_n of F_n above p , and we write U_n for the group of local units in the completion of F_n at v_n that are congruent to 1 mod v_n . Finally, we define C_n to be the completion in the v_n -adic topology of $C_n \cap U_n$. Then Y_∞ is the projective limit of the U_n/C_n taken with respect to the norm maps.

The beauty of (5) is that, via (1), it makes the values of the Riemann zeta function at the odd negative integers appear naturally in the arithmetic of cyclotomic fields. If we assume that the class number of the maximal real subfield of $\mathbb{Q}(\mu_p)$ is prime to p , Iwasawa showed that φ is an isomorphism, and hence (5) implies (3). In 1990 K. Rubin showed that one could use V. Kolyvagin's ideas on Euler systems derived from cyclotomic units to prove just enough about the structure of the kernel and cokernel of the map φ appearing in (4) to be able to derive the main conjecture (3) from Iwasawa's theorem (5) without any restriction on the prime p .

Returning to the module X_∞ defined above, Iwasawa also conjectured that X_∞ is a finitely generated \mathbb{Z}_p -module, and this was proven in 1979 by B. Ferrero and L. Washington. It then follows from (2) that X_∞ is a free \mathbb{Z}_p -module of finite rank, say t_p . It is perhaps of interest to note that the largest value of t_p for $p < 4 \times 10^6$ is $t_p = 7$, and this is achieved for the single prime $p = 3, 238, 481$ (see the paper by Buhler, Crandall, Ernvall, and Metsänkälä in volume 61 (1993) of *Mathematics of Computation*). It should also be noted that (3) says nothing about the value of the integer τ_p appearing in (2). However, if the class number of the maximal real subfield of $\mathbb{Q}(\mu_p)$ is prime to p , then Iwasawa's theorem (5) and the fact that φ is then an isomorphism show that we can take $\tau_p = 1$. No theoretical approach is known for showing that the class number of the maximal real subfield of $\mathbb{Q}(\mu_p)$ is prime to p , but it has been verified numerically for $p < 4 \times 10^6$ (see the above paper).

These brief remarks highlight only several facets of Iwasawa's varied work on cyclotomic fields. For example, another theme of his research, growing out of his proof of (5), was his discovery of a beautiful explicit formula for the Hilbert norm residue symbol in the field generated over \mathbb{Q}_p by the p^n -th roots of unity for all $n \geq 1$. His paper [3] has inspired a large body of work on explicit reciprocity laws in general over the last twenty years.



Left to right: Shigeru Iitaka, Ichiro Satake, André Weil, and Kenkichi Iwasawa. November 1, 1994.

\mathbb{Z}_p -Extensions

As we have already stressed, the deepest aspect of Iwasawa's work on cyclotomic fields was the marriage of algebraic and analytic objects expressed by the main conjecture (3). However, already from his papers published in the late 1950s, Iwasawa saw that many of the algebraic aspects of his theory were not special to cyclotomic fields and could be established in the more general setting of \mathbb{Z}_p -extensions of number fields. Let F be a finite extension of \mathbb{Q} . A \mathbb{Z}_p -extension of F is an infinite tower of fields

$$(6) \quad F = F_0 \subset F_1 \subset \cdots \subset F_n \subset \cdots,$$

where, for each $n \geq 0$, F_n is a cyclic extension of F of degree p^n . The reason for this terminology is that if we define F_∞ to be the union of all the $F_n (n \geq 0)$, then F_∞ is a Galois extension of F whose Galois group over F is topologically isomorphic to the additive group of the p -adic integers \mathbb{Z}_p . It is easy to see that every F has a unique \mathbb{Z}_p -extension contained in $F(\mu_{p^\infty})$, which is called the *cyclotomic* \mathbb{Z}_p -extension of F . However, if F is not totally real, class field theory shows that F admits infinitely many non-cyclotomic \mathbb{Z}_p -extensions. Iwasawa's first general result about arbitrary \mathbb{Z}_p -extensions was the following asymptotic formula. For each $n \geq 0$, let e_n denote the order of the p -primary subgroup of the ideal class group of F_n . Then there exist integers λ, μ , and ν , depending on the \mathbb{Z}_p -extension F_∞/F , such that, for all sufficiently large n , we have

$$(7) \quad e_n = \lambda n + \mu p^n + \nu.$$

What lies behind the proof of (7) is the fact that, if Γ denotes the Galois group of F_∞ over F , then a simple structure theory is known for finitely generated modules over the Iwasawa algebra $\Lambda(\Gamma)$. Iwasawa originally gave an ad hoc proof of this structure theory, but J.-P. Serre pointed out that it followed from known results in commutative

algebra, since $\Lambda(\Gamma)$ is isomorphic to the ring $\mathbb{Z}_p[[T]]$ of formal power series in an indeterminate T with coefficients in \mathbb{Z}_p . Iwasawa wrote a whole series of papers (see, in particular, [4]) in which he exploits this structure theory to study various compact Γ -modules attached to an arbitrary \mathbb{Z}_p -extension F_∞/F , which are important for arithmetic questions. The assertion (2) is typical of the rather general results he obtains in this direction.

Iwasawa himself has said that the discovery of the asymptotic formula (7) suggested to him that there might be analogies between the p -primary subgroup of the ideal class group of a \mathbb{Z}_p -extension F_∞ of F and the p -primary subgroup of the group of points on the Jacobian variety of a curve over a finite field. Such an analogy would suggest that the invariant μ appearing in (7) is zero, and Iwasawa conjectured that this should always be the case if F_∞ is the cyclotomic \mathbb{Z}_p -extension of F . This conjecture was proven by B. Ferrero and L. Washington (and a rather different proof was given by W. Sinnott) when F is an abelian extension of \mathbb{Q} , but it remains open in general. In the early 1970s Iwasawa discovered the first examples of non-cyclotomic \mathbb{Z}_p -extensions where $\mu > 0$ (see [6]). Today there remain many interesting open questions about Iwasawa's invariants λ and μ , including the following two conjectures about the cyclotomic \mathbb{Z}_p -extension F_∞ of F . If F is totally real, R. Greenberg has conjectured that we always have $\lambda = \mu = 0$. Secondly, if we fix F and vary p over all primes, it is conjectured, by analogy with the Jacobian variety of a curve over a finite field, that λ is bounded. This last conjecture is known for no other number field than $F = \mathbb{Q}$, where we have $\lambda = 0$ for all p .

Group Theory

Iwasawa's contributions to group theory, and particularly to the theory of locally compact groups, have also had a lasting impact. His paper [5] gave an essential step towards the solution of Hilbert's fifth problem, which asked whether any locally Euclidean topological group is necessarily a Lie group. One of the many new results about topological groups and Lie groups that are proven in this paper is what is now known as the *Iwasawa decomposition* of a real semisimple Lie group. He also shows that any connected Lie group is topologically the product of a compact Lie group and a Euclidean space. In another direction, he proves that if a locally compact group G has a closed normal subgroup N such that both N and G/N are Lie groups, then G itself is a Lie group. Iwasawa recorded many years later his pleasure as a young man at receiving a letter from C. Chevalley praising this paper. He also was one of the pioneers of employing methods from the theory of locally compact groups to number theory. In particular, independently of J. Tate, he discovered the adelic

approach to E. Hecke's L -functions with Grossencharacters, foreshadowing a vast amount of subsequent work done in this direction from the point of view of automorphic forms.

Influence and Legacy

It is not easy to discern who influenced Iwasawa most in the early stages of his mathematical career. He himself cited S. Iyanaga and Z. Suetuna as having played an important role in assisting his initial research in group theory. When he came to the United States, E. Artin and A. Weil were the dominant influence in the shift of his interests to algebraic number theory. He had relatively few research students of his own, and the best known of these are B. Ferrero, R. Greenberg, and L. Washington.

Although nearly all of Iwasawa's work in number theory was concerned with \mathbb{Z}_p -extensions of number fields, he was very conscious of the parallels with curves over finite fields and was aware that his ideas might be fruitfully applied to a much wider circle of problems. The first step in this direction was carried out by B. Mazur, who initiated, in the late 1960s, the study of the arithmetic of abelian varieties over \mathbb{Z}_p -extensions of number fields. Many others followed, and today it is no exaggeration to say that Iwasawa's ideas have played a pivotal role in many of the finest achievements of modern arithmetical algebraic geometry on such questions as the conjecture of B. Birch and H. Swinnerton-Dyer on elliptic curves; the conjectures of B. Birch, J. Tate, and S. Lichtenbaum on the orders of the K -groups of the rings of integers of number fields; and the work of A. Wiles on the modularity of elliptic curves and Fermat's Last Theorem. In all of these problems, values of L -functions play a central role, and a key step in progress on them has been to establish at least some partial analogue of Iwasawa's main conjecture (3) for the relevant L -function.

It would have been anathema to Iwasawa's great personal modesty to write at too great a length about the way in which his ideas have influenced a whole generation of number theorists in Europe, Japan, and the United States. It is sufficient perhaps to recall Narihira's beautiful tanka about the flowering influence of the Fujiwara family in Heian Japan

Saku hana no	Longer than ever before
Shita ni kakururu	Is the wisteria's shadow -
Hito o oomi	So many are those
Arishi ni masaru	Who find shelter
Fuji no kage kamo	Beneath its blossoms!

and say that it can very aptly be applied to Iwasawa's deep and lasting influence on the whole field of arithmetical algebraic geometry today.



Photograph courtesy of Hideo Wada.

Iwasawa on the occasion of his 77th birthday in Tokyo, June 4, 1994, with (left to right) Mrs. Koizumi, Mrs. Satake, and Mrs. Iwasawa.

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Michael James Lighthill

(1924–1998)

David G. Crighton and T. J. Pedley

David G. Crighton

James Lighthill was acknowledged throughout the world as one of the great mathematical scientists of this century. He was the prototypical applied mathematician, immersing himself thoroughly in the essence and even the detail of every engineering, physical, or biological problem he was seeking to illuminate with mathematical description, formulating a sequence of clear mathematical problems and attacking them with a formidable range of techniques completely mastered, or adapted to the particular need, or newly created for the purpose, and then finally returning to the original problem with understanding, predictions, and advice for action.

His published legacy of six books and some 150 papers (most of them republished in four volumes in 1997 by Oxford University Press) show at every stage a well-nigh perfect correspondence between a clearly identified physical process or mechanism and its expression and description in mathematical terms. His papers or lectures often emphasised the physical aspects and gave the

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mathematics almost as a throwaway for those who like everything formalised, but in fact his style of working was usually the reverse.

In one of his most celebrated works, his first paper on “Sound generated aerodynamically” by jet aircraft and the like, he developed the essential mathematical structure completely in two weeks, but felt that the users (aeroengine designers) would not be able to grasp the implications, and so he delayed submission of his manuscript for sixteen months, in which time he worked backwards from the conclusions, isolating the meaning at each stage—and refining and simplifying the mathematics as he did so.

He was in no sense simply the deployer of existing mathematics against a rich range of practical problems. To be sure, his earliest papers on supersonic flight already showed brilliant mastery and exploitation of classical techniques. But much more powerful techniques were needed for problems such as those of how waves in fluids are generated and propagated, and for this Lighthill made great developments in the theory of Fourier analysis, generalised functions, and asymptotics—all set out with elegance and economy, and full rigour, in a delightful 1958 book, *Introduction to Fourier Analysis and Generalised Functions*. Rather different ideas were needed for nonlinear problems, such as the propagation and focusing of sonic booms, and here Lighthill provided equally

original and elegant new techniques, permanent and frequently used additions to the armoury.

Michael James Lighthill was born in Paris in 1924 and excelled across the board at Winchester before going up to Trinity College, Cambridge, in 1941 for a two-year wartime B.A. He worked on supersonic flight at the National Physical Laboratory, Teddington, for the rest of the Second World War, publishing his first paper before he was twenty. He then went as Senior Lecturer to Manchester University at the age of twenty-two, before taking the Beyer Professorship of Applied Mathematics there, aged twenty-six, in succession to Sydney Goldstein. In his thirteen years at Manchester (1946–59) Lighthill ran one of the most powerful and inventive fluid dynamics groups ever formed anywhere.

He had many Ph.D. students who often rose to considerable heights themselves. Indeed, there was a period in which no fewer than seventeen of his Manchester students held chairs in the UK, and that at a time when the number of universities was no more than a third of its present number. Although prepared to share the credit on a paper with a colleague, Lighthill almost never allowed his name to appear as author on any paper written by a student. And he was, then and since, tireless in his support for young scientists of any promise and for scientists working in disadvantaged circumstances.

During these Manchester years Lighthill worked extensively on gas dynamics, including effects important at very high speed, in his studies of ionisation processes and the diffraction of shock and blast waves. He also launched two major new fields in fluid mechanics. The first of these, “aeroacoustics”, or “sound generated aerodynamically”, was announced in a remarkable paper published by the Royal Society in 1952. Unusually but significantly, that paper neither contains nor needs so much as a single reference to any prior work. This work has remained for nearly fifty years the progenitor of all subsequent work in the field and has been cited in many thousands of later papers. It had immediate implication for noise reduction in jet aeroengines, motivating the trend begun later in the 1950s and still continuing to engines with higher bypass ratio, greater diameter, and lower exhaust speed, as mandated by Lighthill’s famous eighth power law for jet noise. Remarkably, the Lighthill theory was sufficiently versatile to be applied also in problems as diverse as the heating of the Sun’s corona and the noise heard under water due to breaking surface waves and splashing drops.

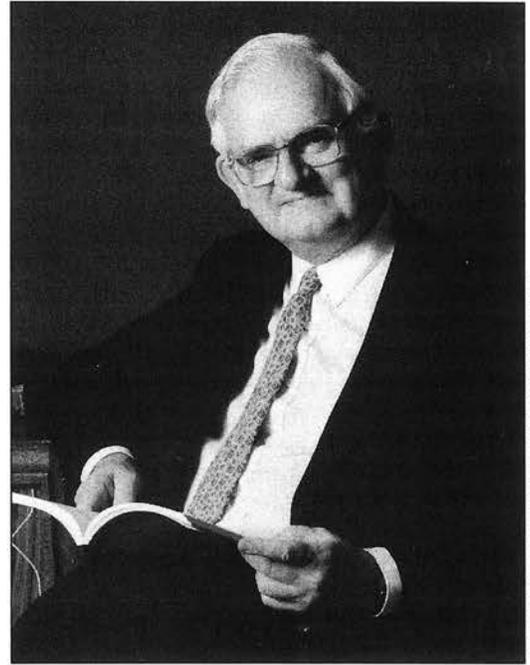
The second new field, “nonlinear acoustics”, was initiated by a famous 100-page article written in 1956 in honour of the seventieth birthday of another great mechanics scientist, Geoffrey Taylor. This field is now represented by many thousands

of papers, and applications include kidney-stone-crushing lithotripsy machines and, with the same mathematics, flood waves in rivers and traffic flow on highways.

From Manchester, Lighthill went on in 1959 to become director of the Royal Aircraft Establishment, Farnborough, where his leadership extended to the critical examination of every report emanating from the RAE. The

years 1959 to 1964 saw him again in his element (“Wouldn’t change it for anything!”), working on the aerodynamics of the slender delta wing for Concorde, on spacecraft, and on short-haul aircraft. He also worked with the post office in developing commercial use of television and communications satellites while managing in unusual detail the work of the 8,000 RAE staff, of whom 1,400 were professional scientists and engineers. Towards the end of his RAE time he became dissatisfied with the support in national societies for applied mathematics and founded the Institute of Mathematics and Its Applications, of which he was the first president, in 1965–67. From 1964 to 1969 Lighthill held a Royal Society research professorship at Imperial College, and here he began his great development of mathematical biofluidynamics: the quantitative understanding of the flow of blood in mammalian cardiovascular systems, of air in the human airways, and of the flying of birds and insects and the swimming of fish. Mastery of biology was, he insisted, the sine qua non for entry into this field. He revelled in lectures, not only in the articulation of all the Latin names, but in his ability to perform the appropriate gymnastics to illustrate certain flying characteristics—in particular the “clap and fling” mechanism employed by the tiny wasp, *Encarsia formosa*, to endow it with a lift coefficient far above that obtainable from the ordinary aerodynamics in which the component parts of the body do not break apart.

In 1969 he succeeded Paul Dirac, founder of much of quantum mechanics, in the Lucasian Professorship of Mathematics at Cambridge—though when he referred to “my predecessor in the chair,” one sensed he was thinking primarily of Newton.



Sir James Lighthill

Photograph courtesy of University College London.

Here he taught indefatigably and with enormous gusto six days of the week at nine in the morning. He widened his range yet further with work on control systems; on active control of sound, or anti-sound; more and more on waves; on oceanography and atmospheric dynamics, including monsoon prediction and propagation; and on biological mechanics at the microscopic level.

From 1979 to 1989 Lighthill was provost of University College London, much engaged in fundraising; in new developments in the college, particularly in the biology and biotechnology sides; and in dramatically improving the representation of women in senior posts. He still maintained his scientific work with studies on the unpredictability of large systems, on wave energy extraction devices, and on features of the human auditory system. After retirement he took up chairmanship of the Special Committee on the International Decade for Natural Disaster Reduction and travelled and lectured worldwide.

His achievements were widely recognised—through election as Fellow of the Royal Society at the age of twenty-nine, through the award of 24 honorary doctorates, through foreign membership of the most prestigious academies, through receipt of many medals and prizes, and through knighthood in 1971.

Stories about Lighthill are legion, and no amount of discounting for exaggeration makes them less amusing or less essentially accurate. It is well known that he was fined £1 for jumping from a train as it passed, to his dismay, through Crewe without stopping and that on more than one occasion he successfully defended himself on charges of speedy driving, turning the spotlight of his presence, charm, and authority on the magistrates as he explained how, as Lucasian Professor, he was fully seized both of the laws of mechanics and of his duty to society not to waste energy, the latter compelling him to desist from applying the brake on any downhill section of road.

He saw everything as a challenge to his brain, or to his physique, or to the coordination of the two. And if no challenge was obviously at hand, he would create one: mastering Portuguese in three weeks to the extent that he could give a (long) after-dinner speech in the language, for example. He listed his leisure interests as music and swimming, to which surely literature, poetry (especially Portuguese), and languages (French, German, Russian, Portuguese) should be added.

His swimming exploits were legendary—careful in his homework on tides and local currents, bold in his ignoring of everything else. On countless occasions he came home safely, against the odds. Last Saturday he almost completed a nine-hour swim round Sark (he was the first ever to do this, at the age of forty-nine) against high winds and huge waves before dying close to the shore.

T. J. Pedley

It was during the fifteen years after he left the Royal Aircraft Establishment (1964–79), first as a Royal Society Research Professor at Imperial College and then as Lucasian Professor of Mathematics at Cambridge, that Lighthill totally transformed the study of biological fluid dynamics. He wrote major reviews of aquatic animal propulsion (1969), of animal flight (1974 and 1977), and of low Reynolds number flagellar hydrodynamics (1976). Each of these is characterised by an exhaustive survey of the animal kingdom to make sure that all actual modes of locomotion are covered by the preliminary fluid dynamical analyses that he then presents in qualitative if not quantitative forms. (The lectures based on these surveys were always splendid occasions, in which Lighthill would alternate between demonstrating his mastery of the relevant taxonomic terminology and making his fluid dynamical audience feel at home by incorporating standard terms from other applications, such as—in the flight context—payload, wing-loading, induced drag, etc.) He himself concurrently made major advances in fluid dynamical analysis in all three areas.

In fact, his first analysis of fish swimming (1960) was published while he was director of the RAE, and in it he set out the principal features of what has become the standard model of fish swimming using body undulations. This small-amplitude, slender- (or elongated-) body theory explains how thrust is generated from the reactive (added-mass) forces experienced by an undulating body as it gives sideways acceleration to fluid which is moving backwards relative to the fish at the approximately steady swimming speed. Moreover, Lighthill showed a full appreciation of the difficulties involved with calculating *recoil* (stemming from the fact that an arbitrary displacement wave will not in general give rise to instantaneous forces and couples that exactly balance the fish's transverse and angular momentum fluctuations) and with analysing the three-dimensional *boundary layer*, needed to check whether the computed thrust does indeed balance the drag at the supposed swimming speed. These features were later expanded (1970), and the whole theory adapted to large amplitudes (1971). Other aspects were taken further by visitors to Cambridge in the early 1970s (D. Weihs, M. G. Chopra, T. Kambe). Lighthill

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himself returned to fish swimming after he had retired from University College, London, through a series of four papers on “Balistiform and gymnotiform locomotion” (1990) and, more recently, with a fascinating analysis of how a herring can control the motion of its head to enable it to sense pressure differences across the head of external origin without being swamped by self-generated pressures (1993).

For flagellar locomotion Lighthill developed a new viscous slender body theory superior to the customary resistive force theory, in which a long, narrow, cylindrical flagellum, beating with a long wavelength, is replaced by a distribution of Stokeslets and dipoles on its centre-line whose strengths are obtained by solving an integral equation representing the no-slip condition on the cylinder surface (1976). In the context of flight Lighthill’s collaboration with the then professor of zoology at Cambridge, T. Weis-Fogh, led to an elegant analysis of a newly observed mode of lift generation in small hovering insects, the clap-and-pling (1973). However, in both these areas many of his ideas were put into effect and subsequently taken much further by Ph.D. students: namely, J. R. Blake, J. J. L. Higdon, and J. M. V. Rayner.

Despite these pivotal contributions to external, or zoological, fluid dynamics, Lighthill’s most significant contribution to the field may have been in internal, or physiological, fluid dynamics—and not through his publications, but through his administrative vision. In the middle 1960s he joined forces with C. G. Caro from St. Thomas’s Hospital to persuade Imperial College to create the Physiological Flow Studies Unit. This research group started work, attached initially to the Aeronautics Department, in 1966. Many students, fellows, academic staff, and visitors have worked there over the years (including this writer, from 1968–73), and now, as part of the Department of Biological and Medical Systems, it has a strong international reputation, especially in the study of the response of artery walls to haemodynamic stresses, an important part of understanding arterial disease.

Lighthill’s direct contributions to physiological fluid dynamics were quite few—though including several masterly, specially written chapters in his 1975 book *Mathematical Biofluidynamics*—until towards the end of his career he developed an interest in the inner ear. In particular, he demonstrated that the ability of the hair cells of the cochlea to sense different frequencies of sound according to their distance from the entrance could be associated with a phenomenon of critical layer absorption of the elasto-acoustic waves set up in that organ (1981, 1991, 1992).

To the students and colleagues who worked with him, Lighthill gave much more than intellectual stimulus. In addition to the generosity with which he shared his ideas and gave his support (he

adhered to the by now rarely found view that a supervisor’s name should not appear on the papers of his students, however much of the work he had done himself), he instilled his own uncompromising principles for interdisciplinary research. The motive for doing fluid mechanics in biology is to help biologists understand how their systems work. To this end it is essential “to talk to zoologists and go on talking to them; to read their works and go on reading them; to study their collections and go on studying them” (1973). He did it, and we must do it too.

Those of us working in biological fluid dynamics know that James Lighthill made huge contributions to many areas of fluid mechanics and applied mathematics in addition to ours. That merely intensifies our admiration for the transformation he wrought in our subject. We honour him deeply and miss him greatly.

Mathematics Without Borders. A History of the International Mathematical Union

Reviewed by J. W. S. Cassels

**Mathematics Without Borders. A History of the
International Mathematical Union**

Olli Lehto

Springer, 1998

ISBN 0-387-98358-9

xvi + 399 pages, \$34.00

The scope of this volume is broader than its title suggests. It is an account of formal international mathematical cooperation from its beginnings at the end of the nineteenth century until 1990, when the author ceased to be secretary of the International Mathematical Union. There are three main threads: the regular sequence of International Congresses of Mathematicians (ICMs); the International Commission on Mathematical Instruction (ICMI, originally known as the International Commission on the Teaching of Mathematics); and the International Mathematical Union (IMU), which also had two avatars. The tangled relation between these threads changes with time, and the whole story must be seen against the background of international scientific organization and politics.

The initiative for the International Congresses was largely German and French. The first two were Zürich 1897 and Paris 1900. Thereafter they have been at four-year intervals except for gaps caused by two world wars and for the delayed Warsaw Congress. At the 1908 Congress in Rome the International Commission on the Teaching of Mathematics was set up. In the aftermath of the First World War the victorious powers set up an

International Research Council from which the defeated Central Powers were excluded. The Council included an International Mathematical Union whose statutes were agreed at an International Congress of Mathematicians of doubtful status: it was held in 1920 in Strasbourg, just reverted to France from Germany, and it excluded German participation. The new Union had a checkered history and was formally suspended in 1932; it seems to have had little or no influence on international mathematical life. The International Research Council was replaced in 1931 as an umbrella organization by the International Council of Scientific Unions (ICSU), which was open to all countries (though boycotted initially by Germany); it had, however, no mathematical union. By 1928 the International Congresses of Mathematicians abandoned the anti-German stance of the IMU: Bologna 1928 and later congresses were open to all mathematicians, irrespective of nationality. The last ICM before the Second World War was Oslo 1936, when it was agreed that the next would be in the USA in 1940. In the meantime the Commission on the Teaching of Mathematics, which was a creature of the congresses, was instructed to dissolve itself in 1920 but was revived in 1928 and worked in full universality (with a German on its Central Committee) until the outbreak of war in 1939.

The congress planned for 1940 ultimately happened in Harvard in the summer of 1950. Every effort was made to attract mathematicians irrespective of national or geographic origin. United States mathematicians also took the initiative to revive an International Mathematical Union. After much negotiation designed to ensure the widest

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possible participation, a constitution was agreed at a conference held just before the Harvard Congress, and after ratification the first General Assembly of the new era took place in Rome in 1952. The new body was in the conventional jargon “a member of the ICSU family”. Whether it was a continuation of the old union or entirely new was left intentionally vague.

The three threads described at the beginning of this review started to come together. The International Commission on the Teaching of Mathematics resumed activity after the war; after a period of some confusion it was reestablished at the 1954 General Assembly of the IMU as a commission of the Union with a new constitution and a new title: the International Commission on Mathematical Instruction (ICMI). Previously there had been no continuing organization of the International Congresses: at each congress the site of the next was chosen, and the new hosts took responsibility. The IMU began now to have an input. The Swedish National Committee and the IMU worked together in the preparation for the 1962 Stockholm Congress. A framework under which the IMU became a partner in the organization of future congresses was adopted at the 1962 General Assembly. The Union also took responsibility for the Fields Medals. These had been established with part of the surplus from the 1924 Toronto Congress and were initially awarded by committees appointed by the organizing committees of congresses.

The way the Union works is roughly as follows. Members are countries, where a sophisticated (and sophisticated?) definition of “country” aims to secure universality (e.g., when a country is not recognized as such by some other countries). Each country is represented by an Adhering Organization (e.g., an academy) which forms a National Committee for Mathematics. Only countries with enough mathematical research activity are admitted, and those admitted are allocated to one of Groups I, II, III, IV, or V agreed between the country and the Union. Countries pay dues: the higher the group, the higher the dues (see below). The supreme body of the Union is the General Assembly, which normally meets every four years, shortly before a congress in a pleasant location nearby. Each country is entitled to appoint a number of delegates equal to the number of its group. The General Assembly appoints an Executive Committee consisting of a president, a secretary, two vice-presidents, and five other members; the immediate past president is also a member. The Executive Committee normally meets once a year. What the volume under review does not bring out, except between the lines, is the degree to which the smooth running depends on the president and on the secretary, who also acts as treasurer and is the linchpin of the entire setup. The Executive Committee of ICMI is also chosen by the General Assembly and includes

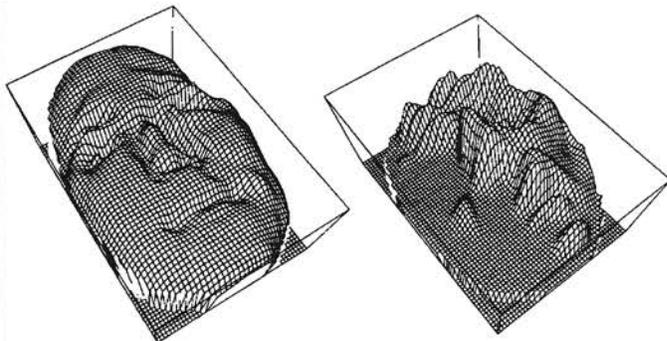
the president and secretary of the IMU ex officio. The scientific programs of the International Congresses are arranged by a committee largely appointed by the IMU Executive Committee, with some members appointed by the local Organizing Committee. This was at first rather misleadingly called the Consultative Committee, but is now known as the Program Committee.

It is not possible to summarize an already condensed account of the subsequent activities of the Union. Main themes are the extension of the activity of the Union to include sponsored Union lectures and the support of specialized symposia, the sometimes difficult relations with Soviet mathematicians, and the problem of finding formulations to bring the Chinese into the IMU without sacrificing the interests of mathematicians in Taiwan. Other developments were the establishment of the *World Directory of Mathematicians* and of a Commission on Development and Exchange, which promotes mathematics in underdeveloped countries. ICMI in practice is largely autonomous. It draws in mathematical communities outside the countries represented in the IMU and has a wide program of activities, including the International Congresses on Mathematical Education held every four years between the ICMs.

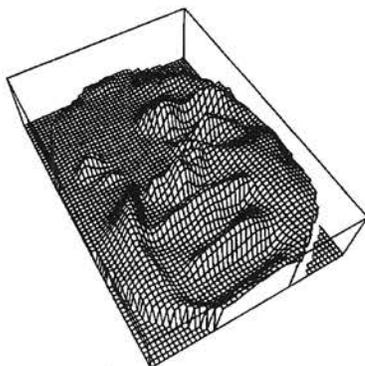
One theme to which Lehto reverts from time to time is the extent to which the Union now runs in the English language. In my time on the Executive Committee (1975–82) it was the only language used, although the official languages of the Union were declared to be English, French, and Russian, with equal validity. When I commented on this to Jacques-Louis Lions, the secretary at the time, he quipped “Some languages are more equal than others.” He also told me that the English-language minutes were translated after the meeting into French and Russian and put in the archive, where they were preserved unread. He added that there were difficulties in translating the pragmatic fudge of the English original into the logical lucidity of the French language. I believe that this practice of translating the minutes has been abandoned.

Perhaps my recollections can shed light on a rather mysterious passage on page 182. As already mentioned, members of the Union are in groups and pay dues accordingly. Originally the dues for Groups I–V were in the ratios of the Fibonacci numbers 1, 2, 3, 5, 8, a formula found in other unions. At the 1974 General Assembly this was changed to 1, 2, 4, 7, 10, a change which Lehto calls a delicate issue. As I remember, what happened was this. The American mathematicians believed that they could persuade their government to contribute more cash to international mathematics and thought that the best way to get it past their bureaucrats was to increase the amount payable in dues by the USA. They therefore proposed either that there should be a Group VI with much

Two- and Three-Dimensional Patterns of the Face

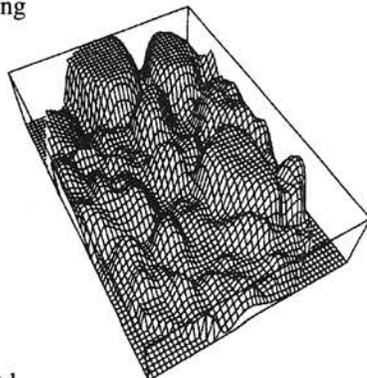


Peter W. Hallinan,
Gaile G. Gordon,
A. L. Yuille,
Peter Giblin, and
David Mumford



1999; Hardcover; 262 pages; ISBN 1-56881-087-3;
\$48.00

The three-dimensional shape of the human face and its two-dimensional images are complex and hard to characterize. This book ties together applied mathematics, applied statistics, and engineering by applying general theories and concepts to the specific and familiar example of the human face. The authors include fully worked out examples of two approaches to face recognition, demonstrating the power of pattern theory and suggesting interesting new mathematics in the two- and three-dimensional aspects of the face.



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higher dues or that the dues of Group V should be substantially increased. At that time Group V consisted of the USA (of course), the USSR (which regarded it as a point of honor to match the USA), Japan (which had just moved up), and the UK. The USSR already had difficulties in finding hard currency to pay the existing dues and regarded the US proposal as a dastardly attempt to push them from the top table. The UK would also have found difficulty in funding the increase and would probably have grimaced and moved down. In the end a compromise was agreed in the expectation that some other countries would move up: indeed, by 1978 France and the Federal Republic of Germany had joined Group V.

For the earlier IMU no formal archive remains. The author uses a wide variety of sources, including personal papers which he has tracked down, and sets the story in the context of general scientific cooperation of the period. "In contrast"—to quote—"the volume of archival material covering the new Union is overwhelming." It was transferred to the University of Helsinki in 1994 (fourteen mail sacks, each twenty kilos), where it has been organized and augmented. The history of the Union and its related organizations is a complicated and tangled tale with a multiplicity of participants. There is much to interest the reader, but I must admit that I did not find the story always easy to follow. I felt a lack of balance: for example, the ceremonies surrounding the awarding of the Fields Medals are reported in inordinate detail. What I found most interesting is where Lehto tells of his personal experiences, in particular the organizing of the Helsinki Congress, in which he had a leading part.

A series of thirteen appendices lists such things as the membership of the Union at various times, the membership of the Executive Committee, the times and places of its meetings, the Fields Medalists, and the membership of the Fields Medal Committees. There is an impressive index, but I did not find it helpful; for example, there is no entry for the Consultative Committee. The text is decorated by portraits of many of the protagonists.

An Imaginary Tale: The Story of $\sqrt{-1}$

Reviewed by Brian E. Blank

An Imaginary Tale: The Story of $\sqrt{-1}$
Paul Nahin
Princeton University Press, 1998
ISBN 0-691-02795-1
248 pages, \$24.95

Paul Nahin's *An Imaginary Tale* begins with a cartoon strip in which an imaginary tiger professes to instinctively understand imaginary numbers. If only real humans were so blessed. Each year a new crop of high school students becomes acquainted with the Quadratic Formula and, along with it, negative discriminants. The number i is magically invoked to resolve the difficulty. Is it a real number? The correct answer is Clintonesque: "It depends on how you define 'real'." So we compromise: we say that it is an *imaginary* number, but we make sure that it is on the exam—that will make it seem real enough. Happily for most students, imaginary numbers are often no more than a fleeting nuisance. Those who do continue beyond high school algebra pass into an imaginary-free zone called calculus. Because we are often successful at extending this respite through linear algebra and ordinary differential equations, many mathematics majors never see an imaginary number during their entire college careers.

It should be conceded that mankind saw no need for algebraically closed fields for several millennia. Although the Quadratic Formula has become the instrument for exposing students to complex numbers, it did not at any time since its discovery some 4,000 years ago inspire the introduction of imaginary numbers into mathematics. When there arose a problem that resulted in a neg-



ative discriminant, it was considered insoluble. Such an interpretation was quite sensible in the Greek and Arab schools of algebra, in which algebraic equations were generally expressions of geometric relationships. The need for imaginary numbers did not manifest itself until the sixteenth century discovery of Cardan's Formula for the roots of the cubic equation.

The seeds for imaginary numbers were planted in the twelfth century when Arab algebra was introduced into Italy through the Latin translation of al-Khwārizmī's great treatise, *Al-jabr wā'l-muqābala*. In 1225 Leonardo of Pisa (Fibonacci) published an approximate solution of a specific cubic and showed that the exact solution could not have a certain form. Incorrect solutions of the cubic were published in 1328 and 1344 by Paolo Gerardi and by Maestro Dardi of Pisa. By the end of the fourteenth century, however, a crucial step was taken. In two anonymous Florentine manuscripts there appears the linear change of variable that transforms a general cubic equation into the so-called *depressed cubic*

$$(1) \quad x^3 + px = q.$$

Progress in the fifteenth century was subtle but essential. Notation improved, abstraction increased. Early in the sixteenth century Scipione del Ferro found the general solution of equation (1):

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$$x = \sqrt[3]{q/2 + \sqrt{\Delta}} + \sqrt[3]{q/2 - \sqrt{\Delta}},$$

$$\Delta = q^2/4 + p^3/27.$$

Cardan's Formula, as this expression came to be known, presented an immediate conundrum. Consider the equation

$$(2) \quad x^3 - 15x = 4$$

in which all three roots are real. In this case Cardan's Formula becomes

$$(3) \quad x = \sqrt[3]{2 + \sqrt{-121}} + \sqrt[3]{2 - \sqrt{-121}}.$$

Rejecting complex numbers here would have meant rejecting three *real* solutions, solutions which were found only after three centuries of struggle.

It is from this juncture that Paul Nahin begins his tale in earnest. Brimming with enthusiasm, he recounts the history of complex numbers through to Cauchy's 1814 memoir on contour integration. In doing so, Nahin interweaves formulaic mathematics with historical narrative, somewhat in the manner of [5]. The story unfolds in three distinct parts: the introduction of and early reactions to complex numbers, the attempts to realize complex numbers geometrically, and the use of complex numbers in the service of elegant mathematics. Along the way the reader will encounter several of the most beautiful exact formulas of classical mathematics: product formulas of Viète, Wallis, and Euler; the reflection formula for the gamma function; the functional equation of the zeta function; and a grab bag of pretty integral and series formulas.

This blend of engaging history and sparkling mathematics has been written for students who have finished freshman calculus, to be "read as a supplement to the more standard presentations of mathematics." By this the author means, one may presume, presentations written by mathematicians: texts that feature accurate statements and carefully reasoned deductions. Nahin, it must be noted, writes from the perspective of the electrical engineer that he is. Be prepared for a notation that expresses the relationship $i = \exp(i\pi/2)$ as $i = 1\angle 90^\circ$. Expect formal manipulations with power series without regard to convergence.

The lack of rigor, one must admit, is defensible: an overly rigorous approach would not be appropriate for Nahin's intended readers. Furthermore, most of the action covered by the book, including that part of Cauchy's work that is discussed, took place before Cauchy introduced the ϵ and δ to analysis. By granting the author some discretion in the matter of rigor, however, we should not forsake our expectations of "honest" mathematics. Readers should not be misled about the validity of an inadequate argument. They should not be confused because the author is reluctant to confront difficult concepts. They should not be kept in the

dark about the ideas that lie behind the formulas. Unfortunately, Nahin often does not meet these pedagogical responsibilities.

Consider del Ferro's solution of equation (1). The first step is to substitute $x = u + v$ into equation (1) to obtain

$$u^3 + v^3 + (3uv + p)(u + v) = q.$$

Nahin states that this single equation "can be rewritten as two individually less complicated statements: $3uv + p = 0$ which then says that $u^3 + v^3 = q$." The reader who forgives the confused wording of the thought must still overcome the confusion (between necessity and sufficiency) of the thought itself. Referring to the expression of the solution as a sum of two terms, Nahin asks, "How did del Ferro know to do this?" Responding to his own question, he asserts that the answer lies in the distinction Mark Kac made between an ordinary genius and a magician: with a magician, we do not know how he came to do something even after we have watched him do it. A pretty distinction, but I am sorry: we all know magicians, and del Ferro was no magician. A glance at the Quadratic Formula provides the rationale for del Ferro's approach. Moreover, the incorrect solutions that Gerardi and Dardi published in the fourteenth century had the forms $u + \sqrt{w}$ and $u + \sqrt[3]{w}$ respectively. There is no mystery here. The author ill serves the student when he mystifies the deductive process in mathematics.

In labeling del Ferro a magician, Nahin sets the tone for his book. By the time we reach its end, we are learning "wizard mathematics." One after another the results presented are said to be "astounding" or "astounding." One mundane result is deemed to be a "bombshell." Fine. Only a killjoy would purge this sort of hyperbole from an elementary exposition. But in mathematics we are not content to allow facts to *remain* astonishing; we try to get to the bottom of them. After solving the equation $(z + 1)^n = z^n$, Nahin observes that all the roots lie on the vertical line $x = -1/2$. He describes this as "rather surprising" and *moves on*. It is not enough for an author to stand back in awe of this apparent coincidence; the author must look to the equation to explain why the proven result is neither a coincidence nor surprising, once it has been understood. To quote E. T. Bell, "So long as there is a shred of mystery attached to any concept, that concept is not mathematical." Words for a mathematical expositor to live by.

A recurring pedagogical concern in *An Imaginary Tale* is that mathematical facts are not put into perspective. The book's contents are an eccentric mix of the essential and the inconsequential sitting cheek by jowl, all treated with equal relish. Students require a stronger guiding hand. They also need a structure in which to frame the facts that they learn. For example, the lengthy

discussion of Cardano's *Ars Magna*, in which appeared the first published solution of the cubic, finds no room to remark that the treatise also contained the first solution of the biquadratic. Galois is not mentioned. Abel appears once and then only to say that he called Cauchy a bigot. In short, once the theory of equations has produced i , it has become dispensable.

At times the divide between the engineer and the mathematician is especially deep. To "demonstrate dramatically" the power of De Moivre's Theorem, the author uses the theorem to write out trigonometric expressions for the roots of $z^5 - 1 = 0$. He then presents Lagrange's algebraic derivation of these same roots *in terms of radicals*. Oblivious to their significance, Nahin gets out his calculator and shows that the floating point approximations of the two sets of solutions agree. He then notes that in contrast to De Moivre's Theorem "Lagrange's clever algebraic substitution that works so well for the degree 5 equation does not work in the general case." He suggests $n = 97$. Is this irony? No mention is made of Gauss's work on the solution of the cyclotomic equation by means of radicals.

The treatment of exponents throughout the book is perplexing. This is not a topic in which intuition alone may serve as a substitute for accurate definitions. Without knowing the precise meaning of complex exponents, how can a student resolve Clausen's "infuriating puzzle," which purports to show that $\exp(-4\pi^2) = 1$? Yet that is just what Nahin challenges the student to do. He warns that this riddle "should keep you sleepless for a few nights," but withholds its solution. (The nineteenth century mathematician Eugène Catalan stripped the algebraic misdirection from Clausen's puzzle to better unmask the nub. In Catalan's condensation, the equation $e^{-\pi} = e^\pi$ is obtained by raising each side of the genuine equality $e^{2\pi i} = e^{-2\pi i}$ to the power $i/2$.)

This is tricky material. My reservations concerning the use of powers, however, arise with the most basic material at the very beginning of the book. Although the student is informed that any cubic equation has three roots (and is advised to read an appendix containing a statement of the Fundamental Theorem of Algebra), the student is not explicitly told that a complex number has three cube roots. Calculating that the student has not made this deduction, Nahin *deliberately* conceals it. Let us reconsider equation (2). Cardan's Formula (3) in this case reduces to 4, $-2 + \sqrt{3}$, and $-2 - \sqrt{3}$ *when the three cube roots are used*. Nahin pretends to be unaware of this when, in order to show that Cardan's Formula yields the obvious root 4, he writes "it is sufficient to see that $\sqrt[3]{2 + \sqrt{-121}} = 2 + \sqrt{-1}$ and $\sqrt[3]{2 - \sqrt{-121}} = 2 - \sqrt{-1}$." There is no mention that the left sides of these supposed equalities are not uniquely

defined. Shortly thereafter, when, speaking of a class of cubics of which equation (2) is an example, Nahin remarks that there is "just one positive root; that is, *the* root given by the Cardan formula" (reviewer's emphasis). Continuing the pretense, Nahin counsels the student to complete the solution of the cubic by dividing by the linear factor provided by Cardan's Formula and then applying the Quadratic Formula. Two chapters later he includes one sentence to redress these deceptions. By that time the derivation of Cardan's Formula has long been forgotten. Any reasonably sharp student may well wonder why formula (3) does not provide *nine* solutions to equation (2).

Heretofore I have cited aspects of Nahin's presentation that might confuse the student. Of equal importance are the numerous instances in which the student might be deceived by a vacuous explanation. For example, the infinite series $\sum (-1)^{n+1}/n^z$ is said to converge for $\text{Re}(z) > 0$ "precisely because of the alternating signs," as if the terms were real-valued. A few pages later Nahin begins to prove the reflection formula for the gamma function. Requiring the evaluation of a certain integral, the proof is suspended until the discussion of complex integration in the final chapter. Unfortunately, when the time comes to complete the deferred evaluation, Nahin does not choose the appropriate contour. Only a trivial case of the reflection formula is actually proved.

Because *An Imaginary Tale* is largely told as history, I cannot let pass several historical inaccuracies. Nahin ascribes to Cardano the method by which the quadratic term is eliminated from a cubic equation: "This was a major achievement in itself, and it is all Cardan's." As mentioned above, the necessary transformation was discovered at least one and a half centuries before Cardano's re-discovery.

After discussing the Fibonacci numbers, Nahin comments "Such recurrences often occur...but in Leonardo's time they were brand new. Indeed, Leonardo's recurrence was the first time such a thing had been encountered." Not so! Consider the following scheme that the ancient Greeks devised for approximating $\sqrt{2}$: let $s_1 = d_1 = 1$ and, for $n > 1$, let $s_n = s_{n-1} + d_{n-1}$, $d_n = 2s_{n-1} + d_{n-1}$. The approximation to $\sqrt{2}$ is d_n/s_n , but that is beside the point here. After separation we find that both sequences satisfy the Fibonacci-like recurrence relation $g_n = 2g_{n-1} + g_{n-2}$ for $n > 2$.

Referring to the product formula for the zeta function, Nahin proclaims "...it gave Euler an entirely new proof of the infinity of the primes, the first since Euclid's from two thousand years before." In fact, Goldbach anticipated Euler by several years. In a letter that he wrote to Euler in 1730, Goldbach established the infinitude of primes by observing that the Fermat numbers are pairwise relatively prime.

In telling the story of the zeta function, Nahin jumps from Euler to Riemann, neglecting Riemann's teacher, Dirichlet, who played a crucial intermediate role. Nahin also neglects to inform the reader that Euler discovered (but did not prove) an equivalent form of the functional equation of the zeta function [7]. By stating that Riemann *attempted* to find a formula for the prime counting function, $\pi(x)$, and leaving it at that, Nahin may give the erroneous impression that Riemann was not successful in his search. (What Riemann was not successful at was using his formula for $\pi(x)$ to prove the Prime Number Theorem.)

Finally, we have long since passed the point when the author of a historically informed work should mention the Leibniz-Gregory series without acknowledging that the name reflects a Western view of history. When the author writes that the Maclaurin series of $\sin(x)$ and $\cos(x)$ were known "at least since Newton's time," he may not be wrong, but his lower bound is several hundred years too great. The Gregory series for $\arctan(x)$, the Leibniz series for $\pi/4$, and the two Maclaurin series just cited were all known to and recorded by the Indian mathematician Mādhavan (ca. 1340-1425).

Permit me a final criticism that concerns both pedagogy and history. Nahin takes complex numbers as a given. Many mathematicians consider it absolutely fundamental that the complex numbers *must* be constructed. To understand the necessity, consider the charming words (unfortunately not found in Nahin's book) of Descartes, in coining the term *imaginary*: "For any equation one can imagine as many roots [as its degree would suggest], but in many cases no quantity exists which corresponds to what one imagines." As late as 1770 Euler stated that imaginary numbers are *impossible*. If these are the opinions of an ordinary genius and a magician, then how can we deny the necessity of constructing such quantities? Even Cauchy, a hero of Nahin's book, felt obliged to construct \mathbb{C} and did so in 1847 as $\mathbb{R}[x]/(x^2 + 1)$. Lest there be any doubt as to his purpose, Cauchy remarked, "We completely repudiate the symbol $\sqrt{-1}$, abandoning it without regret because we do not know what this alleged symbolism signifies nor what meaning to give to it." Of this *An Imaginary Tale* makes no mention. But Nahin *does* condescendingly dismiss William Rowan Hamilton's prior algebraic construction of \mathbb{C} . In fact, the disdainful tone with which the author lessens Hamilton's entire scientific career is irksome. Perhaps it is relevant to note that Nahin has already written a biography of Oliver Heaviside, electrical engineer and scourge of quaternionists. Nahin is not the first to disparage Hamilton, but one is astonished that such attitudes persist.

Because a book published by Princeton University Press tends to bring with it a presumption of

excellence, I have found it appropriate to discuss the shortcomings of *An Imaginary Tale* in detail. That does not mean that the book lacks merit. Nahin set out with a worthy idea, brought tremendous energy to its development, and presented the results with evangelical zeal. He took great care in the execution and recording of his calculations. He has conveniently collected much interesting material, some of which will be new to many readers—I am thinking in particular of two enlightening sections on electronic circuits. Unfortunately, in the transition from promising manuscript to published book advance praise was secured while more important tasks were left undone. *An Imaginary Tale* is not a bad book, but it might have been so much better. Those who teach complex variables may wish to dip into it for ideas to enrich their lectures, but because of its frequent lack of clarity and correctness they may hesitate to recommend it to their students. Fortunately there are several good alternatives: [3], [5], and [10] for history; [4], [8], and [11] for applications of complex variables; [5] and [6] for the work of Euler; and [1] for a serious treatment of the gamma and zeta functions that is within the reach of well-prepared undergraduates. For the history of complex analysis, specialists can turn to [2] and [9] as well as the primary sources.

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 Bourgain, J.(1-ASP)
 Global wellposedness of defocusing critical nonlinear Schrödinger equation in the radial case. (English)
 English summary
J. Amer. Math. Soc. 12 (1999), no. 1, 145--171. [Original Article]

The author studies the global Cauchy problem for the nonlinear Schrödinger equation $i\partial_t u + \Delta u - u|u|^4 = 0$, where the critical power of the nonlinearity is equal to the critical power for the corresponding linear equation. The global Cauchy problem for the critical NLS has been conjectured to be global in three dimensions. In this paper the conjecture is solved for $n=3,4$ in the radially symmetric case. The proof of the last bound is carried out by using Strichartz, and pseudoconformal inequalities in a refined and localized manner.

Reviewed by Tohru Ozawa

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Global wellposedness of defocusing critical nonlinear Schrödinger equation in the radial case
 J. Bourgain

Abstract. We establish global wellposedness and scattering for the H^1 critical defocusing NLS in 3D

$$i\partial_t u + \Delta u - u|u|^4 = 0$$

assuming radial data $\phi \in H^1$, $s \geq 1$. In particular, it proves global existence of classical solutions in the radial case. The same result is obtained in 4D for the equation

$$i\partial_t u + \Delta u - u|u|^2 = 0.$$

J. Bourgain

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Mathematics People

MAA Writing Awards Presented

The Mathematical Association of America (MAA) presented several awards for excellence in expository writing at its Summer Mathfest in Providence in July 1999.

The Carl B. Allendoerfer Awards are given for articles published in *Mathematics Magazine* and carry a cash award of \$500. Two awards were given for 1999. VICTOR KLEE of the University of Washington and JOHN R. REAY of Western Washington University received one award for their article "A surprising but easily proved geometric decomposition theorem", *Mathematics Magazine*, volume 71 (1998). DONALD G. SAARI of Northwestern University and FABRICE VALOGNES of the University of Caen, France, received an award for their article "Geometry, voting, and paradoxes", also in volume 71 (1998) of *Mathematics Magazine*.

The Trevor Evans Award is given to authors of exceptional articles that are accessible to undergraduates and that were published in *Math Horizons*. This prize carries a cash award of \$250. The award for 1999 went to RAVI VAKIL of the Massachusetts Institute of Technology for the article "The youngest tenured professor in Harvard history", *Math Horizons*, September 1998.

The Lester R. Ford Award honors articles published in *The American Mathematical Monthly* and carries a cash prize of \$500. Three awards were made for 1999 to the following mathematicians, all for articles that appeared in the *Monthly*, volume 105, 1998: YOAV BENYAMINI of the Technion-Israel Institute of Technology for the article "Applications of the universal surjectivity of the Cantor set"; JERRY L. KAZDAN of the University of Pennsylvania for the article "Solving equations, an elegant legacy"; and BERND STURMFELS of the University of California, Berkeley, for the article "Polynomial equations and convex polytopes".

The George Pólya Award is given for articles published in *The College Mathematics Journal* and has a cash prize of \$500. Two awards were made for 1999. AARON KLEBANOFF and JOHN RICKERT received an award for their article "Studying the Cantor dust at the edge of the Feigenbaum

diagrams", *College Mathematics Journal*, volume 29 (1998). DAVID BLEECKER and LAWRENCE J. WALLEN were selected for their article "The world's biggest taco", also in *College Mathematics Journal*, volume 29 (1998).

—Mathematical Association of America

London Mathematical Society Prizes Awarded

The London Mathematical Society (LMS) has announced the awarding of several prizes for 1999.

The Pólya Prize, given in recognition of outstanding creativity in, imaginative exposition of, or distinguished contribution to mathematics within the United Kingdom has been awarded to SIMON DONALDSON of Imperial College, London, for his groundbreaking work in geometry and topology. Early in his career he showed how the Yang-Mills equations in four dimensions could be used as a tool for analyzing four-manifolds themselves. This led to completely unexpected results in low-dimensional topology, for which he won a Fields Medal in 1986, and to a whole new and very active area of mathematical progress. By using moment maps in symplectic geometry, he has found a number of new models for important moduli spaces in geometry and mathematical physics. In his current work these methods promise to yield new results in complex three-dimensional geometry. Another recent achievement is a deep theorem which has made possible the use in symplectic geometry of Lefschetz's fruitful method of studying algebraic varieties by pencils of hyperplane sections.

The Senior Whitehead Prize, given in recognition of work in, influence on, or service to mathematics or of outstanding lecturing in mathematics has been awarded to M. J. D. POWELL of the University of Cambridge. He is one of the founders of the modern field of numerical optimization, and he has also had profound influence on the field of numerical approximation of functions. He was one of the originators of the first quasi-Newton iterative method in nonlinear optimization, now known as the Davidon-

Fletcher-Powell (DFP) update. His contributions to the field of approximation of functions have been equally extensive. Perhaps his greatest impact in this area has come with his investigations of radial basis functions for multivariate approximation in the past decade. With various students and collaborators he has developed unexpectedly fast and powerful algorithms for this kind of data fitting and an extensive and elegant mathematical theory that have become the standard tools in use today for the interpolation of scattered multivariate data.

The Junior Berwick Prize was awarded for an outstanding piece of mathematical research that was published by the LMS during the four years ending December 31, 1998, to a mathematician under the age of forty years who is not a Fellow of the Royal Society. The Junior Berwick Prize for 1999 was given to DAVID BURNS of King's College, London, for his article "Adams operations and wild Galois structure invariants", published in the *Proceedings of the London Mathematical Society*. In the article Burns provided a completely new insight into Galois structure theory. He has been at the forefront of recent developments in the study of certain algebraic structures that arise in arithmetical algebraic geometry, particularly the special values of L -functions. This work provides an equivariant generalization of the work of Bloch-Kato.

The Junior Whitehead Prizes are given for work in and influence on mathematics to mathematicians who are under the age of forty years, were educated mainly in the United Kingdom, and are not Fellows of the Royal Society. They are intended to include all aspects of mathematics, including applied mathematics, mathematical physics, and mathematical aspects of computer science. The 1999 Junior Whitehead Prizes were awarded to MARTIN BRIDSON and GERO FRIESECKE (Oxford University), NICHOLAS HIGHAM (University of Manchester), and IMRE LEADER (University College London). Bridson received the prize for his outstanding work in geometric group theory. Much of his work has concerned cocompact groups of isometries of nonpositively curved spaces, the so-called CAT(0) spaces. He has also been at the forefront of applications of formal languages to group theory. Friesecke was awarded the prize in recognition of important contributions to the mathematical analysis of problems in continuum mechanics, materials science, and mathematical physics. In the analysis of microstructure, he obtained a necessary and sufficient condition for the attainment of a minimum in scalar-valued variational problems, and he and J. B. McLeod proved results concerning the unexpected difference between the dynamic behavior of solutions to a model of one-dimensional viscoelasticity and the behavior of minimizing sequences for the corresponding variational problem. He and J. A. D. Wattis proved the existence of solitary waves on a lattice without invoking integrability, and he and R. L. Pego showed that these waves are stable. More recently he has studied the foundations of density functional theory and has given a rigorous proof of the famous formula of Dirac for exchange energy. Higham received the prize for his work in the field of numerical linear algebra. Among the problems in this field that his work has advanced are symmetric indefinite systems of equations, Vandermonde

systems, tridiagonal and triangular systems, least-squares and constrained least-squares, eigenvalues, generalized eigenvalues, singular value decomposition, polar decomposition, pseudospectra, iterative refinement, condition number estimation, matrix square roots, the Sylvester equation, and fast matrix multiplication by Strassen's algorithm. Leader was awarded the prize for major contributions to several areas of combinatorics. Among his results are the first known exact isoperimetric inequality for which the extremal sets are not nested, powerful results in infinite Ramsey theory concerning monochromatic solutions to systems of linear equations, and the solution of the notoriously difficult bounded graph conjecture.

—From an LMS announcement

B. H. Neumann Awards Given

The B. H. Neumann Awards for 1999 have been awarded by the Board of the Australian Mathematics Trust to KEITH HAMANN of the South Australian Department of Education, HOWARD REEVES of the Tasmanian Department of Education, and MARTIN WARD of the Australian National University.

The awards, named for Bernhard H. Neumann, are presented each year to mathematicians who have made important contributions over many years to the enrichment of mathematics learning in Australia and its region.

—Board of the Australian Mathematics Trust

Deaths

HERBERT ALEXANDER, of the University of Illinois at Chicago, died on August 27, 1999. Born on December 24, 1940, he was a member of the Society for 29 years.

JOHAN J. DE IONGH, of Nijmegen, The Netherlands, died on June 9, 1999. Born on July 13, 1915, he was a member of the Society for 38 years.

MANUEL KEEPLER, of North Carolina Central University, Durham, died on July 2, 1999. Born on November 4, 1944, he was a member of the Society for 27 years.

ROLF R. MANTEL, of the University of San Andres, Buenos Aires, died on February 7, 1999. Born on December 19, 1934, he was a member of the Society for 2 years.

JOHN R. McMULLEN, of Netscape Comm. Corp., Mountain View, CA, died on June 23, 1999. Born on May 1, 1947, he was a member of the Society for 29 years.

JERZY POPENDA, of Poznan University of Technology, Poland, died on May 31, 1999. Born on November 4, 1948, he was a member of the Society for 8 years.

GAIL S. YOUNG, professor emeritus of the University of Rochester, died on August 29, 1999. Born on October 3, 1915, he was a member of the Society for 55 years.

Mathematics Opportunities

American Mathematical Society Centennial Fellowships

Invitation for Applications for Awards for 2000-01

Deadline December 1, 1999

The AMS Centennial Research Fellowship Program makes awards annually to outstanding mathematicians to help further their careers in research. Recently, the AMS Council approved changes in the rules for the fellowships. From 1984-96 the fellowship program was aimed at midcareer mathematicians. The changes adopted four years ago redirected the fellowship program toward recent Ph.D.'s. The eligibility rules are as follows.

Applicants must: (1) be citizens or permanent residents of a country in North America, (2) have held their doctoral degrees for at least two years at the time of the award, (3) not have permanent tenure, and (4) have held less than two years of research support at the time of the award. (Each year of a full-time teaching appointment with teaching load less than four [respectively, five] courses per year on the semester [respectively, quarter] system will count in this respect as one-half year of research support.) Recipients may not hold the Centennial Fellowship concurrently with other research fellowships (e.g., Sloan Foundation Fellowships or National Science Foundation Postdoctoral Fellowships), they may not use the stipend solely to reduce teaching at the home institution, and they are expected to spend some of the fellowship period at another institution

that has a stimulating research environment suited to their research development.

The stipend for fellowships awarded for 2000-01 is expected to be approximately \$38,000, with an additional expense allowance of about \$1,500. Acceptance of the fellowship cannot be postponed. A fellowship holder may use the stipend as full support for a year or may combine it with half-time teaching and use it as half support over a two-year period.

The number of fellowships to be awarded is small and depends on the amount of money contributed to the program. The trustees have arranged a matching program from general funds in such a way that funds for at least one fellowship are guaranteed. Because of the generosity of the AMS membership, it has been possible to award four to five fellowships a year for the past five years. A list of previous fellowship winners can be found at <http://www.ams.org/secretary/prizes.html>.

Applications should include a short research plan describing both an outline of the research to be pursued and a program for using the fellowship, including institutions at which it will be used and reasons for the choices. The selection committee will base its decision on both the research potential of the applicant, based upon track record and letters of recommendation, and on the quality and feasibility of the research plan.

The deadline for receipt of applications is **December 1, 1999**. Awards will be announced in February 2000 or earlier if possible.

For application forms, write to the Executive Director, American Mathematical Society, P.O. Box 6248, Providence, RI 02940-6248, or send electronic mail to ams@ams.org,

or call 401-455-4106. Application forms are also available via the Internet at <http://www.ams.org/employment/>.

Please note that completed application and reference forms should not be sent to the AMS, but to the address given on the forms.

—AMS announcement

New NSF Institute Competition Possible

The Division of Mathematical Sciences (DMS) of the National Science Foundation (NSF) is looking at the possibility of a new institute solicitation, based on advice received from the mathematical community, including the 1999 report *U.S. Research Institutes in the Mathematical Sciences: Assessment and Perspectives*, issued by the Board on Mathematical Sciences of the National Research Council. The NSF has not yet approved a call for proposals, but the DMS is hopeful that a competition for new institutes will be approved. The Division is considering this possibility of additional mathematical institutes within a budgetary framework which will enhance the Division's individual investigator grants and increase its capabilities in other areas. Details will be posted on the Web at <http://www.nsf.gov/mps/dms/> as soon as they are available.

—DMS announcement

NSF Graduate Fellowships

The NSF awards Graduate Research Fellowships to graduating seniors and first-year graduate students. These are three-year fellowships awarded to U.S. students for full-time graduate study at the institution of their choice. They include a \$15,000 stipend, tuition coverage, and possible international travel allowances. A review panel of professional mathematicians makes recommendations for awards based on the candidate's intellectual merit and potential for research achievement. The deadline for applications is **November 4, 1999**. For further details of the program, see <http://www.orau.org/nsf/nsffe1.htm>.

The number of fellowships awarded in each scientific discipline depends on the number of applications in the discipline. The chairs of last year's selection panels for mathematics and applied mathematics have observed that there were few or no applicants from many excellent mathematics programs that historically have produced many of our most successful mathematicians. In particular there were comparatively few applicants from mathematics programs at most of the large state universities.

To address this problem, the panel chairs recommend that:

- directors of undergraduate programs actively encourage their best students to apply for these fellowships,
- directors of graduate study urge qualified entering graduate students to apply,

— advisors for Putnam and SIAM modeling competitions recommend that their team members apply for these fellowships, and

— everyone encourage more excellent minority and women students to apply.

—Anthony Knapp

Travel Grants for *Mathematical Challenges of the 21st Century*, August 2000

The AMS has applied to the National Science Foundation for funds to permit travel support for U.S. mathematicians attending the special meeting *Mathematical Challenges of the 21st Century*, to be held on the campus of the University of California, Los Angeles, August 7–12, 2000. In anticipation of the availability of funds, the Society is preparing to administer the selection process. This program is open to U.S. mathematicians who received their doctorates on or after January 1, 1994, and to graduate students enrolled in Ph.D. programs in mathematics at U.S. institutions.

Applications for support appear in this issue of the *Notices* (pp. 1317–1319), and downloadable forms are available on e-MATH at <http://www.ams.org/employment/mathchall.html>. All completed application forms must be mailed to the AMS by **January 31, 2000**. Notification of awards is anticipated by April 15, 2000. This travel grants program, if funded, will be administered by the Professional Services Department, AMS, P.O. Box 6248, Providence, RI 02940; e-mail: mathchall@ams.org; telephone 401-455-4107. Applications will be evaluated by a panel of mathematicians under the terms of the proposal submitted to the National Science Foundation.

—AMS Professional Services announcement

AMS Epsilon Program: Call for Applications

In the year 2000 the AMS Epsilon Program intends to award five grants of approximately \$15,000 each to programs that support and nurture mathematically talented high school students in the United States. The Epsilon Program (in its first year of operation) seeks to fund programs that follow the basic model that has proved so successful in the past: the programs should run over a period of multiple weeks during the summer, bring in at least twenty high school students with mathematical talent, and generally be directed by mathematicians.

Within these broad guidelines many different models of programs will be considered eligible. Programs may focus on any area of mathematics, pure or applied, and may be of narrow or broad focus. Programs that are specifically targeted to one high school year (i.e., ninth graders) or to mathematically talented women or minorities are welcome

to apply. Programs that center around problem solving or mathematical research or both are welcome to apply. Even "summer" is not a firm requirement, though it is expected that most if not all programs will take place during the summer. Programs that use undergraduates or graduate students along with mathematicians in their teaching are particularly encouraged.

Applicant programs for year 2000 must already have a proven track record of at least one year and preferably more. Applicant programs must be physically located in the United States or Canada. It is intended that half of each award should be earmarked for scholarships and half for general support of the program.

Applications for these grants must come directly from the program directors (or equivalent). Individual students or parents may not apply. Applications for support for summer 2000 programs are due **December 15, 1999**. An application form can be obtained by contacting the AMS Professional Services Department at 800-321-4267, ext. 4105, or at emp-info@ams.org. It is expected that an electronically available list of these programs will also be developed, so information is being gathered for that purpose as well.

—AMS Professional Services announcement

Call for Nominations for the Richard C. DiPrima Prize

The Richard C. DiPrima Prize will be presented at the annual meeting of the Society for Industrial and Applied Mathematics (SIAM) in Rio Grande, Puerto Rico, July 10–14, 2000. The award honors the memory of Richard C. DiPrima, long-time chair of the Department of Mathematical Sciences at Rensselaer Polytechnic Institute and former president and energetic supporter of SIAM.

The award is given to a young scientist for an outstanding doctoral dissertation in applied mathematics, defined as those topics covered in SIAM journals or series. To be eligible, a nominee should have completed his or her Ph.D. thesis and all other Ph.D. requirements during the time period from July 1, 1997, to June 30, 1999. The Ph.D. degree must be awarded by December 31, 1999.

The award consists of a certificate and a cash prize of \$1,000. The recipient of the award will be notified in advance and will be invited to attend the annual meeting to receive the award. Travel expenses will be paid by the prize fund.

Nominations along with a copy of the dissertation (in English) should be sent by **February 15, 2000**, to Ronald A. DeVore, Chair, DiPrima Prize Selection Committee, c/o A. G. Bogardo, Society for Industrial and Applied Mathematics, 3600 University City Science Center, Philadelphia, PA 19104-2688; telephone 215-382-9800; fax 215-386-7999; e-mail: bogardo@siam.org.

—SIAM announcement

Program Manager Sought for AFOSR

The Air Force Office of Scientific Research (AFOSR), the single manager of the United States Air Force basic research program, has a position open for a program manager with a strong theoretical computer science background. This position involves managing research programs at various universities across the U.S. and within the Air Force Research Laboratory, evaluating research proposals, determining new research directions, and interfacing with other government funding agencies, operational military organizations, government laboratories, and industry. A large degree of autonomy is provided, and time for individual research or teaching may also be available. AFOSR is located in the Ballston area of Arlington, VA, near the Office of Naval Research, National Science Foundation, and Defense Advanced Research Projects Agency. The present annual salary is up to \$104,851, depending upon individual qualifications and salary history. A very highly qualified candidate may also receive a recruiting or retention bonus.

Candidates should have outstanding communication skills, the ability to work with demanding schedules, and the interpersonal skills to work with a wide variety of customers. Applicants should have a strong research record in theoretical computer science with a solid grounding in mathematics. Breadth is preferred, and the applicant should have the ability to evaluate research outside his or her specific field of expertise. An applicant should also have worked with government funding agencies as a grantee or program manager and should have experience in managing coordinated groups of people on large projects as well as managing budgets.

A highly qualified candidate will have a Ph.D. in computer science or a related field and be an internationally recognized expert in computer science, with experience and noteworthy intellectual contributions in real-time analysis, networking (especially wireless), parallel and distributed processing, information warfare, information fusion, or software engineering. Such an individual will have managed or led a large, multiperson, multimillion-dollar program in basic or applied research in computer science and will have had significant experience in the U.S. military, academic, industrial, or national laboratory settings.

Applicants must be U.S. citizens and be able to obtain a security clearance. Applications should be accompanied by a current curriculum vitae and list of publications. Submit applications to Leanna Heagle, 88 SPTG/DPXCB, 4040 Ogden Avenue, Wright-Patterson AFB, OH 45433. Further information may be obtained by contacting Clifford E. Rhoades Jr., Director of Mathematics and Space Sciences, AFOSR/NM, 801 N. Randolph St., Room 732, Arlington, VA 22203-1977; e-mail: clifford.rhoades@afosr.af.mil; telephone 703-696-7797; fax 703-696-8450.

—From an AFOSR announcement

For Your Information

Hope Daly Retires

H. Hope Daly, the longtime director of the AMS Meetings Department, retired at the end of September 1999 after almost thirty-one years of service to the Society.

Daly came to the AMS in December 1968, initially working as executive secretary for then-executive director Gordon Walker, and later as his administrative assistant. In 1975 she was appointed as head of the Meeting Arrangements Department. Since that time the number of AMS meetings has grown, as have their size and complexity. In 1982 the AMS added the annual Summer Research Conferences, a set of ten week-long meetings held each summer. In 1986 came the largest meeting Daly ever directed, the International Congress of Mathematicians in Berkeley. Two years after that she oversaw planning for another especially large and complex meeting, the AMS Centennial, held in Providence in August 1988. In recent years Daly has successfully marketed the expertise of the AMS Meetings and Conferences Department to other organizations, and her department has planned meetings in Providence for such groups as the International Society for Experimental Hematology and the Estuarine Research Federation.

Daly excelled at the detailed planning and execution that goes into such complicated, large-scale affairs. At the same time she managed to bring a personal touch to meetings that attracted thousands. In addition to her mastery of her vocation, Daly is known as an excellent, fair-minded manager of employees. She also enjoyed very good relations with many in the AMS volunteer leadership, especially through her work with committees overseeing AMS meetings and conferences.

At its meeting in May 1999 the AMS Executive Committee and Board of Trustees passed the following resolution:

“Be it resolved that the Board of Trustees of the American Mathematical Society accept the retirement of H. Hope Daly with deep appreciation for her long record of faithful service.

“For more than 30 years Hope Daly has served the Society, and for almost a quarter century she has led one of the finest meetings departments in the world. To many members who regularly attend meetings, Hope is the face of the AMS. In that way, she has admirably represented the best dedication and devotion of all staff, thereby enabling the AMS to effectively serve its members and the greater mathematical community.

“The Trustees offer Hope their special thanks and heartfelt good wishes for a happy and well-deserved retirement.”

While Daly won accolades for her hard-working, serious side, it is her humor and good cheer that most endear her



H. Hope Daly

to staff and members alike. Her lively presence will be missed.

—Allyn Jackson

Update on Data Disclosure Law

In August 1999 the Office of Management and Budget (OMB) issued a revision of a controversial set of rules pertaining to the availability of federally funded research data. The OMB prepared the revision after receiving a large number of complaints about the set of rules, known as Circular A-110. The deadline for comments on the revision was September 10, 1999, and at the time of this writing the final version was to be issued on September 30, 1999, to go into effect with the start of the new fiscal year on October 1.

The controversy began with an amendment that had been inserted into a spending bill passed in October 1998. The amendment directed OMB to require federal agencies to make available, upon request, data from the research they fund; requests were to follow the procedures of the Freedom of Information Act (FOIA). The scientific community has been concerned about the amendment because it could potentially require scientists to provide raw research data that has not been checked or analyzed or to divulge medical records of human subjects of research. The law could also be interpreted to apply to manuscripts of research articles, e-mail correspondence, computer programs, or other material generated during the process of scientific research. Concerns have also been raised about patent rights and potential abuse by companies seeking to weaken federal regulations that are based on research data.

After members of the scientific community objected, OMB revised Circular A-110 in an attempt to take into account the concerns raised. That version was circulated for comment in February 1999 and generated over 9,000 responses. According to *FYI*, the electronic bulletin of science policy news of the American Institute of Physics, approximately 55 percent of the comments supported the proposed revision and 37 percent opposed it. During the commentary period some attempts were made to introduce new legislation that would either eliminate the law or delay its going into effect for a year, so that the issues could be studied further. At the time of this writing, none of these attempts had succeeded.

The February 1999 revision of Circular A-110 stated that “research findings used by the Federal Government in developing policy or rules” must be made available to the public under FOIA. The revision issued in August 1999 replaces “developing policy or rules” with “developing a regulation”. In addition, the new version attempts to define more clearly terms that appear in Circular A-110, including “research data” and “published”. The revision specifically says that “data” does not include “preliminary analyses, drafts of scientific papers, plans for future research, peer reviews, or communications with colleagues.” Physical objects, medical records, or information that may be

copyrighted or patented are also excluded. Research findings are considered to be “published” “either when (A) research findings are published in a peer-reviewed scientific or technical journal, or (B) a Federal agency publicly and officially cites to [sic] the research findings in support of” an agency action. In addition to calling for comments on these changes, OMB also wants feedback on whether or not the purview of Circular A-110 should be limited to federal regulations that reach what OMB calls “a \$100 million impact threshold.”

At its meeting in March 1999 the AMS Committee on Science Policy (CSP) discussed the revision of Circular A-110 with Kathleen Peroff, deputy associate director of the Energy and Science Division of OMB, and with Arthur Bienenstock, associate director for science of the Office of Science and Technology Policy. Subsequently CSP chair Arthur Jaffe, on behalf of the committee, sent a letter to OMB requesting that any policy for sharing data be established after a study by the National Academy of Sciences.

For further information on Circular A-110, see the article “Scientists weigh in against data disclosure law”, *Notices*, June/July 1999, pages 690–691; the government affairs page on the AMS Web site <http://www.ams.org/government/>; and the OMB Web site <http://www.whitehouse.gov/OMB/fedreg/2ndnotice-a110.html>.

—Allyn Jackson

Millenium Mathematics Project

The Millenium Mathematics Project (MMP) is a new national effort in the United Kingdom that seeks to change public attitudes about mathematics and to improve mathematics instruction. Based at the University of Cambridge, the MMP will be located in the new Centre for Mathematical Sciences, due to open in January 2000.

“For more than three centuries, British mathematicians have had a profound influence on the world’s cultural, scientific and technological development,” states the MMP Web site. “Today, however, mathematics in the UK, as in much of the developed world, is in trouble.” Mathematics is often poorly taught in the schools and is generally seen as a useless and boring subject. “Mathematics has become the ugly duckling of science,” the Web site continues, “surviving on low budgets, given low priority, mistrusted and marginalised by those who cannot understand it, viewed as a dead subject when the level of activity and the importance of new discoveries have never been higher.”

To address these problems, the MMP will work on a variety of fronts. In the educational arena, the MMP aims to improve mathematics education by offering enrichment activities for schoolchildren and resources for mathematics teachers. The MMP is targeting the general public through exhibitions that highlight new developments in mathematics and its connections to scientific and technological developments and to the broader cultural scene. To optimize the accuracy of coverage of mathematics in the press, the MMP will provide materials for media organizations and journalists. There are also plans to develop a national

resource center for written and other materials about mathematics, a database of experts willing to speak on mathematics, and news about events and resources about mathematics across the UK.

The MMP builds on a number of existing Cambridge-based projects that have aimed to increase public understanding and appreciation of mathematics and to improve the teaching of the subject. For example, the University of Cambridge mathematics faculty and colleges provide short summer colloquia for school teachers, open days, popular mathematics lectures, and school teacher fellowships. An international program called NRIC (<http://www.nrich.maths.org.uk/>), a partnership between the University of Cambridge and the Royal Institution, introduces schoolchildren to mathematical topics and ideas outside the range of the traditional mathematics classroom. PASS Maths (<http://www.pass.maths.org.uk/>) is a complementary online magazine that carries stories about new developments in mathematics and about the history of mathematics and science, interviews with mathematicians, information about degree courses, mathematical biographies, and links to other mathematics Web sites and resources.

The director of the MMP is the noted cosmologist and mathematical physicist John D. Barrow. In July 1999 he left the University of Sussex to take up a position as Research Professor of Mathematical Sciences at the University of Cambridge. Barrow is well known among the general public for his popular books on physics, such as *Impossibility: The Limits of Science and the Science of Limits* (Oxford University Press, 1998, ISBN 0-198-51890-0). Another member of the MMP project is David Crighton, head of the Department of Applied Mathematics and Theoretical Physics at Cambridge. Crighton headed the POP Maths Roadshow, which ran in 1989 and visited twenty cities, attracting between 5,000 and 10,000 visitors at each venue. Also involved in MMP are Peter Goddard, professor of theoretical physics and founding co-director of the Isaac Newton Institute; Robert Hunt, lecturer in the Department of Applied Mathematics and Theoretical Physics; and Peter Landshoff, professor of mathematical physics. Funding for the MMP comes from a variety of sources, including Unilever PLC, Ford Motor Company, Microsoft Corporation, Cambridge University Press, the University of Cambridge Local Examinations Syndicate, the Rothschild Trust, and the National Endowment for Science, Technology, and the Arts.

Further information about the MMP may be found at the Web site <http://www.mmp.maths.org.uk/> or by writing to the administrator, Julia Hawkins, at jemh4@damtp.cam.ac.uk.

—Allyn Jackson

Staff Changes at CSMEE

The Center for Science, Mathematics, and Engineering Education (CSMEE) at the National Research Council (NRC) has announced some staffing changes. Responsibilities for mathematics education within the center will be distributed

among the following mathematics staff members: Jane Swafford, Gail Burrill, James Gates, and Brad Findell. Jane Swafford (Illinois State University) is director of the Division on Mathematics and Teacher Education, which is responsible for overseeing mathematics-related activities within the center. Gail Burrill, past president of the National Council of Teachers of Mathematics (NCTM), now serves as director of the Mathematical Sciences Education Board (MSEB), and James Gates, former executive director of NCTM, continues in his role of associate director of MSEB.

On June 1, 1999, Joan Ferrini-Mundy, associate executive director of the center and director of the Mathematical Sciences Education Board, left the NRC to accept a position as Associate Dean for Science and Mathematics Education and Outreach and director of the Division of Science and Mathematics Education in the College of Natural Science at Michigan State University. She will continue to be engaged in her role as chair of the NCTM Standards 2000 Writing Group.

In addition, Rodger Bybee, executive director of the center, has accepted the position of executive director of the Biological Sciences Curriculum Study (BSCS). Suzanne Woolsey, the NRC's chief operating officer, is serving as acting executive director for the center while the search continues for a new executive director.

—CSMEE announcement

UK Symposia Web Site

The Isaac Newton Institute for Mathematical Sciences in Cambridge, England, has set up a new Web site that will be a central point for information about mathematics sciences symposia in the United Kingdom, including conferences, workshops, instructional courses, one-day meetings, and longer research programs. The URL for the Web site is <http://www.newton.cam.ac.uk/symposia.html>.

The site has been set up in cooperation with the London Mathematical Society (LMS), the International Centre for Mathematical Sciences in Edinburgh, the Mathematics Research Centre in Warwick, the Institute for Mathematics and Its Applications in Essex, and the Royal Statistical Society.

—From LMS announcement

Reference and Book List

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.

Contacting the Notices

The preferred method for contacting the Notices is electronic mail. The editor is the person to whom to send articles and letters for consideration. Articles include feature articles, memorial articles, book reviews and other communications, columns for "Another Opinion", and "Forum" pieces. The editor is also the person to whom to send news of unusual interest about mathematics research.

The managing editor is the person to whom to send items for "Mathematics People", "Mathematics Opportunities", "For Your Information", "Reference and Book List", and "Mathematics Calendar". Requests for permissions, as well as all other inquiries, go to the managing editor.

The electronic-mail addresses are notices@math.sunysb.edu in the case of the editor and notices@ams.org in the case of the managing editor. The fax numbers are 516-751-5730 for the editor and 401-331-3842 for the managing editor. Postal addresses may be found in the masthead.

Upcoming Deadlines

November 1, 1999: Deadline for applications for the Fulbright Scholar

Program international education and academic administrator seminars. For more information contact the USIA Fulbright Scholar Program, Council for International Exchange of Scholars, 3007 Tilden Street, NW, Suite 5L, Box GNEWS, Washington, DC 20008-3009; telephone: 202-686-7877; World Wide Web: <http://www.cies.org/>.

November 1, 1999: Deadline for applications for travel grants to ICME-9. Further information on application and selection criteria are available from the NCTM, Department E, 1906 Association Drive, Reston, VA 20191-1593 (telephone: 703-620-9840, extension 2112); or from the NCTM Web site at <http://www.nctm.org/icme9/>.

December 1, 1999: Deadline for applications for American Mathematical Society Centennial Fellowships. For more information and application

forms, write to the Executive Director, American Mathematical Society, P.O. Box 6248, Providence, RI 02940-6248; or send electronic mail to ams@ams.org; or call 401-455-4106. Application forms are also available via the Internet at <http://www.ams.org/employment/>.

December 15, 1999: Deadline for applications for support for summer 2000 programs for the AMS Epsilon Program. For details see "Mathematics Opportunities" in this issue.

January 1, 2000: Deadline for applications for the Fulbright Scholar Program NATO advanced research fellowships and institutional grants. For more information contact the USIA Fulbright Scholar Program, Council for International Exchange of Scholars, 3007 Tilden Street, NW, Suite 5L, Box GNEWS, Washington, DC 20008-3009;

Where to Find It

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

AMS e-mail addresses
November 1999, p. 1267

AMS Ethical Guidelines
June 1995, p. 694

AMS officers and committee members, *November 1999, p. 1269*

Board on Mathematical Sciences and Staff
April 1999, p. 479; June/July 1999, p. 696

Bylaws of the American Mathematical Society
November 1999, p. 1250

Mathematics Research Institutes contact information

May 1999, p. 580; August 1999, p. 804

National Science Board
March 1999, p. 361

NSF Mathematical and Physical Sciences Advisory Committee
March 1999, p. 362

Officers of the Society 1997 and 1998 (Council, Executive Committee, Publications Committees, Board of Trustees)
May 1999, p. 583

Program officers for federal funding agencies (DoD, DoE, NSF)
October 1999, p. 1075, November 1999, p. 1247

telephone: 202-686-7877; World Wide Web: <http://www.cies.org/>.

January 14, 2000: Deadline for applications for the 2000-01 "Mathematics in Multimedia" program of the IMA. For details, see the IMA's Web site at <http://www.ima.umn.edu/programs.html> or contact the Institute for Mathematics and its Applications, University of Minnesota, 400 Lind Hall, 207 Church Street, Minneapolis, MN 55455; telephone: 612-624-6066; e-mail to Fred Dulles, Associate Program Director, at dulles@ima.umn.edu.

January 15, 2000: Deadline for applications for NIST/NRC Postdoctoral Research Associateships Program. Further information may be obtained from the NIST Web site, <http://www.nist.gov/oiaa/postdoc.htm>; or by contacting Joy Brooks, Information Specialist, NIST, telephone: 301-975-3071; or Jack J. Hsia, Chief of Academic Affairs, NIST, telephone: 301-975-3067; or write to the National Research Council, Associateship Programs-TJ2114, 2101 Constitution Avenue, NW, Washington, DC 20418; telephone: 202-334-2760.

January 31, 2000: Deadline for applications for travel grant support for the special meeting Mathematical Challenges of the 21st Century, August 7-12, 2000, in Los Angeles. For details see "Mathematics Opportunities" in this issue.

February 1, 2000: Deadline for applications for NSF/AWM Mentoring Travel Grants for Women. Further information may be obtained by telephone at 301-405-7892; or by e-mail at awm@math.umd.edu.

February 1, 2000: Deadline for applications for NSF/AWM Travel Grants for Women. For further information and details on applying, see the AWM Web site, <http://www.awm-math.org/travelgrants.html>; or telephone 301-405-7892; or send e-mail to awm@math.umd.edu.

February 15, 2000: Deadline for nominations for the Richard C. DiPrima Prize. For details see "Mathematics Opportunities" in this issue.

NSF Division of Mathematical Sciences

Listed below are names, e-mail addresses, and telephone numbers for

the program directors for the coming academic year in the Division of Mathematical Sciences of the National Science Foundation.

Algebra and Number Theory

Joseph Brennan
703-306-1884
jbrennan@nsf.gov

Robert Perlis
703-306-1876
rperlis@nsf.gov

Andrew Pollington
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apolling@nsf.gov

Analysis Program
Joe Jenkins
703-306-1879
jjenkins@nsf.gov

Dmitry Khavinson
703-306-1994
dkhavins@nsf.gov

Peter Polyakov
703-306-1992
ppolyako@nsf.gov

Applied Mathematics
Hans Engler
703-306-1870
hengler@nsf.gov

Deborah F. Lockhart
703-306-1882
dlockhar@nsf.gov

Jong-Shi Pang
703-306-1877
jpang@nsf.gov

Henry Warchall
703-306-0565, ext. 1977
hwarchal@nsf.gov

Computational Mathematics
Michael Steuerwalt
703-306-1878
msteuer@nsf.gov

Infrastructure Program
Lloyd Douglas
703-306-1874
ldouglas@nsf.gov

Alvin Thaler
703-306-1880
thaler@nsf.gov

Statistics and Probability
Keith Crank
703-306-1885
kcrank@nsf.gov

William Smith
703-306-0565, ext. 1959
wbsmith@nsf.gov

James L. Rosenberger
703-306-1883
jrosenbe@nsf.gov

Topology and Foundations
Ralph Krause
703-306-1886
rkrause@nsf.gov

Benjamin Mann
703-306-1886
bmenn@nsf.gov

Gerard Venema
703-306-1887
gvenema@nsf.gov

Geometric Analysis
Benjamin Mann
703-306-1886
bmenn@nsf.gov

Christopher Stark
703-306-1881
cstark@nsf.gov

The administrative staff includes:

Division Director
Phillipe Tondeur
703-306-1871
ptondeur@nsf.gov

Executive Officer
Bernard R. McDonald
703-306-1870
bmcdonal@nsf.gov

Administrative Officer
Tyzcer L. Henson
703-306-1873
thenson@nsf.gov

The mailing address is: Division of Mathematical Sciences, National Science Foundation, Room 1025, 4201

Wilson Boulevard, Arlington, VA 22230; telephone: 703-306-1870. The address for the Division's World Wide Web server is <http://www.nsf.gov/mps/dms/>.

NSF Mathematics Education Staff

The Directorate for Education and Human Resources (EHR) of the National Science Foundation (NSF) sponsors a range of programs that support educational projects in mathematics, science, and engineering. Listed below are the names, telephone numbers, and e-mail addresses of those EHR program officers whose field is in the mathematical sciences or mathematics education. These individuals can provide information about the programs they oversee, as well as information about other EHR programs of interest to mathematicians. The mailing address is: Directorate for Education and Human Resources, National Science Foundation, 4201 Wilson Boulevard, Arlington, VA 22230. The World Wide Web address is <http://www.nsf.gov/ehr/>.

Division of Elementary, Secondary, and Informal Education

Teacher Enhancement Program
Virginia Horak
703-306-1620
vhorak@nsf.gov

Diane Spresser
703-306-1620
dspresser@nsf.gov

Anna Suarez
703-306-1620
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Instructional Materials Development Program

John (Spud) Bradley, Section Head
703-306-1620
jbradley@nsf.gov

George Bright
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Division of Research, Evaluation, and Dissemination

Eric Hamilton, Acting Division Director
703-306-1650
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Division of Undergraduate Education

James Lightbourne
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Division of Human Resource Development

Jesse C. Lewis
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jlewis@nsf.gov

Book List

The Book List highlights books that have mathematical themes and hold appeal for a wide audience, including mathematicians, students, and a significant portion of the general public. When a book has been reviewed in the Notices, a reference is given to the review. Generally the list will contain only books published within the last two years, though exceptions may be made in cases where current events (e.g., the death of a prominent mathematician, coverage of a certain piece of mathematics in the news) warrant drawing readers' attention to older books. Suggestions for books to include on the list may be sent to the Managing Editor, e-mail: notices@ams.org.

Abraham Robinson: The Creation of Nonstandard Analysis, a Personal and Mathematical Odyssey, by Joseph Warren Dauben. Princeton University Press, 1998. ISBN 0-691-05911-X.

The Algorithmic Beauty of Sea Shells (Virtual Laboratory), by Hans Meinhardt, Przemyslaw Prusinkiewicz, and Deborah R. Fowler. Springer-Verlag, 1998. ISBN 3-540-63919-5.

The Applicability of Mathematics as a Philosophical Problem, by Mark Steiner. Harvard University Press, 1998. ISBN 0-674-04097-X.

Challenges, by Serge Lang. Springer-Verlag, 1998. ISBN 0-387-94861-9.

Cryptonomicon, by Neal Stephenson. Avon Books, 1999. ISBN 0-38097-346-4.

Drawbridge Up: Mathematics—A Cultural Anathema (Zugbrücke ausser Betrieb: Die Mathematik im Jenseits der Kultur), by Hans Magnus Enzensberger. A K Peters, 1999. ISBN 1-56881-099-7.

e: The Story of a Number, by Eli Maor. Paperback edition, Princeton University Press, 1998. ISBN 0-691-05854-7.

The Elegant Universe: Superstrings, Hidden Dimensions, and the Quest for the Ultimate Theory, by Brian Greene. W. W. Norton & Company, February 1999. ISBN 0-393-04688-5.

Emergence: From Chaos to Order, by John Holland. Perseus Press, 1998. ISBN 0-201-14943-5.

Euclid: The Creation of Mathematics, by Benno Artmann. Springer-Verlag, 1999. ISBN 0-387-98423-2.

Fermat's Last Theorem for Amateurs, by Paulo Ribenboim. Springer-Verlag, 1999. ISBN 0-387-98508-5.

The Feynman Processor, by Gerard J. Milburn and Paul Davies. Helix Books, Perseus, 1998. ISBN 0-738-20016-6.

Fragile Dominion: Complexity and the Commons, by Simon Levin. Perseus Books, June 1999. ISBN 0-738-20111-1.

Geometry Civilized: History, Culture, and Technique, by J. L. Heilbron, Oxford University Press, 1998. ISBN 0-198-50078-5.

Goodbye, Descartes: The End of Logic and the Search for a New Cosmology of the Mind, by Keith Devlin. John Wiley & Sons, 1998. ISBN 0-471-14216-6.

The Importance of Being Fuzzy and Other Insights from the Border Between Math and Computers, by Arturo Sangalli. Princeton University Press, December 1998. ISBN 0-691-00144-8.

An Imaginary Tale: The Story of $\sqrt{-1}$, by Paul J. Nahin. Princeton University Press, 1998. ISBN 0-691-02795-1. (Reviewed in this issue.)

In the Light of Logic, by Solomon Feferman. Oxford University Press, 1998. ISBN 0-195-08030-0.

The Invention of Infinity: Mathematics and Art in the Renaissance, by

J. V. Field. Oxford University Press, 1997. ISBN 0-198-52394-7.

Jacques Hadamard, A Universal Mathematician, by Vladimir Maz'ya and Tatyana Shaposhnikova. AMS/London Mathematical Society, 1998. ISBN 0-821-80841-9.

James Joseph Sylvester: Life and Work in Letters, by Karen Hunger Parshall. Oxford University Press, 1998. ISBN 0-198-50391-1.

The Jungles of Randomness: A Mathematical Safari, by Ivars Peterson. Paperback edition, John Wiley & Sons, 1998. ISBN 0-471-29587-6. (Reviewed June/July 1999.)

Knowing And Teaching Elementary Mathematics: Teachers' Understanding of Fundamental Mathematics in China and the United States, by Liping Ma. Lawrence Erlbaum Publishers, 1999. ISBN 0-8058-2908-3 (cloth), 0-8058-2909-1 (paper). (Reviewed September 1999.)

The Language of Mathematics: Making the Invisible Visible, by Keith Devlin. W. H. Freeman and Company, 1998. ISBN 0-716-73379-X.

Life by the Numbers, by Keith Devlin. John Wiley & Sons, 1998. ISBN 0-471-24044-3.

The Magical Maze: Seeing the World through Mathematical Eyes, by Ian Stewart. John Wiley & Sons, 1998. ISBN 0-471-19297-X.

The Mathemagician and the Pied Puzzler: A Collection in Tribute to Martin Gardner, edited by Elwyn Berlekamp and Tom Rodgers. A. K. Peters, 1999. ISBN 1-568-81075-X.

A Mathematical Mystery Tour: Discovering the Truth and Beauty of the Cosmos, by A. K. Dewdney. John Wiley & Sons, March 1999. ISBN 0-471-23847-3.

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Moral Calculations: Game Theory, Logic, and Human Frailty, by László Mészáros. Copernicus-Springer Verlag, 1998. ISBN 0-387-98419-4.

My Brain is Open: The Mathematical Journeys of Paul Erdős, by Bruce Schecter. Simon & Schuster, 1998. ISBN 0-684-84635-7.

Mystic, Geometer, and Intuitionist: The Life of L. E. J. Brouwer, by Dirk Van Dalen. Oxford University Press, 1999. ISBN 0-198-50297-4.

New Directions in the Philosophy of Mathematics: An Anthology, Thomas Tymoczko, Editor. Princeton University Press, revised edition, 1998. ISBN 0-691-03498-2.

Noeuds: Genèse d'une théorie mathématique (Knots: Genesis of a Mathematical Theory), by Alexsi Sossinsky (in French). Seuil, 1999. ISBN 2-020-32089-4.

The Number Devil, by Hans Magnus Enzensberger. Metropolitan Books, 1998. ISBN 0-805-05770-6.

The Number Sense: How the Mind Creates Mathematics, by Stanislas Dehaene. Oxford University Press, 1997. ISBN 0-195-11004-8.

Once Upon a Number: The Hidden Mathematical Logic of Stories, by John Allen Paulos. Basic Books, 1998. ISBN 0-465-05158-8. (Reviewed September 1999.)

Philosophy of Mathematics: An Introduction to a World of Proofs and Pictures, by James Robert Brown. Routledge, to appear 1999. ISBN 0-415-12274-0.

Pioneers of Representation Theory: Frobenius, Burnside, Schur, and

Brauer, by Charles W. Curtis. AMS/London Mathematical Society, 1999. ISBN 0-8218-9002-6.

Proofs from THE BOOK, by Martin Aigner and Günter Ziegler. Springer-Verlag, 1998. ISBN 3-540-63698-6. (Reviewed August 1999.)

The Queen of Mathematics: A Historically Motivated Guide to Number Theory, by Jay R. Goldman. A K Peters, 1998. ISBN 1-568-81006-7.

Randomness, Deborah Bennett. Harvard University Press, 1998. ISBN 0-674-10745-4.

Reasoning with the Infinite: From the Closed World to the Mathematical Universe, by Michel Blay. University of Chicago Press, 1998. ISBN 0-226-05834-4.

Shadows of the Circle: Conic Sections, Optimal Figures and Non-Euclidean Geometry, by Vagn Lundsgaard Hansen. World Scientific Publishing Company, November 1998. ISBN 9-810-23418-X.

Strength in Numbers, by Sherman Stein. John Wiley & Sons, 1996. ISBN 0-471-152528-8. (Reviewed May 1999.)

Tracking the Automatic Ant, and Other Mathematical Explorations, by David Gale. Springer-Verlag, 1998. ISBN 0-387-98272-8.

Turing and the Computer (The Big Idea), by Paul Strathern. Anchor Books, April 1999. ISBN 0-385-49243-X.

What Counts: How Every Brain Is Hardwired for Math, by Brian Butterworth. Free Press, August 1999. ISBN 0-684-85417-1.

What is Mathematics, Really?, by Reuben Hersh. Oxford University Press, 1997. ISBN 0-19-511368-3. (Reviewed October 1999.)

What's Happening in the Mathematical Sciences, 1998-1999, by Barry Cipra. AMS, 1999. ISBN 0-821-80766-8.

Why Do Buses Come In Threes?, by Rob Eastaway and Jeremy Wyndham. John Wiley & Sons, 1999. ISBN 0-471-34756-6.

The World According to Wavelets, by Barbara Burke Hubbard. A K Peters, second edition, 1999. ISBN 1-568-81072-5. (Reviewed October 1999.)

Backlog of Mathematics Research Journals (Updated)

The original article in the September 1999 issue of *Notices* listed the information incorrectly in the "Acceptance to Electronic Posting" and "Acceptance to Print" columns for the journals listed. The corrected information appears below.

1998 Median Time. This information is as reported by the editor of the journal.

Observed Waiting Time. The quartiles give a measure of normal dispersion. They do not include extremes which may be misleading. Waiting times are measured in months from receipt of manuscript in **final form** to receipt of the journal in Rhode Island.

* From acceptance to publication in print. Electronic publication will be less.

** From date accepted.

Journal (Print and Electronic)	Number issues per Year	Approximate Number Pages per Year	1998 Median Time (in Months) from:			Editor's Estimate of Waiting Time for Paper Submitted Currently to be Published (in Months)	Observed Waiting Time in Latest Published Issue (in Months)		
			Submission to Final Acceptance	Acceptance to Electronic Posting	Acceptance to Print		Q ₁	M	Q ₃
Indiana Univ. Math. J.	4	1500-1600	6	5	6	12	9	14	16
SIAM J. Appl. Math.	6	2300	8.6	13	16.7	15*	13	16**	20
SIAM J. Comput.	6	2300	18.4	21.8	25	15*	26	27**	27
SIAM J. Control Optim.	6	1980	12.6	9.4	12.8	12*	10	11**	14
SIAM J. Discrete Math.	4	600	20	9.6	12.4	6*	7	9**	14
SIAM J. Math. Anal.	6	1400	7.3	6	12.7	12*	11	11**	13
SIAM J. Matrix Anal. Appl.	4	1100	11.7	9.4	11.9	11*	13	15**	16
SIAM J. Numer. Anal.	6	1980	10.3	10.7	14.5	12*	11	12**	16
SIAM J. Optim.	4	1150	16	12	14	12*	12	14**	16
SIAM J. Sci. Comput.	6	2300	10.8	18	21	16*	20	21**	22

AMS CALL FOR MANUSCRIPTS

The AMS invites authors to submit manuscripts to be considered for publication in the **Student Mathematical Library**, a new series of undergraduate studies in mathematics. Books to be published in the series should be suitable for honors courses, upper-division seminars, reading courses, or self-study.

The following perspectives may serve as guidelines:

- Continuations from standard undergraduate courses: Topics may include coding theory, following on from number theory and/or algebra, Fourier series from analysis or ODEs, and elementary PDEs from analysis and ODEs, or others.
- Introducing students to topics covered in graduate school: Appropriate subjects may include for example, introductory differential geometry, minimal surfaces, introductory algebraic geometry, topics in representation theory, complex analysis, or probability.
- Covering topics outside the standard undergraduate curriculum: Such topics may include game theory, mathematical physics, mathematics of finance, mathematical biology, or others.

Manuscripts intended for submission should ideally contain problems either within the body of the text or at the end of each chapter or section. Connections to current research are encouraged. This could take the form of reports on recent results and/or lists of open problems of continuing interest.

For more information contact:

Sergei Gelfand, Director of Acquisitions (sxxg@ams.org) or Edward Dunne, Editor for the Book Program (egd@ams.org), at the American Mathematical Society, P. O. Box 6248, Providence, RI 02940-6248, U.S.A.; telephone 1-800-321-4267 (U.S. and Canada) or 1-401-455-4000 (worldwide); fax 1-401-331-3842.

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AMS

AMERICAN MATHEMATICAL SOCIETY

From the AMS

Bylaws of the American Mathematical Society

Article I

Officers

Section 1. There shall be a president, a president elect (during the even-numbered years only), an immediate past president (during the odd-numbered years only), three vice presidents, a secretary, four associate secretaries, a treasurer, and an associate treasurer.

Section 2. It shall be a duty of the president to deliver an address before the Society at the close of the term of office or within one year thereafter.

Article II

Board of Trustees

Section 1. There shall be a Board of Trustees consisting of eight trustees, five trustees elected by the Society in accordance with Article VII, together with the president, the treasurer, and the associate treasurer of the Society *ex officio*. The Board of Trustees shall designate its own presiding officer and secretary.

Section 2. The function of the Board of Trustees shall be to receive and administer the funds of the Society, to have full legal control of its investments and properties, to make contracts, and, in general, to conduct all business affairs of the Society.

Section 3. The Board of Trustees shall have the power to appoint such assistants and agents as may be necessary or convenient to facilitate the conduct of the affairs of the Society and to fix the terms and conditions of their employment. The Board may delegate to the officers of the Society duties and powers normally inhering in their respective corporate offices, subject to supervision by the Board. The Board of Trustees may appoint committees to facilitate the conduct of the financial business of the So-

ciety and delegate to such committees such powers as may be necessary or convenient for the proper exercise of those powers. Agents appointed, or members of committees designated, by the Board of Trustees need not be members of the Board.

Nothing herein contained shall be construed to empower the Board of Trustees to divest itself of responsibility for, or legal control of, the investments, properties, and contracts of the Society.

Article III

Committees

Section 1. There shall be eight editorial committees as follows: committees for the *Bulletin*, for the *Proceedings*, for the *Colloquium Publications*, for the *Journal*, for *Mathematical Surveys and Monographs*, for *Mathematical Reviews*; a joint committee for the *Transactions* and the *Memoirs*; and a committee for *Mathematics of Computation*.

Section 2. The size of each committee shall be determined by the Council.

Article IV

Council

Section 1. The Council shall consist of fifteen members at large and the following *ex officio* members: the officers of the Society specified in Article I, except that it shall include only one associate secretary, the chairman of each of the editorial committees specified in Article III, any former secretary for a period of two years following the terms of office, and members of the Executive Committee (Article V) who remain on the Council by the operation of Article VII, Section 4.

The chairman of any committee designated as a Council member may name a deputy from the committee as substitute. The associate secretary shall be the one charged with the scientific program of the meeting at which the Council meets except that at a meeting associated with no scientific meeting of the Society the secretary may designate the associate secretary.

Section 2. The Council shall formulate and administer the scientific policies of the Society and shall act in an advisory capacity to the Board of Trustees.

Section 3. In the absence of the secretary from any meeting of the Council, a member may be designated as acting secretary for the meeting, either by written authorization of the secretary, or, failing that, by the presiding officer.

Section 4. All members of the Council shall be voting members. Each member, including deputies and the designated associate secretary, shall have one vote. The method for settling matters before the Council at any meeting shall be by majority vote of the members present. If the result of a vote is challenged, it shall be the duty of the presiding officer to determine the true vote by a roll call. In a roll call vote, each Council member shall vote only once (although possibly a member of the Council in several capacities).

Section 5. Any five members of the Council shall constitute a quorum for the transaction of business at any meeting of the Council.

Section 6. Between meetings of the Council, business may be transacted by a mail vote. Votes shall be counted as specified in Section 4 of this Article, "members present" being replaced by "members voting". An affirmative vote by mail on any proposal shall be declared if, and only if, (a) more than half of the total number of possible votes is received by the time announced for the closing of the polls, and (b) at least three-quarters of the votes received by then are affirmative. If five or more members request postponement at the time of voting, action on the matter at issue shall be postponed until the next meeting of the Council, unless either (1) at the discretion of the secretary, the question is made the subject of a second vote by mail, in connection with which brief statements of reason, for and against, are circulated; or (2) the Council places the matter at issue before the Executive Committee for action.

Section 7. The Council may delegate to the Executive Committee certain of its duties and powers. Between meetings of the Council, the Executive Committee shall act for the Council on such matters and in such ways as the Council may specify. Nothing herein contained shall be construed as empowering the Council to divest itself of responsibility for formulating and administering the scientific policies of the Society.

Section 8. The Council shall also have power to speak in the name of the Society with respect to matters affecting the status of mathematics or mathematicians, such as proposed or enacted federal or state legislation; conditions of employment in universities, colleges, or business, research or industrial organizations; regulations, policies, or acts of governmental agencies or instrumentalities; and other items which tend to affect the dignity and effective position of mathematics.

With the exception noted in the next paragraph, a favorable vote of two-thirds of the entire membership of the Council shall be necessary to authorize any statement in the name of the Society with respect to such matters. With the exception noted in the next paragraph, such a vote may be taken only if written notice shall have been given to the

secretary by the proposer of any such resolution not later than one month prior to the Council meeting at which the matter is to be presented, and the vote shall be taken not earlier than one month after the resolution has been discussed by the Council.

If, at a meeting of the Council, there are present twelve members, then the prior notification to the secretary may be waived by unanimous consent. In such a case, a unanimous favorable vote by those present shall empower the Council to speak in the name of the Society.

The Council may also refer the matter to a referendum by mail of the entire membership of the Society and shall make such reference if a referendum is requested, prior to final action by the Council, by two hundred or more members. The taking of a referendum shall act as a stay upon Council action until the votes have been canvassed, and thereafter no action may be taken by the Council except in accordance with a plurality of the votes cast in the referendum.

Article V

Executive Committee

Section 1. There shall be an Executive Committee of the Council, consisting of four elected members and the following *ex officio* members: the president, the secretary, the president elect (during even-numbered years), and the immediate past president (during odd-numbered years).

Section 2. The Executive Committee of the Council shall be empowered to act for the Council on matters which have been delegated to the Executive Committee by the Council. If three members of the Executive Committee request that any matter be referred to the Council, the matter shall be so referred. The Executive Committee shall be responsible to the Council and shall report its actions to the Council. It may consider the agenda for meetings of the Council and may make recommendations to the Council.

Section 3. Each member of the Executive Committee shall have one vote. An affirmative vote on any proposal before the Executive Committee shall be declared if, and only if, at least four affirmative votes are cast for the proposal. A vote on any proposal may be determined at a meeting of the Executive Committee, but it shall not be necessary to hold a meeting to determine a vote.

Article VI

Executive Director

Section 1. There shall be an Executive Director who shall be a paid employee of the Society. The Executive Director shall have charge of the offices of the Society, except for the office of the secretary, and shall be responsible for the general administration of the affairs of the Society in accordance with the policies that are set by the Board of Trustees and by the Council.

Section 2. The Executive Director shall be appointed by the Board of Trustees with the consent of the Council. The terms and conditions of employment shall be fixed by the Board of Trustees, and the performance of the Executive Director will be reviewed regularly by the Board of Trustees.

Section 3. The Executive Director shall be responsible to and shall consult regularly with a liaison committee consisting of the president as chair, the secretary, the treasurer, and the chair of the Board of Trustees.

Section 4. The Executive Director shall attend meetings of the Board of Trustees, the Council, and the Executive Committee, but shall not be a member of any of these bodies.

Article VII

Election of Officers and Terms of Office

Section 1. The term of office shall be one year in the case of the president elect and the immediate past president; two years in the case of the president, the secretary, the associate secretaries, the treasurer, and the associate treasurer; three years in the case of vice presidents and members at large of the Council, one vice president and five members at large retiring annually; and five years in the case of the trustees. In the case of members of the editorial committees and appointed members of the communications committees, the term of office shall be determined by the Council. The term of office for elected members of the Executive Committee shall be four years, one of the elected members retiring annually. All terms of office shall begin on February 1 and terminate on January 31, with the exception that the officials specified in Articles I, II, III, IV, and V (excepting the president elect and immediate past president) shall continue to serve until their successors have been duly elected or appointed and qualified.

Section 2. The president elect, the vice presidents, the trustees, and the members at large of the Council shall be elected by written ballot. An official ballot shall be sent to each member of the Society by the secretary on or before October 10, and such ballots, if returned to the secretary in envelopes bearing the name of the voter and received within thirty days, shall be counted. Each ballot shall contain one or more names proposed by the Council for each office to be filled, with blank spaces in which the voter may substitute other names. A plurality of all votes cast shall be necessary for election. In case of failure to secure a plurality for any office, the Council shall choose by written ballot among the members having the highest number of votes. The secretary, the associate secretaries, the treasurer, and the associate treasurer shall be appointed by the Council in a manner designated by the Council. Each committee named in Article III shall be appointed by the Council in a manner designated by the Council. Each such committee shall elect one of its members as chairman in a manner designated by the Council.

Section 3. The president becomes immediate past president at the end of the term of office and the president elect becomes president.

Section 4. On or before February 15, the secretary shall send to all members of the Council for a mail vote a ballot containing two names for each place to be filled on the Executive Committee. The nominees shall be chosen by a committee appointed by the president. Members of the Council may vote for persons not nominated. Any member of the Council who is not an *ex officio* member of the Executive Committee (see Article V, Section 1) shall be el-

igible for election to the Executive Committee. In case a member is elected to the Executive Committee for a term extending beyond the regular term on the Council, that person shall automatically continue as a member of the Council during the remainder of that term on the Executive Committee.

Section 5. The president and vice presidents shall not be eligible for immediate re-election to their respective offices. A member at large or an *ex officio* member of the Council shall not be eligible for immediate election (or re-election) as a member at large of the Council.

Section 6. If the president of the Society should die or resign while a president elect is in office, the president elect shall serve as president for the remainder of the year and thereafter shall serve the regular two-year term. If the president of the Society should die or resign when no president elect is in office, the Council, with the approval of the Board of Trustees, shall designate one of the vice presidents to serve as president for the balance of the regular presidential term. If the president elect of the Society should die or resign before becoming president, the office shall remain vacant until the next regular election of a president elect, and the Society shall, at the next annual meeting, elect a president for a two-year term. If the immediate past president should die or resign before expiration of the term of office, the Council, with the approval of the Board of Trustees, shall designate a former president of the Society to serve as immediate past president during the remainder of the regular term of the immediate past president. Such vacancies as may occur at any time in the group consisting of the vice presidents, the secretary, the associate secretaries, the treasurer, and the associate treasurer shall be filled by the Council with the approval of the Board of Trustees. If a member of an editorial or communications committee should take temporary leave from duties, the Council shall then appoint a substitute. The Council shall fill from its own membership any vacancy in the elected membership of the Executive Committee.

Section 7. If any elected trustee should die while in office or resign, the vacancy thus created shall be filled for the unexpired term by the Board of Trustees.

Section 8. If any member at large of the Council should die or resign more than one year before the expiration of the term, the vacancy for the unexpired term shall be filled by the Society at the next annual meeting.

Section 9. In case any officer should die or decline to serve between the time of election and the time to assume office, the vacancy shall be filled in the same manner as if that officer had served one day of the term.

Article VIII

Members and Their Election

Section 1. Election of members shall be by vote of the Council or of its Executive Committee.

Section 2. There shall be four classes of members, namely, ordinary, contributing, corporate, and institutional.

Section 3. Application for admission to ordinary membership shall be made by the applicant on a blank provided by the secretary. Such applications shall not be acted upon

until at least thirty days after their presentation to the Council (at a meeting or by mail), except in the case of members of other societies entering under special action of the Council approved by the Board of Trustees.

Section 4. An ordinary member may become a contributing member by paying the dues for such membership. (See Article IX, Section 3.)

Section 5. A university or college, or a firm, corporation, or association interested in the support of mathematics may be elected a corporate or an institutional member.

Article IX

Dues and Privileges of Members

Section 1. Any applicant shall be admitted to ordinary membership immediately upon election by the Council (Article VIII) and the discharge within sixty days of election of the first annual dues. Dues may be discharged by payment or by remission when the provision of Section 7 of this Article is applicable. The first annual dues shall apply to the year of election, except that any applicant elected after August 15 of any year may elect to have the first annual dues apply to the following year.

Section 2. The annual dues of an ordinary member of the Society shall be established by the Council with the approval of the Trustees. The Council, with the approval of the Trustees, may establish special rates in exceptional cases and for members of an organization with which the Society has a reciprocity agreement.

Section 3. The minimum dues for a contributing member shall be three-halves of the dues of an ordinary member per year. Members may, upon their own initiative, pay larger dues.

Section 4. The minimum dues of an institutional member shall depend on the scholarly activity of that member. The formula for computing these dues shall be established from time to time by the Council, subject to approval by the Board of Trustees. Institutions may pay larger dues than the computed minimum.

Section 5. The privileges of an institutional member shall depend on its dues in a manner to be determined by the Council, subject to approval by the Board of Trustees. These privileges shall be in terms of Society publications to be received by the institution and of the number of persons it may nominate for ordinary membership in the Society.

Section 6. Dues and privileges of corporate members of the Society shall be established by the Council subject to approval by the Board of Trustees.

Section 7. The dues of an ordinary member of the Society shall be remitted for any years during which that member is the nominee of an institutional member.

Section 8. After retirement from active service on account of age or on account of long-term disability, any ordinary or contributing member who is not in arrears of dues and with membership extending over at least twenty years may, by giving proper notification to the secretary, have dues remitted. Such a member shall receive the *Notices* and may request to receive *Bulletin* as privileges of membership during each year until membership ends.

Section 9. An ordinary or contributing member shall receive the *Notices* and *Bulletin* as privileges of membership during each year for which dues have been discharged.

Section 10. The annual dues of ordinary, contributing, and corporate members shall be due by January 1 of the year to which they apply. The Society shall submit bills for dues. If the annual dues of any member remain undischarged beyond what the Board of Trustees deems to be a reasonable time, the name of that member shall be removed from the list of members after due notice. A member wishing to discontinue membership at any time shall submit a resignation in writing to the Society.

Section 11. Any person who has attained the age of 62 and has been a member for at least twenty years may become a life member by making a single payment equal to five times the dues of an ordinary member for the coming year. Insofar as there is more than one level of dues for ordinary membership, it is the highest such dues that shall be used in the calculation, with the exception for members by reciprocity noted in the following paragraph. A life member is subsequently relieved of the obligation of paying dues. The status and privileges are those of ordinary members.

A member of the Society by reciprocity who has reached the age of 62, has been a member for at least 20 years, has been a member by reciprocity for at least 15 of those 20 years and asserts the intention of continuing to be a member by reciprocity may purchase a life membership by a one-time payment of a special rate established by the Council, with the approval of the Trustees.

Article X

Meetings

Section 1. The annual meeting of the Society shall be held between the fifteenth of December and the tenth of February next following. Notice of the time and place of this meeting shall be mailed by the secretary or an associate secretary to the last known post office address of each member of the Society. The times and places of the annual and other meetings of the Society shall be designated by the Council.

Section 2. There shall be a business meeting of the Society only at the annual meeting. The agenda for the business meeting shall be determined by the Council. A business meeting of the Society can take action only on items notified to the full membership of the Society in the call for the meeting. A business meeting can act on items recommended to it jointly by the Council and the Board of Trustees; a majority of members present and voting is required for passage of such an item. A business meeting of the Society can place action items on the agenda for a future business meeting. Final action on an item proposed by a previous business meeting can be taken only provided there is a quorum of 400 members, a majority of members at a business meeting with a quorum being required for passage of such an item.

Section 3. Meetings of the Executive Committee may be called by the president. The president shall call a meeting at any time upon the written request of two of its members.

Section 4. The Council shall meet at the annual meeting of the Society. Special meetings of the Council may be called by the president. The president shall call a special meeting at any time upon the written request of five of its members. No special meeting of the Council shall be held unless written notice of it shall have been sent to all members of the Council at least ten days before the day set for the meeting.

Section 5. The Board of Trustees shall hold at least one meeting in each calendar year. Meetings of the Board of Trustees may be called by the president, the treasurer, or the secretary of the Society upon three days' notice of such meetings mailed to the last known post office address of each trustee. The secretary of the Society shall call a meeting upon the receipt of a written request of two of the trustees. Meetings may also be held by common consent of all the trustees.

Section 6. Papers intended for presentation at any meeting of the Society shall be passed upon in advance by a program committee appointed by or under the authority of the Council, and only such papers shall be presented as shall have been approved by such committee. Papers in form unsuitable for publication, if accepted for presentation, shall be referred to on the program as preliminary communications or reports.

Article XI

Publications

Section 1. The Society shall publish an official organ called the *Bulletin of the American Mathematical Society*. It shall publish four journals, known as the *Journal of the American Mathematical Society*, the *Transactions of the American Mathematical Society*, the *Proceedings of the American Mathematical Society*, and *Mathematics of Computation*. It shall publish a series of mathematical papers known as the *Memoirs of the American Mathematical Society*. The object of the *Journal*, *Transactions*, *Proceedings*, *Memoirs*, and *Mathematics of Computation* is to make known important mathematical researches. It shall publish a periodical called *Mathematical Reviews*, containing abstracts or reviews of current mathematical literature. It shall publish a series of volumes called *Colloquium Publications* which shall embody in book form new mathematical developments. It shall publish a series of monographs called *Mathematical Surveys and Monographs* which shall furnish expositions of the principal methods and results of particular fields of mathematical research. It shall publish a news periodical known as the *Notices of the American Mathematical Society*, containing programs of meetings, items of news of particular interest to mathematicians, and such other materials as the Council may direct.

Section 2. The editorial management of the publications of the Society listed in Section 1 of this article, with the exception of the *Notices*, shall be in the charge of the respective editorial committees as provided in Article III, Section 1. The editorial management of the *Notices* shall be in the hands of a committee chosen in a manner established by the Council.

Article XII

Indemnification

Any person who at any time serves or has served as a trustee or officer of the Society, or as a member of the Council, or, at the request of the Society, as a director or officer of another corporation, whether for profit or not for profit, shall be indemnified by the Society and be reimbursed against and for expenses actually and necessarily incurred in connection with the defense or reasonable settlement of any action, suit, legal or administrative proceeding, whether civil, criminal, administrative or investigative, threatened, pending or completed, to which that person is made a party by reason of being or having been such trustee, officer or director or Council member, except in relation to matters as to which the person shall be adjudged in such action, suit, or proceeding to be liable for negligence or misconduct in the performance of official duties. Such right of indemnification and reimbursement shall also extend to the personal representatives of any such person and shall be in addition to and not in substitution for any other rights to which such person or personal representatives may now or hereafter be entitled by virtue of the provisions of applicable law or of any other agreement or vote of the Board of Trustees, or otherwise.

Article XIII

Amendments

These bylaws may be amended or suspended on recommendation of the Council and with the approval of the membership of the Society, the approval consisting of an affirmative vote by two-thirds of the members present at a business meeting or of two-thirds of the members voting in a mail ballot in which at least ten percent of the members vote, whichever alternative shall have been designated by the Council, and provided notice of the proposed action and of its general nature shall have been given in the call for the meeting or accompanies the ballot in full.

As amended December 1998

AMS Lecturers, Officers, Prizes, and Funds

Colloquium Lecturers

James Pierpont, 1896
 Maxime Bôcher, 1896
 W. F. Osgood, 1898
 A. G. Webster, 1898
 Oskar Bolza, 1901
 E. W. Brown, 1901
 H. S. White, 1903
 F. S. Woods, 1903
 E. B. Van Vleck, 1903
 E. H. Moore, 1906
 E. J. Wilczynski, 1906
 Max Mason, 1906
 G. A. Bliss, 1909
 Edward Kasner, 1909
 L. E. Dickson, 1913
 W. F. Osgood, 1913
 G. C. Evans, 1916
 Oswald Veblen, 1916
 G. D. Birkhoff, 1920
 F. R. Moulton, 1920
 L. P. Eisenhart, 1925
 Dunham Jackson, 1925
 E. T. Bell, 1927
 Anna Pell-Wheeler, 1927
 A. B. Coble, 1928
 R. L. Moore, 1929
 Solomon Lefschetz, 1930
 Marston Morse, 1931
 J. F. Ritt, 1932
 R. E. A. C. Paley, 1934
 Norbert Wiener, 1934
 H. S. Vandiver, 1935
 E. W. Chittenden, 1936
 John von Neumann, 1937
 A. A. Albert, 1939
 M. H. Stone, 1939
 G. T. Whyburn, 1940
 Oystein Ore, 1941
 R. L. Wilder, 1942
 E. J. McShane, 1943
 Einar Hille, 1944
 Tibor Radó, 1945
 Hassler Whitney, 1946
 Oscar Zariski, 1947
 Richard Brauer, 1948
 G. A. Hedlund, 1949
 Deane Montgomery, 1951
 Alfred Tarski, 1952
 Antoni Zygmund, 1953
 Nathan Jacobson, 1955
 Salomon Bochner, 1956
 N. E. Steenrod, 1957
 J. L. Doob, 1959
 S. S. Chern, 1960
 G. W. Mackey, 1961
 Saunders Mac Lane, 1963
 C. B. Morrey, Jr., 1964
 A. P. Calderón, 1965
 Samuel Eilenberg, 1967
 D. C. Spencer, 1968

J. W. Milnor, 1968
 Raoul H. Bott, 1969
 Harish-Chandra, 1969
 R. H. Bing, 1970
 Lipman Bers, 1971
 Armand Borel, 1971
 Stephen Smale, 1972
 John T. Tate, 1972
 M. F. Atiyah, 1973
 E. A. Bishop, 1973
 F. E. Browder, 1973
 Louis Nirenberg, 1974
 John G. Thompson, 1974
 H. Jerome Keisler, 1975
 Ellis R. Kolchin, 1975
 Elias M. Stein, 1975
 I. M. Singer, 1976
 Jürgen K. Moser, 1976
 William Browder, 1977
 Herbert Federer, 1977
 Hyman Bass, 1978
 Phillip A. Griffiths, 1979
 George D. Mostow, 1979
 Julia B. Robinson, 1980
 Wolfgang M. Schmidt, 1980
 Mark Kac, 1981
 Serge Lang, 1981
 Dennis Sullivan, 1982
 Morris W. Hirsch, 1982
 Charles L. Fefferman, 1983
 Bertram Kostant, 1983
 Barry Mazur, 1984
 Paul H. Rabinowitz, 1984
 Daniel Gorenstein, 1985
 Karen K. Uhlenbeck, 1985
 Shing-Tung Yau, 1986
 Peter D. Lax, 1987
 Edward Witten, 1987
 Victor W. Guillemin, 1988
 Nicholas Katz, 1989
 William P. Thurston, 1989
 Shlomo Sternberg, 1990
 Robert D. MacPherson, 1991
 Robert P. Langlands, 1992
 Luis A. Caffarelli, 1993
 Sergiu Klainerman, 1993
 Jean Bourgain, 1994
 Clifford H. Taubes, 1995
 Andrew W. Wiles, 1996
 Daniel W. Stroock, 1997
 Gian-Carlo Rota, 1998
 Helmut H. Hofer, 1999

Gibbs Lecturers

M. I. Pupin, 1923
 Robert Henderson, 1924
 James Pierpont, 1925
 H. B. Williams, 1926
 E. W. Brown, 1927
 G. H. Hardy, 1928
 Irving Fisher, 1929

E. B. Wilson, 1930
 P. W. Bridgman, 1931
 R. C. Tolman, 1932
 Albert Einstein, 1934
 Vannevar Bush, 1935
 H. N. Russell, 1936
 C. A. Kraus, 1937
 Theodore von Kármán, 1939
 Sewall Wright, 1941
 Harry Bateman, 1943
 John von Neumann, 1944
 J. C. Slater, 1945
 S. Chandrasekhar, 1946
 P. M. Morse, 1947
 Hermann Weyl, 1948
 Norbert Wiener, 1949
 G. E. Uhlenbeck, 1950
 Kurt Gödel, 1951
 Marston Morse, 1952
 Wassily Leontief, 1953
 K. O. Friedrichs, 1954
 J. E. Mayer, 1955
 M. H. Stone, 1956
 H. J. Muller, 1958
 J. M. Burgers, 1959
 Julian Schwinger, 1960
 J. J. Stoker, 1961
 C. N. Yang, 1962
 C. E. Shannon, 1963
 Lars Onsager, 1964
 D. H. Lehmer, 1965
 Martin Schwarzschild, 1966
 Mark Kac, 1967
 E. P. Wigner, 1968
 R. L. Wilder, 1969
 W. H. Munk, 1970
 E. F. F. Hopf, 1971
 F. J. Dyson, 1972
 J. K. Moser, 1973
 Paul A. Samuelson, 1974
 Fritz John, 1975
 Arthur S. Wightman, 1976
 Joseph B. Keller, 1977
 Donald E. Knuth, 1978
 Martin D. Kruskal, 1979
 Kenneth G. Wilson, 1980
 Cathleen Synge Morawetz, 1981
 Elliott W. Montroll, 1982
 Samuel Karlin, 1983
 Herbert A. Simon, 1984
 Michael O. Rabin, 1985
 L. E. Scriven, 1986
 Thomas C. Spencer, 1987
 David P. Ruelle, 1988
 Elliott H. Lieb, 1989
 George B. Dantzig, 1990
 Michael F. Atiyah, 1991
 Michael E. Fisher, 1992
 Charles S. Peskin, 1993
 Robert M. May, 1994
 Andrew J. Majda, 1995

Steven Weinberg, 1996
 Persi Diaconis, 1997
 Edward Witten, 1998
 Nancy Kopell, 1999

Presidents

J. H. Van Amringe, 1889, 1890
 J. E. McClintock, 1891–1894
 G. W. Hill, 1895, 1896
 Simon Newcomb, 1897, 1898
 R. S. Woodward, 1899, 1900
 E. H. Moore, 1901, 1902
 T. S. Fiske, 1903, 1904
 W. F. Osgood, 1905, 1906
 H. S. White, 1907, 1908
 Maxime Bôcher, 1909, 1910
 H. B. Fine, 1911, 1912
 E. B. Van Vleck, 1913, 1914
 E. W. Brown, 1915, 1916
 L. E. Dickson, 1917, 1918
 Frank Morley, 1919, 1920
 G. A. Bliss, 1921, 1922
 Oswald Veblen, 1923, 1924
 G. D. Birkhoff, 1925, 1926
 Virgil Snyder, 1927, 1928
 E. R. Hedrick, 1929, 1930
 L. P. Eisenhart, 1931, 1932
 A. B. Coble, 1933, 1934
 Solomon Lefschetz, 1935, 1936
 R. L. Moore, 1937, 1938
 G. C. Evans, 1939, 1940

Marston Morse, 1941, 1942
 M. H. Stone, 1943, 1944
 T. H. Hildebrandt, 1945, 1946
 Einar Hille, 1947, 1948
 J. L. Walsh, 1949, 1950
 John von Neumann, 1951, 1952
 G. T. Whyburn, 1953, 1954
 R. L. Wilder, 1955, 1956
 Richard Brauer, 1957, 1958
 E. J. McShane, 1959, 1960
 Deane Montgomery, 1961, 1962
 J. L. Doob, 1963, 1964
 A. A. Albert, 1965, 1966
 C. B. Morrey, Jr., 1967, 1968
 Oscar Zariski, 1969, 1970
 Nathan Jacobson, 1971, 1972
 Saunders Mac Lane, 1973, 1974
 Lipman Bers, 1975, 1976
 R. H. Bing, 1977, 1978
 Peter D. Lax, 1979, 1980
 Andrew M. Gleason, 1981, 1982
 Julia B. Robinson, 1983, 1984
 Irving Kaplansky, 1985, 1986
 George Daniel Mostow, 1987,
 1988
 William Browder, 1989, 1990
 Michael Artin, 1991, 1992
 Ronald L. Graham, 1993, 1994
 Cathleen Synge Morawetz, 1995,
 1996

Arthur M. Jaffe, 1997, 1998
 Felix E. Browder, 1999, 2000

Secretaries

T. S. Fiske, 1888–1895
 F. N. Cole, 1896–1920
 R. G. D. Richardson, 1921–1940
 J. R. Kline, 1941–1950
 E. G. Begle, 1951–1956
 J. W. Green, 1957–1966
 Everett Pitcher, 1967–1988
 Robert M. Fossum, 1989–1998
 Robert J. Daverman, 1999–

Treasurers

T. S. Fiske, 1890, 1891
 Harold Jacoby, 1892–1894
 R. S. Woodward, 1895, 1896
 Harold Jacoby, 1897–1899
 W. S. Dennett, 1900–1907
 J. H. Tanner, 1908–1920
 W. B. Fite, 1921–1929
 G. W. Mullins, 1930–1936
 P. A. Smith, 1937
 B. P. Gill, 1938–1948
 A. E. Meder, Jr., 1949–1964
 W. T. Martin, 1965–1973
 Franklin P. Peterson, 1973–1998
 John M. Franks, 1999–

Prizes

The George David Birkhoff Prize in Applied Mathematics

This prize was established in 1967 in honor of Professor George David Birkhoff. The initial endowment of \$2,066 was contributed by the Birkhoff family and there have been subsequent additions by others. It is normally awarded every five years, beginning in 1968, for an outstanding contribution to “applied mathematics in the highest and broadest sense.” The award is made jointly by the American Mathematical Society and the Society for Industrial and Applied Mathematics. The recipient must be a member of one of these societies and a resident of the United States, Canada, or Mexico.

First award, 1968: To Jürgen K. Moser for his contributions to the theory of Hamiltonian dynamical systems, especially his proof of the stability of periodic solutions of Hamiltonian systems having two degrees of freedom and his specific applications of the ideas in connection with this work.

Second award, 1973: To Fritz John for his outstanding work in partial differential equations, in numerical analysis, and, particularly, in nonlinear elasticity theory; the latter work has led to his study of quasi-isometric mappings as well as functions of bounded mean oscillation, which have had impact in other areas of analysis.

Third award, 1973: To James B. Serrin for his fundamental contributions to the theory of nonlinear partial differential equations, especially his work on existence

and regularity theory for nonlinear elliptic equations, and applications of his work to the theory of minimal surfaces in higher dimensions.

Fourth award, 1978: To Garrett Birkhoff for bringing the methods of algebra and the highest standards of mathematics to scientific applications.

Fifth award, 1978: To Mark Kac for his important contributions to statistical mechanics and to probability theory and its applications.

Sixth award, 1978: To Clifford A. Truesdell for his outstanding contributions to our understanding of the subjects of rational mechanics and nonlinear materials, for his efforts to give precise mathematical formulation to these classical subjects, for his many contributions to applied mathematics in the fields of acoustic theory, kinetic theory, and nonlinear elastic theory, and the thermodynamics of mixtures, and for his major work in the history of mechanics.

Seventh award, 1983: To Paul R. Garabedian for his important contributions to partial differential equations, to the mathematical analysis of problems of transonic flow and airfoil design by the method of complexification, and to the development and application of scientific computing to problems of fluid dynamics and plasma physics.

Eighth award, 1988: To Elliott H. Lieb for his profound analysis of problems arising in mathematical physics.

Ninth award, 1994: To Ivo Babuška for important contributions to the reliability of finite element methods, the development of a general framework for finite element error

estimation, and the development of p and $h - p$ finite element methods; and to S. R. S. Varadhan for important contributions to the martingale characterization of diffusion processes, to the theory of large deviations for functionals of occupation times of Markov processes, and to the study of random media.

Tenth award, 1998: To Paul H. Rabinowitz for his deep influence on the field of nonlinear analysis.

The Bôcher Memorial Prize

This prize was founded in memory of Professor Maxime Bôcher with an original endowment of \$1,450. It is awarded every five years for a notable research memoir in analysis that has appeared during the past five years in a recognized North American journal. This provision, introduced in 1971 and modified in 1993, is a liberalization of the terms of the award.

First (preliminary) award, 1923: To G. D. Birkhoff for his memoir, *Dynamical systems with two degrees of freedom*. Transactions of the American Mathematical Society, volume 18 (1917), pp. 199–300.

Second award, 1924: To E. T. Bell for his memoir, *Arithmetical paraphrases*. I, II, Transactions of the American Mathematical Society, volume 22 (1921), pp. 1–30, 198–219; and to Solomon Lefschetz for his memoir, *On certain numerical invariants with applications to Abelian varieties*, Transactions of the American Mathematical Society, volume 22 (1921), pp. 407–482.

Third award, 1928: To J. W. Alexander for his memoir, *Combinatorial analysis situs*, Transactions of the American Mathematical Society, volume 28 (1926), pp. 301–329.

Fourth award, 1933: To Marston Morse for his memoir, *The foundations of a theory of the calculus of variations in the large in m -space*, Transactions of the American Mathematical Society, volume 31 (1929), pp. 379–404; and to Norbert Wiener for his memoir, *Tauberian theorems*, Annals of Mathematics, Series 2, volume 33 (1932), pp. 1–100.

Fifth award, 1938: To John von Neumann for his memoir, *Almost periodic functions and groups*. I, II, Transactions of the American Mathematical Society, volume 36 (1934), pp. 445–492, and volume 37 (1935), pp. 21–50.

Sixth award, 1943: To Jesse Douglas for his memoirs, *Green's function and the problem of Plateau*, American Journal of Mathematics, volume 61 (1939), pp. 545–589; *The most general form of the problem of Plateau*, American Journal of Mathematics, volume 61 (1939), pp. 590–608; and *Solution of the inverse problem of the calculus of variations*, Proceedings of the National Academy of Sciences, volume 25 (1939), pp. 631–637.

Seventh award, 1948: To A. C. Schaeffer and D. C. Spencer for their memoir, *Coefficients of schlicht functions*. I, II, III, IV, Duke Mathematical Journal, volume 10 (1943), pp. 611–635, volume 12 (1945), pp. 107–125, and the Proceedings of the National Academy of Sciences, volume 32 (1946), pp. 111–116, volume 35 (1949), pp. 143–150.

Eighth award, 1953: To Norman Levinson for his contributions to the theory of linear, nonlinear, ordinary, and partial differential equations contained in his papers of recent years.

Ninth award, 1959: To Louis Nirenberg for his work in partial differential equations.

Tenth award, 1964: To Paul J. Cohen for his paper, *On a conjecture of Littlewood and idempotent measures*, American Journal of Mathematics, volume 82 (1960), pp. 191–212.

Eleventh award, 1969: To I. M. Singer in recognition of his work on the index problem, especially his share in two joint papers with Michael F. Atiyah, *The index of elliptic operators*. I, III, Annals of Mathematics, Series 2, volume 87 (1968), pp. 484–530, 546–604.

Twelfth award, 1974: To Donald S. Ornstein in recognition of his paper, *Bernoulli shifts with the same entropy are isomorphic*, Advances in Mathematics, volume 4 (1970), pp. 337–352.

Thirteenth award, 1979: To Alberto P. Calderon in recognition of his fundamental work on the theory of singular integrals and partial differential equations, and in particular for his paper *Cauchy integrals on Lipschitz curves and related operators*, Proceedings of the National Academy of Sciences, USA, volume 74 (1977), pp. 1324–1327.

Fourteenth award, 1984: To Luis A. Caffarelli for his deep and fundamental work in nonlinear partial differential equations, in particular his work on free boundary problems, vortex theory and regularity theory.

Fifteenth award, 1984: To Richard B. Melrose for his solution of several outstanding problems in diffraction theory and scattering theory and for developing the analytical tools needed for their resolution.

Sixteenth award, 1989: To Richard M. Schoen for his work on the application of partial differential equations to differential geometry, in particular his completion of the solution to the Yamabe Problem in *Conformal deformation of a Riemannian metric to constant scalar curvature*, Journal of Differential Geometry, volume 20 (1984), pp. 479–495.

Seventeenth award, 1994: To Leon Simon for his profound contributions toward understanding the structure of singular sets for solutions of variational problems.

Eighteenth award, 1999: To Demetrios Christodoulou for his contributions to the mathematical theory of general relativity, and to Sergiu Klainerman for his contributions to nonlinear hyperbolic equations, and to Thomas Wolff for his work in harmonic analysis.

The Frank Nelson Cole Prize in Algebra

The Frank Nelson Cole Prize in Number Theory

These prizes were founded in honor of Professor Frank Nelson Cole on the occasion of his retirement as secretary of the American Mathematical Society after twenty-five years of service and as editor-in-chief of the *Bulletin* for twenty-one years. The original fund was donated by Professor Cole from moneys presented to him on his retirement, was augmented by contributions from members of the Society, and was later doubled by his son, Charles A. Cole. The present endowment is \$2,250. The prizes are awarded at five-year intervals for contributions to algebra and the theory of numbers, respectively, under restrictions similar to those for the Bôcher Prize.

First award, 1928: To L. E. Dickson for his book *Algebra und ihre Zahlentheorie*, Orell Füssli, Zürich and Leipzig, 1927.

Second award, 1931: To H. S. Vandiver for his several papers on Fermat's last theorem published in the Transactions of the American Mathematical Society and in the Annals of Mathematics during the preceding five years, with special reference to a paper entitled *On Fermat's last theorem*, Transactions of the American Mathematical Society, volume 31 (1929), pp. 613–642.

Third award, 1939: To A. Adrian Albert for his papers on the construction of Riemann matrices published in the Annals of Mathematics, Series 2, volume 35 (1934) and volume 36 (1935).

Fourth award, 1941: To Claude Chevalley for his paper, *La théorie du corps de classes*, Annals of Mathematics, Series 2, volume 41 (1940), pp. 394–418.

Fifth award, 1944: To Oscar Zariski for four papers on algebraic varieties published in the American Journal of Mathematics, volumes 61 (1939) and 62 (1940), and in the Annals of Mathematics, Series 2, volumes 40 (1939) and 41 (1940).

Sixth award, 1946: To H. B. Mann for his paper, *A proof of the fundamental theorem on the density of sums of sets of positive integers*, Annals of Mathematics, Series 2, volume 43 (1942), pp. 523–527.

Seventh award, 1949: To Richard Brauer for his paper, *On Artin's L-series with general group characters*, Annals of Mathematics, Series 2, volume 48 (1947), pp. 502–514.

Eighth award, 1951: To Paul Erdős for his many papers in the theory of numbers, and in particular for his paper, *On a new method in elementary number theory which leads to an elementary proof of the prime number theorem*, Proceedings of the National Academy of Sciences, volume 35 (1949), pp. 374–385.

Ninth award, 1954: To Harish-Chandra for his papers on representations of semisimple Lie algebras and groups, and particularly for his paper, *On some applications of the universal enveloping algebra of a semisimple Lie algebra*, Transactions of the American Mathematical Society, volume 70 (1951), pp. 28–96.

Tenth award, 1956: To John T. Tate for his paper, *The higher dimensional cohomology groups of class field theory*, Annals of Mathematics, Series 2, volume 56 (1952), pp. 294–297.

Eleventh award, 1960: To Serge Lang for his paper, *Unramified class field theory over function fields in several variables*, Annals of Mathematics, Series 2, volume 64 (1956), pp. 285–325; and to Maxwell A. Rosenlicht for his papers, *Generalized Jacobian varieties*, Annals of Mathematics, Series 2, volume 59 (1954), pp. 505–530, and *A universal mapping property of generalized Jacobians*, Annals of Mathematics, Series 2, volume 66 (1957), pp. 80–88.

Twelfth award, 1962: To Kenkichi Iwasawa for his paper, *Gamma extensions of number fields*, Bulletin of the American Mathematical Society, volume 65 (1959), pp. 183–226; and to Bernard M. Dwork for his paper, *On the rationality of the zeta function of an algebraic variety*, American Journal of Mathematics, volume 82 (1960), pp. 631–648.

Thirteenth award, 1965: To Walter Feit and John G. Thompson for their joint paper, *Solvability of groups of odd*

order, Pacific Journal of Mathematics, volume 13 (1963), pp. 775–1029.

Fourteenth award, 1967: To James B. Ax and Simon B. Kochen for a series of three joint papers, *Diophantine problems over local fields*. I, II, III, American Journal of Mathematics, volume 87 (1965), pp. 605–630, 631–648, and Annals of Mathematics, Series 2, volume 83 (1966), pp. 437–456.

Fifteenth award, 1970: To John R. Stallings for his paper, *On torsion-free groups with infinitely many ends*, Annals of Mathematics, Series 2, volume 88 (1968), pp. 312–334; and to Richard G. Swan for his paper, *Groups of cohomological dimension one*, Journal of Algebra, volume 12 (1969), pp. 585–610.

Sixteenth award, 1972: To Wolfgang M. Schmidt for the following papers: *On simultaneous approximation of two algebraic numbers by rationals*, Acta Mathematica (Uppsala), volume 119 (1967), pp. 27–50; *T-numbers do exist*, Symposia Mathematica, volume IV, Academic Press, 1970, pp. 1–26; *Simultaneous approximation to algebraic numbers by rationals*, Acta Mathematica (Uppsala), volume 125 (1970), pp. 189–201; *On Mahler's T-numbers*, Proceedings of Symposia in Pure Mathematics, volume 20, American Mathematical Society, 1971, pp. 275–286.

Seventeenth award, 1975: To Hyman Bass for his paper, *Unitary algebraic K-theory*, Springer Lecture Notes in Mathematics, volume 343, 1973; and to Daniel G. Quillen for his paper, *Higher algebraic K-theories*, Springer Lecture Notes in Mathematics, volume 341, 1973.

Eighteenth award, 1977: To Goro Shimura for his two papers, *Class fields over real quadratic fields and Hecke operators*, Annals of Mathematics, Series 2, volume 95 (1972), pp. 130–190; and *On modular forms of half integral weight*, Annals of Mathematics, Series 2, volume 97 (1973), pp. 440–481.

Nineteenth award, 1980: To Michael Aschbacher for his paper, *A characterization of Chevalley groups over fields of odd order*, Annals of Mathematics, Series 2, volume 106 (1977), pp. 353–398; and to Melvin Hochster for his paper *Topics in the homological theory of commutative rings*, CBMS Regional Conference Series in Mathematics, Number 24, American Mathematical Society, 1975.

Twentieth award, 1982: To Robert P. Langlands for pioneering work on automorphic forms, Eisenstein series and product formulas, particularly for his paper *Base change for GL(2)*, Annals of Mathematics Studies, volume 96, Princeton University Press, 1980; and to Barry Mazur for outstanding work on elliptic curves and Abelian varieties, especially on rational points of finite order, and his paper *Modular curves and the Eisenstein ideal*, Publications Mathématiques de l'Institut des Hautes Etudes Scientifiques, volume 47 (1977), pp. 33–186.

Twenty-First award, 1985: To George Lusztig for his fundamental work on the representation theory of finite groups of Lie type. In particular for his contributions to the classification of the irreducible representations in characteristic zero of the groups of rational points of reductive groups over finite fields, appearing in *Characters of reductive groups over finite fields*, Annals of Mathematics Studies, volume 107, Princeton University Press, 1984.

Twenty-Second award, 1987: To Dorian M. Goldfeld for his paper, *Gauss's class number problem for imaginary quadratic fields*, Bulletin of the American Mathematical Society, volume 13, (1985), pp. 23-37; and to Benedict H. Gross and Don B. Zagier for their paper, *Heegner points and derivatives of L-Series*, Inventiones Mathematicae, volume 84 (1986), pp. 225-320.

Twenty-Third award, 1990: To Shigefumi Mori for his outstanding work on the classification of algebraic varieties and, in particular, for his paper *Flip theorem and the existence of minimal models for 3-folds*, Journal of the American Mathematical Society, volume 1 (1988), pp. 117-253.

Twenty-Fourth award, 1992: To Karl Rubin for his work in the area of elliptic curves and Iwasawa Theory with particular reference to his papers *Tate-Shafarevich groups and L-functions of elliptic curves with complex multiplication* and *The "main conjectures" of Iwasawa theory for imaginary quadratic fields* and to Paul Vojta for his work on Diophantine problems with particular reference to his paper *Siegel's theorem in the compact case*.

Twenty-Fifth award, 1995: To Michel Raynaud and David Harbater for their solution of Abhyankar's conjecture. This work appeared in the papers *Revêtements de la droite affine en caractéristique $p > 0$* , Invent. Math. **116** (1994) 425-462 (Raynaud), and *Abhyankar's conjecture on Galois groups over curves*, Invent. Math. **117** (1994) 1-25 (Harbater).

Twenty-Sixth award, 1997: To Andrew J. Wiles for his work on the Shimura-Taniyama conjecture and Fermat's Last Theorem, published in *Modular elliptic curves and Fermat's Last Theorem*, Ann. of Math. **141** (1995), 443-551.

The Delbert Ray Fulkerson Prize

Gifts of friends of the late Professor Fulkerson have provided a fund in excess of \$7,000. Part or all of the proceeds is to be used jointly by the Mathematical Programming Society and the American Mathematical Society for the award of one or more prizes in discrete mathematics at regular intervals.

First award, 1979: To Richard M. Karp, for *On the computational complexity of combinatorial problems*, Networks, volume 5 (1975), pp. 45-68; to Kenneth Appel and Wolfgang Haken, for *Every planar map is four colorable*, Part I: *Discharging*, Illinois Journal of Mathematics, volume 21 (1977), pp. 429-490; and to Paul D. Seymour, for *The matroids with the max-flow min-cut property*, Journal of Combinatorial Theory, Series B, volume 23 (1977), pp. 189-222.

Second award, 1982: To D. B. Judin and A. S. Nemirovskii, for *Informational complexity and effective methods of solution for convex extremal problems*, Ekonomika i Matematicheskie Metody **12** (1976), 357-369, and to L. G. Khachiyan for *A polynomial algorithm in linear programming*, Akademiia Nauk SSSR. Doklady **244** (1979), 1093-1096; to G. P. Egorychev, for *The solution of van der Waerden's problem for permanents*, Akademiia Nauk SSSR. Doklady **258** (1981), 1041-1044, and D. I. Falikman, for *A proof of the van der Waerden conjecture on the permanent of a doubly stochastic matrix*, Matematicheskie Zametki **29** (1981), 931-938; and to M. Grötschel, L. Lovasz, and A. Schri-

jver, for *The ellipsoid method and its consequences in combinatorial optimization*, Combinatorica **1** (1981), 169-197.

Third award, 1985: To Jozsef Beck, for *Roth's estimate of the discrepancy of integer sequences is nearly sharp*, Combinatorica **1** (4), 319-325, (1981); and H. W. Lenstra Jr., for *Integer programming with a fixed number of variables*, Mathematics of Operations Research **8** (4), 538-548, (1983); and Eugene M. Luks for *Isomorphism of graphs of bounded valence can be tested in polynomial time*, Journal of Computer and System Sciences **25** (1), 42-65, (1982).

Fourth award, 1988: To Éva Tardos for *A strongly polynomial minimum cost circulation algorithm*, Combinatorica, volume 5 (1985), pp. 247-256; and to Narendra Karmarkar for *A new polynomial-time algorithm for linear programming*, Combinatorica, volume 4 (1984), pp. 373-395.

Fifth award, 1991: To Martin Dyer, Alan Frieze, and Ravi Kannan for *A random polynomial time algorithm for approximating the volume of convex bodies*, Journal of the Association for Computing Machinery, volume 38/1 (1991) pp. 1-17; to Alfred Lehman for *The width-length inequality and degenerate projective planes*, W. Cook and P. D. Seymour (eds.), Polyhedral Combinatorics, DIMACS Series in Discrete Mathematics and Theoretical Computer Science, volume 1, (American Mathematical Society, 1990) pp. 101-105; and to Nikolai E. Mnev for *The universality theorems on the classification problem of configuration varieties and convex polytope varieties*, O. Ya. Viro (ed.), Topology and Geometry-Rohlin Seminar, Lecture Notes in Mathematics **1346** (Springer-Verlag, Berlin, 1988) pp. 527-544.

Sixth award, 1994: To Lou Billera for *Homology of smooth splines: Generic triangulations and a conjecture of Strang*, Transactions of the AMS, volume 310 (1988) pp. 325-340; to Gil Kalai for *Upper bounds for the diameter and height of graphs of the convex polyhedra*, Discrete and Computational Geometry, volume 8 (1992) pp. 363-372; and to Neil Robertson, Paul D. Seymour, and Robin Thomas for *Hadwiger's conjecture for K_6 free graphs*, Combinatorica, volume 13 (1993) pp. 279-361.

Seventh award, 1997: To Jeong Han Kim for "The Ramsey Number $R(3, t)$ Has Order of Magnitude $\frac{t^2}{\log t}$ " which appeared in *Random Structures and Algorithms*, volume 7, issue 3, 1995, pages 173-207.

The Frank and Brennie Morgan Prize for Outstanding Research in Mathematics by an Undergraduate Student

This prize, which was established in 1995, is to be awarded to an undergraduate student (or students having submitted joint work) for outstanding research in mathematics: it is entirely endowed by a gift of approximately \$25,000 from Mrs. Frank (Brennie) Morgan. Any student who is an undergraduate in a college or university in Canada, Mexico, or the United States or its possessions is eligible to be considered for this prize. No more than one prize shall be awarded each year and a few honorable mentions may be made. The award is made jointly by the American Mathematical Society, the Mathematical Association of America, and the Society for Industrial and Applied Mathematics.

First award, 1995: Kannan Soundararajan for truly exceptional research in analytic number theory. Honorable mention: Kiran Kedlaya.

Second award, 1996: Manjul Bhargava for truly outstanding mathematical research in algebra. Honorable mention: Lenhard L. Ng.

Third award, 1997: Jade Vinson for wide-ranging research in analysis and geometry. Honorable mention: Vikaas Sohal.

Eighth award, 1998: Daniel Biss for his remarkable breadth, as well as depth. The most exciting aspect of his submission was his extension of a category which more closely binds the associations between combinatorial group theory and combinatorial topology. Honorable mention: Aaron E. Archer.

The Award for Distinguished Public Service

To provide encouragement and recognition to those individuals who contribute their time to public service activities in support of mathematics, the Council of the Society established the Award for Distinguished Public Service. The award was established in response to a recommendation by the Society's Committee on Science Policy. The award is presented every two years to a research mathematician who has made a distinguished contribution to the mathematics profession during the preceding five years.

First award, 1990: Kenneth M. Hoffman for his outstanding leadership in establishing channels of communication between the mathematical community and makers of public policy as well as the general public.

Second award, 1992: Harvey B. Keynes for his multifaceted efforts to revitalize mathematics education, especially for young people.

Third award, 1993: Isadore M. Singer in recognition of his outstanding contributions to his profession, to science more broadly, and to the public good by bringing the best of mathematics and his own insights to bear on the activities of the National Academy of Sciences; on committees of the National Research Council, including the two so-called David Committees on the health of the mathematical sciences, and the Committee on Science, Engineering, and Public Policy; on the President's Science Advisory Council; on decisions of Congress, through testimony concerning the support of mathematics and mathematical research; and on a host of critical situations over many years in which his wisdom and intervention helped gain a hearing for the problems of his community and the contributions it makes to the nation.

Fourth award, 1995: Donald J. Lewis for his many contributions to mathematical education, mathematics policy, and mathematical research and administration during a career that has spanned several decades.

Fifth award, 1997: No award made.

Sixth award, 1998: Kenneth C. Millett for his work devoted to underrepresented minority students in the mathematical sciences. Professor Millett founded the University of California, Santa Barbara, Achievement Program and directed the mathematics component of the Summer Acad-

emic Research Internship and the Summer Institute in Mathematics at UCSB.

The Citation for Public Service

To provide encouragement and recognition for contributions to public service activities in support of mathematics, the Council of the Society established the Citation for Public Service. The award was established in response to a recommendation by the Society's Committee on Science Policy. One to three citations are presented each year for notable contributions to the mathematics profession through public service.

First award, 1991: Andre Z. Manitius for the contributions he made to the mathematical community while employed in the Division of Mathematical Sciences at the National Science Foundation.

Second award, 1992: Marcia P. Sward for her contributions toward establishing and directing the Mathematical Sciences Education Board from its inception in the fall of 1985 until August 1989.

Third award, 1998: Liang-Shin Hahn and Arnold E. Ross. Liang-Shin Hahn for carrying forward and developing the New Mexico High School Mathematics Contest and for exposition and popularization of mathematics attractive to and suitable for potential candidates for the contest and others with similar intellectual interests. Arnold E. Ross for inspiring generations of young people through the mathematics programs he created and has continued to run for nearly forty years.

The Ruth Lyttle Satter Prize in Mathematics

The prize was established in 1990 using funds donated by Joan S. Birman in memory of her sister, Ruth Lyttle Satter. Professor Birman requested that the prize be established to honor her sister's commitment to research and to encouraging women in science. The prizes are awarded every two years to recognize an outstanding contribution to mathematics research by a woman in the previous five years.

First award, 1991: To Dusa McDuff for her outstanding work during the past five years on symplectic geometry.

Second award, 1993: To Lai-Sang Young for her leading role in the investigation of the statistical (or ergodic) properties of dynamical systems.

Third award, 1995: To Sun-Yung Alice Chang for her deep contributions to the study of partial differential equations on Riemannian manifolds and in particular for her work on extremal problems in spectral geometry and the compactness of isospectral metrics within a fixed conformal class on a compact 3-manifold.

Fourth award, 1997: To Ingrid Daubechies for her deep and beautiful analysis of wavelets and their applications.

Fifth award, 1999: To Bernadette Perrin-Riou for her number theoretical research on p -adic L -functions and Iwasawa Theory.

The Leroy P. Steele Prizes

These prizes were established in 1970 in honor of George David Birkhoff, William Fogg Osgood, and William Caspar Graustein, and are endowed under the terms of a bequest amounting to \$145,000 from Leroy P. Steele. From 1970 to 1976 one or more prizes were awarded each year for outstanding published mathematical research; most favorable consideration was given to papers distinguished for their exposition and covering broad areas of mathematics. In 1977 the Council of the AMS modified the terms under which the prizes are awarded. Since then, up to three prizes have been awarded each year in the following categories: (1) for the cumulative influence of the total mathematical work of the recipient, high level of research over a period of time, particular influence on the development of a field, and influence on mathematics through Ph.D. students; (2) for a book or substantial survey or expository-research paper; (3) for a paper, whether recent or not, that has proved to be of fundamental or lasting importance in its field, or a model of important research. In 1993, the Council formalized the three categories of the prize by naming each of them: (1) The Leroy P. Steele Prize for Lifetime Achievement; (2) The Leroy P. Steele Prize for Mathematical Exposition; and (3) The Leroy P. Steele Prize for Seminal Contribution to Research.

August 1970: To Solomon Lefschetz for his paper, *A page of mathematical autobiography*, Bulletin of the American Mathematical Society, volume 74 (1968), pp. 854–879.

August 1971: To James B. Carrell for his paper, written jointly with Jean A. Dieudonné, *Invariant theory, old and new*, Advances in Mathematics, volume 4 (1970), pp. 1–80.

August 1971: To Jean A. Dieudonné for his paper, *Algebraic geometry*, Advances in Mathematics, volume 3 (1969), pp. 223–321, and for his paper, written jointly with James B. Carrell, *Invariant theory, old and new*, Advances in Mathematics, volume 4 (1970), pp. 1–80.

August 1971: To Phillip A. Griffiths for his paper, *Periods of integrals on algebraic manifolds*, Bulletin of the American Mathematical Society, volume 76 (1970), pp. 228–296.

August 1972: To Edward B. Curtis for his paper, *Simplicial homotopy theory*, Advances in Mathematics, volume 6 (1971), pp. 107–209.

August 1972: To William J. Ellison for his paper, *Waring's problem*, American Mathematical Monthly, volume 78 (1971), pp. 10–36.

August 1972: To Lawrence F. Payne for his paper, *Isoperimetric inequalities and their applications*, SIAM Review, volume 9 (1967), pp. 453–488.

August 1972: To Dana S. Scott for his paper, *A proof of the independence of the continuum hypothesis*, Mathematical Systems Theory, volume 1 (1967), pp. 89–111.

January 1975: To Lipman Bers for his paper, *Uniformization, moduli, and Kleinian groups*, Bulletin of the London Mathematical Society, volume 4 (1972), pp. 257–300.

January 1975: To Martin D. Davis for his paper, *Hilbert's tenth problem is unsolvable*, American Mathematical Monthly, volume 80 (1973), pp. 233–269.

January 1975: To Joseph L. Taylor for his paper, *Measure algebras*, CBMS Regional Conference Series in Mathematics, Number 16, American Mathematical Society, 1972.

August 1975: To George W. Mackey for his paper, *Ergodic theory and its significance for statistical mechanics and probability theory*, Advances in Mathematics, volume 12 (1974), pp. 178–286.

August 1975: To H. Blaine Lawson for his paper, *Foliations*, Bulletin of the American Mathematical Society, volume 80 (1974), pp. 369–418.

1976, 1977, 1978: No awards were made.

January 1979: To Salomon Bochner for his cumulative influence on the fields of probability theory, Fourier analysis, several complex variables, and differential geometry.

January 1979: To Hans Lewy for three fundamental papers: *On the local character of the solutions of an atypical linear differential equation in three variables and a related theorem for regular functions of two complex variables*, Annals of Mathematics, Series 2, volume 64 (1956), pp. 514–522; *An example of a smooth linear partial differential equation without solution*, Annals of Mathematics, Series 2, volume 66 (1957), pp. 155–158; *On hulls of holomorphy*, Communications in Pure and Applied Mathematics, volume 13 (1960), pp. 587–591.

August 1979: To Antoni Zygmund for his cumulative influence on the theory of Fourier series, real variables, and related areas of analysis.

August 1979: To Robin Hartshorne for his expository research article *Equivalence relations on algebraic cycles and subvarieties of small codimension*, Proceedings of Symposia in Pure Mathematics, volume 29, American Mathematical Society, 1975, pp. 129–164; and his book *Algebraic geometry*, Springer-Verlag, Berlin and New York, 1977.

August 1979: To Joseph J. Kohn for his fundamental paper *Harmonic integrals on strongly convex domains*. I, II, Annals of Mathematics, Series 2, volume 78 (1963), pp. 112–248 and volume 79 (1964), pp. 450–472.

August 1980: To André Weil for the total effect of his work on the general course of twentieth century mathematics, especially in the many areas in which he has made fundamental contributions.

August 1980: To Harold M. Edwards for mathematical exposition in his books *Riemann's zeta function*, Pure and Applied Mathematics, number 58, Academic Press, New York and London, 1974; and *Fermat's last theorem*, Graduate Texts in Mathematics, number 50, Springer-Verlag, New York and Berlin, 1977.

August 1980: To Gerhard P. Hochschild for his significant work in homological algebra and its applications.

August 1981: To Oscar Zariski for his work in algebraic geometry, especially his fundamental contributions to the algebraic foundations of this subject.

August 1981: To Eberhard Hopf for three papers of fundamental and lasting importance: *Abzweigung einer periodischen Lösung von einer stationären Lösung eines Differential systems*, Berichte über die Verhandlungen der Sächsischen Akademie der Wissenschaften zu Leipzig. Mathematisch-Naturwissenschaftliche Klasse, volume 95 (1943), pp. 3–22; *A mathematical example displaying*

features of turbulence, Communications on Applied Mathematics, volume 1 (1948), pp. 303–322; and *The partial differential equation $u_t + uu_x = \mu u_{xx}$* , Communications on Pure and Applied Mathematics, volume 3 (1950), pp. 201–230.

August 1981: To Nelson Dunford and Jacob T. Schwartz for their expository book, *Linear operators*, Part I, *General theory*, 1958; Part II, *Spectral theory*, 1963; Part III, *Spectral operators*, 1971, Interscience Publishers, New York.

August 1982: To Lars V. Ahlfors for his expository work in *Complex analysis* (McGraw-Hill Book Company, New York, 1953), and in *Lectures on quasiconformal mappings* (D. Van Nostrand Co., Inc., New York, 1966) and *Conformal invariants* (McGraw-Hill Book Company, New York, 1973).

August 1982: To Tsit-Yuen Lam for his expository work in his book *Algebraic theory of quadratic forms* (1973), and four of his papers: K_0 and K_1 -an introduction to algebraic K -theory (1975), *Ten lectures on quadratic forms over fields* (1977), *Serre's conjecture* (1978), and *The theory of ordered fields* (1980).

August 1982: To John W. Milnor for a paper of fundamental and lasting importance, *On manifolds homeomorphic to the 7-sphere*, *Annals of Mathematics* (2) 64 (1956), pp. 399–405.

August 1982: To Fritz John for the cumulative influence of his total mathematical work, high level of research over a period of time, particular influence on the development of a field, and influence on mathematics through Ph.D. students.

August 1983: To Paul R. Halmos for his many graduate texts in mathematics and for his articles on how to write, talk, and publish mathematics.

August 1983: To Steven C. Kleene for three important papers which formed the basis for later developments in generalized recursion theory and descriptive set theory: *Arithmetical predicates and function quantifiers*, *Transactions of the American Mathematical Society* 79 (1955), pp. 312–340; *On the forms of the predicates in the theory of constructive ordinals (second paper)*, *American Journal of Mathematics* 77 (1955), pp. 405–428; and *Hierarchies of number-theoretic predicates*, *Bulletin of the American Mathematical Society* 61 (1955), pp. 193–213.

August 1983: To Shiing-Shen Chern for the cumulative influence of his total mathematical work, high level of research over a period of time, particular influence on the development of the field of differential geometry, and influence on mathematics through Ph.D. students.

August 1984: To Elias M. Stein for his book, *Singular integrals and the differentiability properties of functions*, Princeton University Press (1970).

August 1984: To Lennart Carleson for his papers: *An interpolation problem for bounded analytic functions*, *American Journal of Mathematics*, volume 80 (1958), pp. 921–930; *Interpolation by bounded analytic functions and the Corona problem*, *Annals of Mathematics* (2), volume 76 (1962), pp. 547–559; and *On convergence and growth of partial sums of Fourier series*, *Acta Mathematica* volume 116 (1966), pp. 135–157.

August 1984: To Joseph L. Doob for his fundamental work in establishing probability as a branch of mathematics and for his continuing profound influence on its development.

August 1985: To Michael Spivak for his five-volume set, *A Comprehensive Introduction to Differential Geometry* (second edition, Publish or Perish, 1979).

August 1985: To Robert Steinberg for three papers on various aspects of the theory of algebraic groups: *Representations of algebraic groups*, *Nagoya Mathematical Journal*, volume 22 (1963), pp. 33–56; *Regular elements of semi-simple algebraic groups*, *Institut des Hautes Études Scientifiques, Publications Mathématiques*, volume 25 (1965), pp. 49–80; and *Endomorphisms of linear algebraic groups*, *Memoirs of the American Mathematical Society*, volume 80 (1968).

August 1985: To Hassler Whitney for his fundamental work on geometric problems, particularly in the general theory of manifolds, in the study of differentiable functions on closed sets, in geometric integration theory, and in the geometry of the tangents to a singular analytic space.

January 1986: To Donald E. Knuth for his expository work, *The Art of Computer Programming*, 3 Volumes (1st Edition 1968, 2nd Edition 1973).

January 1986: To Rudolf E. Kalman for his two fundamental papers: *A new approach to linear filtering and prediction problems*, *Journal of Basic Engineering*, volume 82, (1960), pp. 35–45; and *Mathematical description of linear dynamical systems*, *SIAM Journal on Control and Optimization*, volume 1 (1963), pp. 152–192; and for his contribution to a third paper, (with R. S. Bucy) *New results in linear filtering and prediction theory*, *Journal of Basic Engineering*, volume 83D (1961), pp. 95–108.

January 1986: To Saunders MacLane for his many contributions to algebra and algebraic topology, and in particular for his pioneering work in homological and categorical algebra.

August 1987: To Martin Gardner for his many books and articles on mathematics and particularly for his column “Mathematical Games” in *Scientific American*.

August 1987: To Herbert Federer and Wendell Fleming for their pioneering paper, *Normal and integral currents*, *Annals of Mathematics*, volume 72 (1960), pp. 458–520.

August 1987: To Samuel Eilenberg for his fundamental contributions to topology and algebra, in particular for his classic papers on singular homology and his work on axiomatic homology theory which had a profound influence on the development of algebraic topology.

August 1988: To Sigurdur Helgason for his books *Differential Geometry and Symmetric Spaces* (Academic Press, 1962), *Differential Geometry, Lie Groups, and Symmetric Spaces* (Academic Press, 1978); and *Groups and Geometric Analysis* (Academic Press, 1984).

August 1988: To Gian-Carlo Rota for his paper *On the foundations of combinatorial theory, I. Theory of Möbius functions*, *Zeitschrift für Wahrscheinlichkeitstheorie und Verwandte Gebiete*, volume 2 (1964), pp. 340–368.

August 1988: To Deane Montgomery for his lasting impact on mathematics, particularly mathematics in America. He is one of the founders of the modern theory of

transformation groups and is particularly known for his contributions to the solution of Hilbert's fifth problem.

August 1989: To Daniel Gorenstein for his book *Finite Simple Groups, An Introduction to their Classification* (Plenum Press, 1982); and his two survey articles *The classification of finite simple groups* and *Classifying the finite simple groups*, Bulletin of the American Mathematical Society, volume 1 (1979) pp. 43-199, and volume 14 (1986) pp. 1-98, respectively.

August 1989: To Alberto P. Calderon for his paper *Uniqueness in the Cauchy problem for partial differential equations*, American Journal of Mathematics, volume 80 (1958), pp. 16-36.

August 1989: To Irving Kaplansky for his lasting impact on mathematics, particularly mathematics in America. By his energetic example, his enthusiastic exposition, and his overall generosity, he has made striking changes in mathematics and has inspired generations of younger mathematicians.

August 1990: To R. D. Richtmyer for his book *Difference Methods for Initial-Value Problems* (Interscience, 1st Edition 1957 and 2nd Edition, with K. Morton, 1967).

August 1990: To Bertram Kostant for his paper, *On the existence and irreducibility of certain series of representations*, Lie Groups and their Representations (1975), pp. 231-329.

August 1990: To Raoul Bott for having been instrumental in changing the face of geometry and topology, with his incisive contributions to characteristic classes, K -theory, index theory, and many other tools of modern mathematics.

August 1991: To Jean-François Trèves for *Pseudodifferential and Fourier Integral Operators*, Volumes 1 and 2 (Plenum Press, 1980).

August 1991: To Eugenio Calabi for his fundamental work on global differential geometry, especially complex differential geometry.

August 1991: To Armand Borel for his extensive contributions in geometry and topology, the theory of Lie groups, their lattices and representations and the theory of automorphic forms, the theory of algebraic groups and their representations and extensive organizational and educational efforts to develop and disseminate modern mathematics.

January 1993: To Jacques Dixmier for his books *von Neumann Algebras (Algèbres de von Neumann)*, Gauthier-Villars, Paris (1957); *C*-Algebras (Les C*-Algèbres et leurs Représentations)*, Gauthier-Villars, Paris (1964); and *Enveloping Algebras (Algèbres Enveloppantes)*, Gauthier-Villars, Paris (1974).

January 1993: To James Glimm for his paper, *Solution in the large for nonlinear hyperbolic systems of conservation laws*, Communications on Pure and Applied Mathematics, XVIII (1965), pp. 697-715.

January 1993: To Peter D. Lax for his numerous and fundamental contributions to the theory and applications of linear and nonlinear partial differential equations and functional analysis, for his leadership in the development of computational and applied mathematics, and for his extraordinary impact as a teacher.

August 1993 - Mathematical Exposition: To Walter Rudin for his books *Principles of Mathematical Analysis*, McGraw-Hill (1953, 1964, and 1976); and *Real and Complex Analysis*, McGraw-Hill (1966, 1974, and 1976).

August 1993 - Seminal Contribution to Research: To George Daniel Mostow for his paper *Strong rigidity of locally symmetric spaces*, Annals of Mathematics Studies, number 78, Princeton University Press (1973).

August 1993 - Lifetime Achievement: To Eugene B. Dynkin for his foundational contributions to Lie algebras and probability theory over a long period and his production of outstanding research students in both Russia and the United States, countries to whose mathematical life he has contributed so richly.

August 1994 - Mathematical Exposition: To Ingrid Daubechies for her book, *Ten Lectures on Wavelets* (CBMS 61, SIAM, 1992, ISBN 0-8987-1274-2).

August 1994 - Seminal Contribution to Research: To Louis de Branges for his proof of the Bieberbach Conjecture.

August 1994 - Lifetime Achievement: To Louis Nirenberg for his numerous basic contributions to linear and nonlinear partial differential equations and their application to complex analysis and differential geometry.

August 1995 - Mathematical Exposition: To Jean-Pierre Serre for his 1970 book *Cours d'Arithmétique*, with its English translation, published in 1973 by Springer Verlag, *A Course in Arithmetic*.

August 1995 - Seminal Contribution to Research: To Edward Nelson for the following two papers in mathematical physics characterized by leaders of the field as extremely innovative: "A quartic interaction in two dimensions" in *Mathematical Theory of Elementary Particles*, MIT Press, 1966, pages 69-73; and "Construction of quantum fields from Markoff fields" in *Journal of Functional Analysis*, 12 (1973), 97-112. In these papers he showed for the first time how to use the powerful tools of probability theory to attack the hard analytic questions of constructive quantum field theory, controlling renormalizations with L^p estimates in the first paper, and in the second turning Euclidean quantum field theory into a subset of the theory of stochastic processes.

August 1995 - Lifetime Achievement: To John T. Tate for scientific accomplishments spanning four and a half decades. He has been deeply influential in many of the important developments in algebra, algebraic geometry, and number theory during this time.

August 1996 - Mathematical Exposition: To Bruce C. Berndt for the four volumes, *Ramanujan's Notebooks*, Parts I, II, III, and IV (Springer, 1985, 1989, 1991, and 1994).

August 1996 - Mathematical Exposition: To William Fulton for his book, *Intersection Theory*, Springer-Verlag, "Ergebnisse series," 1984.

August 1996 - Seminal Contribution to Research: To Daniel Stroock and S.R.S. Varadhan for their four papers: *Diffusion processes with continuous coefficients I and II*, Comm. Pure Appl. Math. 22 (1969), 345-400, 479-530; *On the support of diffusion processes with applications to the strong maximum principle*, Sixth Berkeley Sympos. Math. Statist. Probab., vol. III, 1970, pp. 333-360; *Diffusion*

processes with boundary conditions, *Comm. Pure Appl. Math.* 34 (1971), 147–225; *Multidimensional diffusion processes*, Springer-Verlag, 1979.

August 1996 – Lifetime Achievement: To Goro Shimura for his important and extensive work on arithmetical geometry and automorphic forms; concepts introduced by him were often seminal, and fertile ground for new developments, as witnessed by the many notations in number theory that carry his name and that have long been familiar to workers in the field.

January 1997 – Mathematical Exposition: To Anthony W. Knaapp for his book, *Representation Theory of Semisimple Groups (An overview based on examples)*, Princeton University Press, 1986, a beautifully written book which starts from scratch but takes the reader far into a highly developed subject.

January 1997 – Seminal Contribution to Research: To Mikhael Gromov for his paper, *Pseudo-holomorphic curves in symplectic manifolds*, *Inventiones Math.* 82 (1985), 307–347, which revolutionized the subject of symplectic geometry and topology and is central to much current research activity, including quantum cohomology and mirror symmetry.

January 1997 – Lifetime Achievement: To Ralph S. Phillips for being one of the outstanding analysts of our time. His early work was in functional analysis: his beautiful theorem on the relation between the spectrum of a semigroup and its infinitesimal generator is striking as well as very useful in the study of PDEs. His extension theory for dissipative linear operators predated the interpolation approach to operator theory and robust control. He made major contributions to acoustical scattering theory in his joint work with Peter Lax, proving remarkable results on local energy decay and the connections between poles of the scattering matrix and the analytic properties of the resolvent. He later extended this work to a spectral theory for the automorphic Laplace operator, relying on the Radon transform on horospheres to avoid Eisenstein series. In the last fifteen years, Ralph Phillips has done brilliant work, in collaboration with others, on spectral theory for the Laplacian on symmetric spaces, on the existence and stability of cusp forms for general noncompact quotients of the hyperbolic plane, on the explicit construction of sparse optimal expander graphs, and on the structure of families of isospectral sets in two dimensions (the collection of drums that sound the same).

January 1998 – Lifetime Achievement: To Nathan Jacobson for his many contributions to research, teaching, exposition, and the mathematical profession. Few mathematicians have been as productive over such a long career or have had as much influence on the profession as has Professor Jacobson.

January 1998 – Seminal Contribution to Research: To Herbert Wilf and Doron Zeilberger for their joint paper, “Rational functions certify combinatorial identities,” *Journal of the American Mathematical Society*, 3 (1990), 147–158.

January 1998 – Mathematical Exposition: To Joseph Silverman for his books, *The Arithmetic of Elliptic Curves*, Graduate Texts in Mathematics 106, Springer-Verlag, New York-Berlin, 1986; and *Advanced Topics in the Arithmetic*

of Elliptic Curves, Graduate Texts in Mathematics 151, Springer-Verlag, New York, 1994.

January 1999 – Lifetime Achievement: To Richard V. Kadison. For almost half a century, Professor Kadison has been one of the world leaders in the subject of operator algebras, and the tremendous flourishing of this subject in the last thirty years is largely due to his efforts.

January 1999 – Seminal Contribution to Research: To Michael G. Crandall for two seminal papers: “Viscosity solutions of Hamilton-Jacobi equations” (joint with P.-L. Lions), *Trans. Amer. Math. Soc.* 277 (1983), 1–42; and “Generation of semi-groups of nonlinear transformations on general Banach spaces” (joint with T. M. Liggett), *Amer. J. Math.* 93 (1971), 265–298.

January 1999 – Seminal Contribution to Research: To John F. Nash for his remarkable paper “The embedding problem for Riemannian manifolds,” *Ann. of Math.* (2) 63 (1956), 20–63

January 1999 – Mathematical Exposition: To Serge Lang for his many books. Among Lang’s most famous texts are *Algebra* [Addison-Wesley, Reading, MA, 1965; Second edition, 1984; Third edition, 1993, ISBN 0-201-55540-9] and *Algebraic Number Theory* [Addison-Wesley, Reading, MA, 1970; Second edition, Graduate Texts in Mathematics 110, Springer-Verlag, New York, 1994, ISBN 0-387-94225-4].

The Oswald Veblen Prize in Geometry

This prize was established in 1961 in memory of Professor Oswald Veblen through a fund contributed by former students and colleagues. The fund was later doubled by the widow of Professor Veblen, bringing the fund to \$2,000. The first two awards of the prize were made in 1964 and the next in 1966; thereafter, an award will ordinarily be made every five years for research in geometry or topology under conditions similar to those for the Bôcher Prize.

First award, 1964: To C. D. Papakyriakopoulos for his papers, *On solid tori*, *Annals of Mathematics*, Series 2, volume 66 (1957), pp. 1–26, and *On Dehn’s lemma and the asphericity of knots*, *Proceedings of the National Academy of Sciences*, volume 43 (1957), pp. 169–172.

Second award, 1964: To Raoul Bott for his papers, *The space of loops on a Lie group*, *Michigan Mathematical Journal*, volume 5 (1958), pp. 35–61, and *The stable homotopy of the classical groups*, *Annals of Mathematics*, Series 2, volume 70 (1959), pp. 313–337.

Third award, 1966: To Steven Smale for his contributions to various aspects of differential topology.

Fourth award, 1966: To Morton Brown and Barry Mazur for their work on the generalized Schoenflies theorem.

Fifth award, 1971: To Robion C. Kirby for his paper, *Stable homeomorphisms and the annulus conjecture*, *Annals of Mathematics*, Series 2, volume 89 (1969), pp. 575–582.

Sixth award, 1971: To Dennis P. Sullivan for his work on the Hauptvermutung summarized in the paper, *On the Hauptvermutung for manifolds*, *Bulletin of the American Mathematical Society*, volume 73 (1967), pp. 598–600.

Seventh award, 1976: To William P. Thurston for his work on foliations.

Eighth award, 1976: To James Simons for his work on minimal varieties and characteristic forms.

Ninth award, 1981: To Mikhael Gromov for his work relating topological and geometric properties of Riemannian manifolds.

Tenth award, 1981: To Shing-Tung Yau for his work in nonlinear partial differential equations, his contributions to the topology of differentiable manifolds, and for his work on the complex Monge-Ampère equation on compact complex manifolds.

Eleventh award, 1986: To Michael H. Freedman for his work in differential geometry and, in particular, the solution of the four-dimensional Poincaré conjecture.

Twelfth award, 1991: To Andrew J. Casson for his work on the topology of low-dimensional manifolds, and to Clifford H. Taubes for his foundational work in Yang-Mills theory.

Thirteenth award, 1996: To Richard Hamilton for his continuing study of the Ricci flow and related parabolic equations for a Riemannian metric, and to Gang Tian for his contributions to geometric analysis.

The Norbert Wiener Prize in Applied Mathematics

This prize was established in 1967 in honor of Professor Norbert Wiener and was endowed by a fund amounting to \$2,000 from the Department of Mathematics of the Massachusetts Institute of Technology. The prize is normally awarded every five years, beginning in 1970, for an outstanding contribution to "applied mathematics in the highest and broadest sense." The award is made jointly by the American Mathematical Society and the Society for Industrial and Applied Mathematics. The recipient must be a member of one of these societies and a resident of the United States, Canada, or Mexico.

First award, 1970: To Richard E. Bellman for his pioneering work in the area of dynamic programming, and for his related work on control, stability, and differential-delay equations.

Second award, 1975: To Peter D. Lax for his broad contributions to applied mathematics, in particular, for his work on numerical and theoretical aspects of partial differential equations and on scattering theory.

Third award, 1980: To Tosio Kato for his distinguished work in the perturbation theory of quantum mechanics.

Fourth award, 1980: To Gerald B. Whitham for his broad contributions to the understanding of fluid dynamical phenomena and his innovative contributions to the methodology through which that understanding can be constructed.

Fifth award, 1985: To Clifford S. Gardner for his contributions to applied mathematics in the areas of supersonic aerodynamics, plasma physics and hydromagnetics, and especially for his contributions to the truly remarkable development of inverse scattering theory for the solution of nonlinear partial differential equations.

Sixth award, 1990: To Michael Aizenman for his outstanding contribution of original and nonperturbative mathematical methods in statistical mechanics by means of which he was able to solve several long open important

problems concerning critical phenomena, phase transitions, and quantum field theory; and to Jerrold E. Marsden for his outstanding contributions to the study of differential equations in mechanics: he proved the existence of chaos in specific classical differential equations; his work on the momentum map, from abstract foundations to detailed applications, has had great impact.

Seventh award, 1995: To Hermann Flaschka for deep and original contributions to our understanding of completely integrable systems; and to Ciprian Foias, for basic contributions to operator theory, analysis, and dynamics and their applications.

Funds

AMS Centennial Fellowship Fund

This fund was established by the Society in 1973 and provides one-year Research Fellowships awarded each year in March. In 1988 the Fellowship was named to honor the AMS Centennial. The number of fellowships granted each year depends on the contributions the Society receives, matched by a contribution from the Society of not more than \$50,000. Over the years the fund has been targeted at different groups. In 1995 the Council of the AMS voted to direct the fellowships toward applicants who are citizens or permanent residents of a country in North America, who will have held their doctoral degrees for at least two years at the time of the award, who do not have permanent tenure, and who will have held less than two years of research support at the time of the award.

First award, 1974-1975: Fred G. Abramson, James Li-Ming Wang.

Second award, 1975-1976: Terence J. Gaffney, Paul Nèvai, George M. Reed.

Third award, 1976-1977: Fredric D. Ancel, Joseph A. Sgro.

Fourth award, 1977-1978: Steven Kalikow, Charles Patton, Duong-Hong Phong, David Vogan.

Fifth award, 1978-1979: Alan Dankner, David Harbater, Howard Hiller, Steven P. Kerckhoff, Robert C. McOwen.

Sixth award, 1979-1980: Scott W. Brown, Jeffrey E. Hoffstein, Jeffrey N. Kahn, James E. McClure, Rick L. Smith, Mark Steinberger.

Seventh award, 1980-1981: Robert K. Lazarsfeld, Thomas H. Parker, Robert Sachs.

Eighth award, 1981-1982: Lawrence Man-Hou Ein, Mark Williams.

Ninth award, 1982-1983: Nicholas J. Kuhn.

Tenth award, 1983-1984: Russell David Lyons.

Eleventh award, 1984-1985: Richard Timothy Durrett.

Twelfth award, 1985-1986: R. Michael Beals.

Thirteenth award, 1986-1987: Dinakar Ramakrishnan.

Fourteenth award, 1987-1988: Richard Hain, Bill Jacob.

Fifteenth award, 1988-1989: Steven R. Bell, Don M. Blasius, David Gabai.

Sixteenth award, 1989-1990: Isaac Y. Efrat, John M. Lee, Ralf J. Spatzier.

Seventeenth award, 1990-1991: Michael Anderson, Carolyn Gordon, Steven Mitchell.

Eighteenth award, 1991-1992: Daniel Blump, Kari Vilonen.

Nineteenth award, 1992-1993: Krzysztof Kurdzy, William Menasco, David Morrison.

Twentieth award, 1993-1994: Jacques Hurtubise, Andre Scedrov, David Webb.

Twenty-first award, 1994-1995: Patricia E. Bauman, David E. Marker.

Twenty-second award, 1995-1996: Rafael de la Llave, William Gordon McCallum, Kent Edward Orr.

Twenty-third award, 1996-1997: Yi Hu, Robert McCann, Alexander Voronov, Jiaping Wang.

Twenty-fourth award, 1997-1998: Ovidiu Costin, Fred Diamond, Gang Liu, Zhongwei Shen, Stephanie Singer.

Twenty-fifth award, 1998-1999: Mark Andrea A. de Cataldo, Stavros Garoufalidis, Sándor Kovács, Yanguang Li.

Twenty-sixth award, 1999-2000: Charles W. Rezk, Bin Wang, Changyou Wang, Tonghai Yang.

The Levi L. Conant Fund

Levi L. Conant bequeathed a sum of \$9,500 which the Trustees incorporated with the permanent endowments for prize funds.

Endowment Fund

In 1923 an Endowment Fund was collected to meet the greater demands on the publication program of the Society, demands caused by the ever-increasing number of important mathematical memoirs. Of this fund, which amounted to approximately \$94,000 in 1960, a considerable proportion was contributed by members of the Society. In 1961, upon the death of the last legatees under the will of the late Robert Henderson—for many years a Trustee of the Society—the entire principal of the estate was received by the Society, thereby bringing the Endowment Fund to approximately \$648,000.

Friends of Mathematics Fund

A Friends of Mathematics Fund has been created to incorporate monetary gifts to the Society of a general nature. The principal of this fund is now \$123,572. The proceeds of the fund are a part of the invested assets of the Society. The following gifts are components of this fund: \$1,000 from the estate of Professor Ernest William Brown; \$1,000 from the estate of Genevra B. Hutchinson; \$3,000 from Solomon A. Joffe; \$650 from the estate of Professor Helen A. Merrill; \$23,600 from the estate of Dean Marion Reilly; \$1,000 from the estate of James K. Whittemore; and \$2,700 from an anonymous donor.

The Karl Menger Fund

The family of the late Karl Menger were the major contributors to a fund established at Duke University totalling \$40,000. The majority of the income from this fund is to be used by the Society for annual awards at the International Science and Engineering Fair.

First award, 1990: Daniel K. Dugger, Joshua Erlich, Joshua B. Fischman, Min-Horng Chen, Matthew Baker, Michael L. Harrison, Virginia A. DiDomizio.

Second award, 1991: Monwhea Jeng, Hans Christian Gromoll, Jesse L. Tseng, Andrew Olstrom Dittmer, Matthew A. Neimark, Rageshree Ramachandran, Jeb E. Willenbring.

Third award, 1992: Mahesh Kalyana Mahanthappa, Harrison Kwei Tsai, Andrew Olstrom Dittmer, Jonobie Dale Baker, Joshua Brody, Yen-Hsiang Li, Robert Jordon Pollock.

Fourth award, 1993: Mahesh Kalyana Mahanthappa, Steve Shaw-Tang Chien, Andrew Olstrom Dittmer, Moon Duchin, Robert Michael Kirby II, Sarah Ann Lord, Anna Ruth Terry.

Fifth award, 1994: Davesch Maulik, Eric Matthew Dennis, Sarah Ann Lord, Timothy Stephen Eller, Rahul Manu Kohli, Fam-ye Lin, Benedek Valko, Mary Kathleen Clavenna, Vinay Kumak Goyal-Singhal, Jan Kristian Haugland, Wes Andres Watters, Ian George Zacharia.

Sixth award, 1995: Davesch Maulik, Benjamin Michael Goetz, Jacob Lurie, Daniel Kalman Biss, Samit Dasgupta, Yueh-Hsing Lin, Claus Mazanti Soerensen, Theodore Haw-Yun Hwa, Samuel Jacob Klein Jr., Katherine Anne Paur, Bridget Helen Penny, Scott Nicholas Sanders.

Seventh award, 1996: Davesch Maulik, Nicholas Karl Eriksson, Logan Joseph Kleinwaks, Eric Jon Landquist, Vanesa Miranda-Diaz, Jason Charles Stone, Lauren Kiyomi Williams, Ryan Thomas Hebert, Kendrick Norris Kay, Scott Nicholas Sanders, Claus Mazanti Sorensen, Yvette Karen Wood.

Eighth award, 1997: Davesch Maulik, Nicholas Eriksson, Jeremy Rahe, Jennifer Pelka, Yen-Jen Chen, Sylvain Halle, Melanie Schechter, Matthew Seligman, Thomas Mack, Susannah Rutherglen, Jy-Ying Janet Chen, Chun-Hsiang Fu, Daniel Ying-Jeh Little.

Ninth award, 1998: Jonathan Adam Kelner, Michael Yanchee Lee, Daniel Yamins, Alexey Evgenjevitch Eroshin, Sarah Flannery, Jeremy Ryan Rahe, Jennifer Rose Walk, Richard Lee Barnes, Matthew Christopher Ong, David Carl Rennard, Anna Welling Salamon, Hui Yu.

The Eliakim Hastings Moore Fund

This fund was donated in 1922 in honor of Professor Eliakim Hastings Moore on the occasion of the twenty-fifth anniversary of the Chicago (Western) section of the Society. The fund is \$2,575 and the income from the fund is to be used at the discretion of the Council for the publication of important mathematical books and memoirs and for the award of prizes.

The C. V. Newsom Fund

In 1990 the Society received a bequest of \$100,000 from the estate of Carroll V. Newsom. The bequest was made to memorialize John von Neumann and his accomplishments. The income from this fund is to be used to support a quadrennial symposium, called the von Neumann Symposium, that will focus on fundamental concepts in the forefront of mathematics.

The Program Development Fund

In 1993 the Executive Committee and Board of Trustees (ECBT) established the Program Development Fund

(formerly referred to as the General Fund). Gifts to the Program Development Fund are directed toward initiatives which address immediate needs of the mathematics community, enabling the AMS to act decisively and quickly. Contributions are matched dollar-for-dollar to a maximum of \$50,000. Programs supported are approved by the ECBT.

The Joseph Fels Ritt Memorial Fund

From the estate of Estelle F. Ritt, the income from a fund of \$22,500 is available for the publication of works in the field of mathematics as shall be determined by the governing bodies of the Society.

The Waldemar J. Trjitzinsky Memorial Fund

The Society received a bequest from the estate of Waldemar J., Barbara G., and Juliet Trjitzinsky, the income from which is used to assist students who have declared a major in mathematics at a college or university that is an institutional member of the AMS. These funds help support students who lack adequate financial resources and who may be in danger of not completing the degree program in mathematics for financial reasons. Each year the Society selects four geographically distributed schools who in turn make one-time awards of roughly \$2,500 each to beginning mathematical students to assist them in pursuit of careers in mathematics.

First award, 1992: Duke University, University of Scranton, Montana State University, Howard Payne University.

Second award, 1993: Allegheny College, Memphis State University, University of California at Irvine, University of Puerto Rico.

Third award, 1994: University of California at Los Angeles, State University of New York at Geneseo, Eastern New Mexico University, University of Virginia.

Fourth award, 1995: Boise State University, Illinois Institute of Technology, Temple University, University of Maryland at College Park.

Fifth award, 1996: Murray State University, Stanford University, Union College, Western Illinois University.

Sixth award, 1997: Georgetown University, Loyola Marymount University, New York University, Southern Illinois University at Carbondale.

AMS E-mail Support for Frequently Asked Questions

A number of non-user-specific electronic addresses have been established for contacting the AMS staff. The following is an updated list of those addresses together with a description of the types of inquiries that should be made through each address. This list is also available on the AMS's Web site, e-MATH, at <http://www.ams.org/ams/email.html>.

abs-info@ams.org

for questions regarding a particular abstract.

abs-submit@ams.org

for information on how to submit abstracts for AMS meetings and MAA sessions at January Joint Mathematics meetings. Type HELP as the subject line.

acquisitions@ams.org

to send correspondence to the AMS Acquisitions Department.

ams@ams.org

to contact the headquarters office in Providence, Rhode Island.

amsdc@ams.org

to contact the Society's office in Washington, DC.

amsmem@ams.org

to request information about membership in the AMS, or about dues payments, or to ask any general membership questions; may also be used to submit address changes.

bookstore@ams.org

for inquiries related to the online AMS bookstore.

classad@ams.org

to submit classified advertising for the *Notices*.

cust-serv@ams.org

for general information about AMS products (including electronic products); to send address changes, place credit card orders for AMS products, or conduct any general correspondence with the Society's Customer Services Department.

eims-info@ams.org

to request general information about deadlines and rates for *Employment Information in the Mathematical Sciences*.

ejour-submit@ams.org

to submit a manuscript to the AMS for *Representation Theory* and *Conformal Geometry and Dynamics*, electronic journals of the AMS. Each submission must be accompanied by the journal template. A copy of the template is available by sending e-mail to ejour-submit@ams.org. Put the word `template` in the subject field of the e-mail message. To get additional help, put the word `help` in the subject field in a separate mail message.

ejour-info@ams.org

for information about submitting to *Representation Theory* and *Conformal Geometry and Dynamics*, electronic journals of the AMS.

emp-info@ams.org

for information on AMS employment and career services.

eprod-support@ams.org

for technical questions regarding AMS electronic products and services.

era-submit@ams.org

for authors to submit research announcements to the electronic RA journal.

mathcal@ams.org



The Swiss Federal Institute of Technology Lausanne (EPFL) invites applications for three posts of

Professor of Applied Mathematics in the Department of Mathematics

The future professors will be mathematicians with an international reputation, proven by published work at the forefront of their fields. Candidates from all areas of applied mathematics are welcome. Specialists in the fields of probability or statistics, differential geometry, and discrete mathematics or optimization are particularly encouraged to apply. A taste and talent for multidisciplinary collaboration would be an asset. Teaching will be an important responsibility; the positions demand strong interest and skills in teaching and the ability to direct PhD/advanced research in mathematics.

The EPFL is an internationally-oriented technical university which offers competitive salaries, substantial start-up packages and excellent research and teaching facilities.

Applications are sought for appointments at the associate or full professor levels. The EPFL strongly encourages women to apply.

Deadline for registration: October 29, 1999. Starting date: upon mutual agreement. Please ask for the application form by writing or faxing to: **Présidence de l'Ecole polytechnique fédérale de Lausanne, CE-Ecublens, CH-1015 Lausanne, Suisse, fax +41 21 693 70 84.** For further information, please consult also URL: <http://www.epfl.ch>, <http://dmawww.epfl.ch/>, <http://admwww.epfl.ch/pres/profs.html> or <http://research.epfl.ch/>

From the AMS

to send information to be included in the "Mathematics Calendar" section of the *Notices*.

mathdoc@ams.org

for users of *Current Mathematical Publications*, *Mathematical Reviews*, and MathSci who wish to order a copy of an original item from the MathDoc document delivery system.

mathrev@ams.org

to submit reviews to *Mathematical Reviews* and to send related correspondence.

meet@ams.org

to request general information about Society meetings and conferences.

meetreg-request@ams.org

to request e-mail meeting registration forms.

meetreg-submit@ams.org

to submit completed e-mail registration forms.

msn-support@ams.org

for MathSciNet technical support.

notices@ams.org

to send correspondence to the managing editor of the *Notices*, including letters to the editor, contributed articles, and news items.

pub@ams.org

to send correspondence to the AMS Publication Division.

pub-submit@ams.org

to submit accepted manuscripts to AMS publications (other than *Abstracts*).

reprint-permission@ams.org

to request permission to reprint material from Society publications.

sales@ams.org

to inquire about reselling or distributing AMS publications, or send correspondence to the AMS sales department.

secretary@ams.org

to communicate with the secretary of the Society.

sos@ams.org

for information about AMS services to publishers.

statements@ams.org

to correspond regarding a balance due shown on a monthly statement.

tech-support@ams.org

to contact the Society's typesetting Technical Support group.

textbooks@ams.org

to inquire about using AMS publications as course texts.

webmaster@ams.org

for general information or for assistance in accessing and using e-MATH.

Scientific WorkPlace Word Notebook

The convergence of mathematical typesetting and computer algebra

The screenshot shows the Scientific Workplace interface. At the top, it says "The wave equation" and shows the partial differential equation $\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0$. Below this, it says "We solve this equation using MapleSolve PDE to get $u(x, y) = F_1(y+z) + F_2(y-z)$ let $F_1(t) = \cos t$ and $F_2(t) = -\sin t$. The resulting plot of $u(x, y)$ is:" followed by a 3D surface plot of a wave. At the bottom, it shows the formula
$$H_n = \frac{1}{2^n} \sum_{k=0}^n (-1)^k (n-k)^{n-2} \sum_{i_1, \dots, i_k=1}^n \prod_{j=1}^k \binom{n}{i_j}$$

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Publish using LaTeX
Solve complex problems with Maple® using standard math notation

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www.mackichan.com

Officers and Committee Members

Numbers to the left of headings are used as points of reference in an index to AMS committees which follows this listing. Primary and secondary headings are:

1. Officers
 - 1.1. Liaison Committee
2. Council
 - 2.1. Executive Committee of the Council
3. Board of Trustees
4. Committees
 - 4.1. Committees of the Council
 - 4.2. Editorial Committees
 - 4.3. Committees of the Board of Trustees
 - 4.4. Committees of the Executive Committee and Board of Trustees
 - 4.5. Internal Organization of the AMS
 - 4.6. Program and Meetings
 - 4.7. Status of the Profession
 - 4.8. Prizes and Awards
 - 4.9. Institutes and Symposia
 - 4.10. Joint Committees
5. Representatives
6. Index

Terms of members expire on January 31 following the year given unless otherwise specified.

1. Officers

President	Felix E. Browder	2000
Immediate Past President	Arthur M. Jaffe	1999
Vice Presidents	James G. Arthur	2001
	Jennifer Tour Chayes	2000
	H. Blaine Lawson, Jr.	1999
Secretary	Robert J. Daverman	2000
Former Secretary	Robert M. Fossum	2000
Associate Secretaries	John L. Bryant	2000
	Susan J. Friedlander	1999
	Bernard Russo	2001
	Lesley M. Sibner	2000
Treasurer	John M. Franks	2000
Associate Treasurer	B. A. Taylor	2000

1.1. Liaison Committee

All members of this committee serve *ex officio*.

Chair	Felix E. Browder
	Michael G. Crandall
	Robert J. Daverman
	John M. Franks

2. Council

2.0.1. Officers of the AMS

President	Felix E. Browder	2000
Immediate Past President	Arthur M. Jaffe	1999
Vice Presidents	James G. Arthur	2001
	Jennifer Tour Chayes	2000
	H. Blaine Lawson, Jr.	1999
Secretary	Robert J. Daverman	2000
Former Secretary	Robert M. Fossum	2000
Associate Secretaries*	John L. Bryant	2000
	Susan J. Friedlander	1999
	Bernard Russo	2001
	Lesley M. Sibner	2000
Treasurer	John M. Franks	2000
Associate Treasurer	B. A. Taylor	2000

2.0.2. Representatives of Committees

Bulletin	Donald G. Saari	2001
Colloquium	Susan J. Friedlander	2001
Executive Committee	John B. Conway	2000
Executive Committee	Andrew M. Odlyzko	1999
Executive Committee	Joel H. Spencer	2001
Journal of the AMS	Benedict H. Gross	2000
Mathematical Reviews	Hugh L. Montgomery	1998
and Monographs	Tudor Stefan Ratiu	2000
Mathematics of	Lars B. Wahlbin	2000
Computation	Clifford J. Earle, Jr.	2000
Proceedings		
Transactions and		
Memoirs	Peter B. Shalen	1999

*Only one Associate Secretary at a time is a voting member of the Council, namely the cognizant Associate Secretary for the scientific sessions.

2.0.3. Members at Large

Francis Bonahon	1999	M. Beth Ruskai	2000
Haim Brezis	2001	Donald G. Saari	2001
Robert L. Bryant	2000	Joel H. Spencer	1999
Robert A. Fefferman	2001	Michael Starbird	2000
Frederick P. Gardiner	1999	Tatiana Toro	2001
Jane M. Hawkins	2000	Karen Vogtmann	1999
Karen H. Parshall	2000	Nolan R. Wallach	2001
Gail D. L. Ratcliff	1999		

2.1. Executive Committee of the Council

Felix E. Browder	<i>ex officio</i>
John B. Conway	2000
Robert J. Daverman	<i>ex officio</i>
Arthur M. Jaffe	<i>ex officio</i>
Andrew M. Odlyzko	1999
Joel H. Spencer	2001
Karen Vogtmann	2002

3. Board of Trustees

Secretary	Roy L. Adler	2002
	Felix E. Browder	<i>ex officio</i>
Chair	Michael G. Crandall	2000
	John M. Franks	<i>ex officio</i>
	Linda Keen	2003
	Andy R. Magid	2001
	Donald E. McClure	1999
	B. A. Taylor	<i>ex officio</i>

4. Committees

4.1. Committees of the Council

Standing Committees

4.1.1. Editorial Boards

	George E. Andrews	2001
	Eric D. Bedford	1999
	David Jerison	2000
Chair	Abel Klein	2000
	Krystyna M. Kuperberg	2001
	Richard S. Palais	1999

4.1.2. Nominating Committee

Terms begin on January 1 and end on December 31 of the year listed.

	William Browder	2001
	Lisa Claire Jeffrey	2001
	Barbara L. Osofsky	1999
	John C. Polking	1999
Chair	Paul H. Rabinowitz	2000
	Marc A. Rieffel	2001
	James D. Stasheff	1999
	Elias M. Stein	2000
	Sylvia M. Wiegand	2000

4.2. Editorial Committees

4.2.1. Abstracts Editorial Committee

All members of this committee serve *ex officio*.

	John L. Bryant
Chair	Robert J. Daverman
	Susan J. Friedlander
	Bernard Russo
	Lesley M. Sibner

4.2.2. Bulletin (New Series)

	Haynes R. Miller	1999
Chief Editor	Donald G. Saari	2001
	Bhama Srinivasan	2000

Associate Editors for Book Reviews

Jim Douglas	1999	Ruth J. Williams	1999
Lawrence Craig Evans	2001	Wolfgang Ziller	2001
Alex J. Wilkie	2000		

Associate Editors for Research Reports

John M. Franks	2001	Hugo Rossi	2001
Eric M. Friedlander	2001	Daniel Ruberman	2001
Barry Mazur	2001	David A. Vogan	2001
Haynes R. Miller	2001	Robert J. Zimmer	1999

Associate Editors for Research – Expository Surveys

John C. Baez	2001	Karen Vogtmann	1999
Craig L. Huneke	2001	_____	1999
Douglas Lind	2001		

4.2.3. Collected Works

Chair	Jonathan L. Alperin	2000
	Elliott H. Lieb	1999
	Cathleen S. Morawetz	2000

4.2.4. Colloquium

	Joan S. Birman	2000
Chair	Susan J. Friedlander	2001
	Stephen Lichtenbaum	1999

4.2.5. Contemporary Mathematics

	Andreas Blass	2001
Chair	Dennis DeTurck	2001
	Andy R. Magid	2001
	Michael Vogelius	2001

4.2.6. Electronic Research Announcements

	Stuart Antman	1999
	Douglas N. Arnold	2000
	David J. Benson	2001
	Dimitri Burago	2000
	Alexandre J. Chorin	1999
	Mark Freidlin	1999
	James G. Glimm	2000
	Ronald L. Graham	2000
Chair	Svetlana R. Katok	2000
	Yitzhak Katznelson	2001
	David Kazhdan	2001
	Alexander S. Kechris	1999
	Alexandre A. Kirillov	1999
	Frances C. Kirwan	1999
	Krystyna M. Kuperberg	1999
	Robert K. Lazarsfeld	2001
	Grigori A. Margulis	1999
	Hugh L. Montgomery	2000
	Walter David Neumann	2000
	Klaus Schmidt	2000
	Richard M. Schoen	2001
	Masamichi Takesaki	2000

Michael E. Taylor	2001
Thomas H. Wolff	1999
Zhihong (Jeff) Xia	2000
Don B. Zagier	2001
Efim I. Zelmanov	2000

4.2.7. Graduate Studies in Mathematics

Chair	James E. Humphreys	2000
	David J. Saltman	1999
	David Sattinger	2001
	Ronald J. Stern	2001

4.2.8. Journal of the AMS

Chair	Ingrid Daubechies	2001
	Benedict H. Gross	2000
	Carlos E. Kenig	2000
	Bernd Sturmfels	2001
	Clifford Taubes	2000

Associate Editors

James G. Arthur	1999	Robert K. Lazarsfeld	1999
Alexander Beilinson	2001	Grigori A. Margulis	2000
F. Michael Christ	2001	Curtis T. McMullen	1999
Constantine M. Dafermos	2001	Marina Ratner	2000
A. J. de Jong	2001	Richard M. Schoen	2000
Lawrence Craig Evans	2001	Richard P. Stanley	2000
Michael J. Hopkins	1999	W. Hugh Woodin	1999
Ehud Hrushovski	2000	Efim I. Zelmanov	2001
Henryk Iwaniec	1999		

4.2.9. Mathematical Reviews

AMS staff contact: Jane E. Kister.

	Jonathan L. Alperin	2000
	Yuji Ito	2000
	Jean-Louis Loday	1999
	Joyce R. McLaughlin	1999
Chair	Hugh L. Montgomery	1998
	Clarence Wilkerson	1998

4.2.10. Mathematical Surveys and Monographs

	Georgia Benkart	1999
	Peter Landweber	2000
	Michael Loss	2001
Chair	Tudor Stefan Ratiu	2000

4.2.11. Mathematics of Computation

	Stanley J. Osher	2001
	René Schoof	2001
Chair	Lars B. Wahlbin	2000
	Joseph D. Ward	2001

Associate Editors

David W. Boyd	2000	Harald Niederreiter	1999
James H. Bramble	2000	Ricardo Horacio Nochetto	
Susanne C. Brenner	2001		2001
Richard P. Brent	2000	Haesun Park	2001
Joe P. Buhler	2000	Joseph E. Pasciak	2001
Carsten Carstensen	2000	Lothar Reichel	2001
Arjeh M. Cohen	1999	Chi-Wang Shu	2001
Howard Elman	2000	Frank Stenger	2001
Richard Falk	2001	Nico M. Temme	2001
Andrew J. Granville	2001	Vidar Thomée	2000
Daniel W. Lozier	2001	Hugh C. Williams	2000
James N. Lyness	1999	Stephen J. Wright	2000
Roswitha März	1999		

4.2.12. Notices Editorial Board

Terms begin on January 1 and expire on December 31 of the year listed

Editor	Anthony W. Knapp	2000
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Associate Editors

Hyman Bass	2000	Steven G. Krantz	2000
Robert J. Daverman		Susan Landau	2000
		<i>ex officio</i> Andy R. Magid	2000
Susan J. Friedlander	2000	Judith Roitman	2000
Martin Golubitsky	2000	M. Beth Ruskai	2000
Victor W. Guillemin	2000	Mark E. Saul	2000
David Jerison	2000		

4.2.13. Proceedings

Coordinating	Mark J. Ablowitz	2002
	Dale Alspach	1999
	Albert Baernstein	1999
	Joseph A. Ball	2002
	Dan Barbasch	2002
Coordinating	Eric D. Bedford	2000
	Steven R. Bell	2000
	Jonathan Borwein	2002
	John A. Burns	1999
	Suncica Canic	2000
	Carmen C. Chicone	2003
	Bennett Chow	2002
	Ralph L. Cohen	2000
	Christopher B. Croke	1999
	J. Dodziuk	2000
	Alan Dow	1999
Chair	Clifford J. Earle, Jr.	2000
Coordinating	Ronald A. Fintushel	2002
	Kenneth R. Goodearl	2000
	Michael Handel	2001
	Dennis A. Hejhal	1999
	Rebecca A. Herb	2002
	Carl G. Jockusch, Jr.	2000
Coordinating	Linda Keen	2001
	David R. Larson	2000
	Wei Y. Loh	1999
	Claudia M. Neuhauser	2002
	David Preiss	2002
	David E. Rohrlich	2000
	Leslie D. Saper	1999
	David H. Sharp	1999
Coordinating	Lance W. Small	1999
	Stephen D. Smith	2002
	Christopher D. Sogge	2001
	John R. Stembridge	2001
	Michael Stillman	2002
	David S. Tartakoff	2002
	Wolmer V. Vasconcelos	1999

4.2.14. Proceedings of Symposia in Applied Mathematics

Chair	Marsha J. Berger	2000
	Peter S. Constantin	2001
	Eitan Tadmor	1999

4.2.15. Transactions and Memoirs

	Rodrigo Banuelos	1999
	William Beckner	2002
	Bruce E. Blackadar	2001
	Daniel M. Burns	1998
	Charles W. Curtis	2001
	Lawrence M. Ein	2002
	Philip J. Hanlon	1999
	Barbara L. Keyfitz	2001
	John E. Luecke	2000
	John J. Mallet-Paret	1999
	Stewart B. Priddy	1999
Chair	Peter B. Shalen	1999
	Alice Silverberg	1999
	Theodore A. Slaman	2000
	Robert J. Stanton	2001
	Chuu-Lian Terng	2000
	Robert F. Williams	2001

4.2.16. Translation from Chinese

	Sun-Yung Alice Chang	
	S.-Y. Cheng	
Chair	Tsit-Yuen Lam	
	Tai-Ping Liu	
	Chung-Chun Yang	

4.2.17. Translation from Japanese

Chair	Shoshichi Kobayashi	1999
	Masamichi Takesaki	1999

Standing Committees

4.2.18. Conformal Geometry and Dynamics

	Kari Astala	2000
	Frederick W. Gehring	2000
Chair	Linda Keen	1999
	Tan Lei	2002
	Misha Lyubich	1999
	Howard Masur	1998
	Mitsuhiro Shishikura	1998

4.2.19. History of Mathematics

	George E. Andrews	1999
	Bruce Chandler	1999
Chair	Karen H. Parshall	2000
	George B. Seligman	2000

4.2.20. Representation Theory

	Anthony W. Knap	2000
	James Lepowsky	2001
	George Lusztig	2000
	Dragan Milicic	2001
	Birgit Speh	1999
Chair	David A. Vogan	1999

4.2.21. Reprinted Books

	Charles W. Curtis	2001
	Oscar S. Rothaus	2000
	Guido Weiss	1999

4.2.22. Student Mathematics Library

	David M. Bressoud	2001
Chair	Robert L. Devaney	2001
	Carl Pomerance	2001
	Hung-Hsi Wu	2001

4.2.23. University Lecture Series

Chair	Jerry L. Bona	1999
	Jean-Luc Brylinski	2001
	Nicolai Reshetikhin	1999
	Leonard L. Scott	1999

4.3. Committees of the Board of Trustees

4.3.1. Agenda and Budget

All members of this committee serve *ex officio*.

Felix E. Browder
Michael G. Crandall
Robert J. Daverman
John M. Franks
Andrew M. Odlyzko
B. A. Taylor

4.3.2. Appeals Committee on Discounted Subscriptions

AMS staff contact: Cheryl Marino.

	Michael G. Crandall	
	John H. Ewing	<i>ex officio</i>
	John M. Franks	
Chair	Morton Lowengrub	
Consultant	Cheryl Marino	
Consultant	Hugh L. Montgomery	

4.3.3. Audit

All members of this committee serve *ex officio*.

AMS staff contact: Gary G. Brownell.

Michael G. Crandall
John M. Franks

4.3.4. Endowment and Planned Giving

AMS staff contact: Timothy J. Goggins.

	Roy L. Adler	2000
Chair	Michael G. Crandall	<i>ex officio</i>
	Arthur M. Jaffe	2000
	Cathleen S. Morawetz	2000
	_____	2000

4.3.5. Investment

AMS staff contact: Gary G. Brownell.

	Roy L. Adler	<i>ex officio</i>
Chair	John M. Franks	<i>ex officio</i>
	B. A. Taylor	<i>ex officio</i>
	_____	2000

4.3.6. Salaries

All members of this committee serve *ex officio*.

	Michael G. Crandall
Chair	John M. Franks
	Andy R. Magid
	B. A. Taylor

4.3.7. Staff and Services

All members of this committee serve *ex officio*.

	Roy L. Adler
	John M. Franks
Chair	B. A. Taylor

Special Committee

4.3.8. Search Committee for the Editor of the Notices

Chair	Robert J. Daverman
	John H. Ewing
	David Jerison
	Krystyna M. Kuperberg

4.4. Committees of the Executive Committee and Board of Trustees

4.4.1. Long Range Planning

All members of this committee serve *ex officio*.
AMS staff contact: Raquel E. Storti.

	Felix E. Browder
Chair	John B. Conway
	Michael G. Crandall
	Robert J. Daverman
	John H. Ewing
	John M. Franks
	Joel H. Spencer

4.4.2. Nominating

All members of this committee serve *ex officio*.

	Roy L. Adler
Chair	Andy R. Magid
	Andrew M. Odlyzko
	Paul H. Rabinowitz
	Joel H. Spencer

4.5. Internal Organization of the American Mathematical Society

Standing Committees

4.5.1. Archives

	Robert M. Fossum	2001
Chair	Karen H. Parshall	1999
	Everett Pitcher	2000

4.5.2. Committee on Committees

	Josefina Alvarez	2000
Chair	Jerry L. Bona	2000
	Felix E. Browder	<i>ex officio</i>
	Tony F. Chan	2000
	Robert J. Daverman	<i>ex officio</i>
	Carlos E. Kenig	2000
	Yanyan Li	2000
	Andy R. Magid	2000
	William A. Massey	2000
	Frank S. Quinn	2000
	Karen E. Smith	2000
	Joel H. Spencer	2000
	Efim I. Zelmanov	2000

4.5.3. Library Committee

Co-chair	Bruce C. Berndt	2000
	R. Keith Dennis	2000
	Lawrence S. Husch	1999
	Carol Hutchins	1999
	Robert S. Seeds	2000
	Martha A. Tucker	1999
	Molly White	2000
	Hung-Hsi Wu	1999

4.5.4. Publications

AMS staff contact: Donald G. Babbitt.

	Roy L. Adler	1999
	Donald G. Babbitt	<i>ex officio</i>
	Felix E. Browder	<i>ex officio</i>
	Robert L. Bryant	2000
	Robert J. Daverman	<i>ex officio</i>
	John H. Ewing	<i>ex officio</i>
	Jay R. Goldman	2001
	Abel Klein	1999
	M. Susan Montgomery	1999
	Gail D. L. Ratcliff	1999
	Donald G. Saari	2001
	Ronald J. Stern	2001
Chair	Srinivasa S. R. Varadhan	1999
		2001

4.6. Program and Meetings

Standing Committees

4.6.1. Meetings and Conferences

AMS staff contact: H. Hope Daly.

	James G. Arthur	2001
	Felix E. Browder	<i>ex officio</i>
	Karen L. Collins	2001
	Robert J. Daverman	<i>ex officio</i>
	John H. Ewing	<i>ex officio</i>
	Donald E McClure	1999
	Rick Miranda	2001
	Karen H. Parshall	2000
Chair	Joel H. Spencer	1999
	Michael Starbird	2000
	Karen Vogtmann	1999
	Sylvia M. Wiegand	1999

4.6.2. Program Committee for National Meetings

	Robert J. Daverman	<i>ex officio</i>
	Daniel S. Freed	2000
	Isom H. Herron	1999
	George C. Papanicolaou	2001
Chair	Linda P. Rothschild	2000
	Leon A. Takhtajan	2000
	Dan Voiculescu	1999

4.6.3. Short Course Subcommittee

	Samuel R. Buss	2001
	Martin Golubitsky	2001
Chair	Michael J. Kallaher	2000
	Svetlana R. Katok	2000
	Bertram M. Schreiber	2000
	James A. Sethian	1999

4.6.4. Central Section Program Committee

	Georgia Benkart	2000
	Susan J. Friedlander	<i>ex officio</i>
Chair	Jerry Kaminker	1999
	Rafael de la Llave	2000
	Henri Moscovici	1999

4.6.5. Eastern Section Program Committee

	Paul F. Baum	1999
	Louis J. Billera	2000
	David A. Cox	2000
Chair	Mikhail A. Shubin	1999
	Lesley M. Sibner	<i>ex officio</i>

Officers and Committee Members

4.6.6. Southeastern Section Program Committee

	John L. Bryant	<i>ex officio</i>
	Eric A. Carlen	1999
Chair	Andrew J. Granville	1999
	Richard M. Hain	2000
	Irena M. Lasiecka	2000

4.6.7. Western Section Program Committee

Chair	William G. Faris	1999
	David Gabai	2000
	Sorin Popa	1999
	Bernard Russo	<i>ex officio</i>
	Audrey A. Terras	2000

4.6.8. Agenda for Business Meetings

Chair	Robert J. Daverman	<i>ex officio</i>
	Raymond L. Johnson	2000
	Robert K. Lazarsfeld	2000

4.6.9. Arnold Ross Lecture Series Committee

	Kenneth I. Gross	2000
Chair	Deborah T. Haimo	2000
	Robert Osserman	1999
Consultant	Paul J. Sally, Jr.	
	Andre Toom	2000

4.6.10. Colloquium Lecture

	David Jerison	2001
Chair	Richard M. Schoen	1999
	Andrew Wiles	2000

4.6.11. Gibbs Lecturer for 1999 and 2000, Committee to Select

Chair	George W. Mackey
	David Ruelle
	Clarence Eugene Wayne

4.6.12. Program Committee for the Year 2000 Meeting on Problems, Programs, and Prospects of 21st Century Mathematics

	Richard A. Askey	1999
	Spencer J. Bloch	1999
Chair	Felix E. Browder	1999
	Charles L. Fefferman	1999
	Arthur M. Jaffe	1999
	Peter D. Lax	1999
	Robert D. MacPherson	1999
	David Mumford	1999
	Gian-Carlo Rota	1999
	Peter Sarnak	1999
	Audrey A. Terras	1999
	Srinivasa S. R. Varadhan	1999

4.6.13. Progress in Mathematics

_____	2000
_____	2001
_____	2000

4.6.14. World Mathematical Year 2000, Blue Ribbon Committee for

Chair	Felix E. Browder
	Robert M. Fossum
	Ronald L. Graham
	Peter D. Lax
	Cathleen S. Morawetz
	Peter Sarnak
	Audrey A. Terras
	William P. Thurston

Special Committee

4.6.15. Arrangements Committee for Mathematical Challenges of the 21st Century, University of California, Los Angeles, August 7–12, 2000

	Christopher R. Anderson
Chair	Tony Chan
	Philip C. Curtis, Jr.
	Bjorn Engquist
	John B. Garnett
	Thomas M. Liggett
	Barry Simon
	Eitan Tadmor

4.7. Status of the Profession

Standing Committees

4.7.1. Academic Freedom, Tenure, and Employment Security

	William Abikoff	1999
	Bruce E. Blackadar	2001
	James L. Heitsch	2001
	Irwin Kra	2000
Chair	Arlan B. Ramsay	1999
	Seymour Schuster	2000
	Abigail A. Thompson	2001

4.7.2. Education

AMS staff contact: Samuel M. Rankin III.

	Michael Aschbacher	1999
	Richard A. Askey	2000
Chair	Hyman Bass	1999
	Francis Bonahon	1999
	Felix E. Browder	<i>ex officio</i>
	Charles Herbert Clemens	2001
	Jere Confrey	2000
	Robert J. Daverman	<i>ex officio</i>
	John H. Ewing	<i>ex officio</i>
	Robert A. Fefferman	2001
	Arthur M. Jaffe	<i>ex officio</i>
	William James Lewis	2001
	Andy R. Magid	1999
	Judith Roitman	2001
	Alan C. Tucker	1999

4.7.3. Human Rights of Mathematicians

	Francis Bonahon	2000
	Susan J. Friedlander	2000
	Pao-sheng Hsu	2001
	Neal I. Koblitz	1999
	Tsit-Yuen Lam	2001
Chair	Joel L. Lebowitz	1999
	Robert D. MacPherson	1999
	Alice T. Schafer	2000
	David A. Vogan	2001

4.7.4. Profession

AMS staff contact: James W. Maxwell.

	M. Salah Baouendi	1999
	William Beckner	2001
	Haim Brezis	2001
	Felix E. Browder	<i>ex officio</i>
	Jennifer Tour Chayes	2000
	Annalisa Crannell	1999
	Robert J. Daverman	<i>ex officio</i>
	John H. Ewing	<i>ex officio</i>
	Linda Keen	1999
	H. Blaine Lawson, Jr.	1999
	Joseph Lipman	1999
Chair	Donald E. McClure	2001
	Frank S. Quinn	2001
	Jonathan Rosenberg	2001
	Karen E. Smith	2001

4.7.5. Professional Ethics

	Donald L. Burkholder	2000
	Sylvain E. Cappell	2001
	Lee D. Mosher	2000
	Paul S. Muhly	2001
	Christel Rotthaus	2000
Chair	Claude L. Schochet	1999

4.7.6. Science Policy

AMS staff contact: Samuel M. Rankin III.

	Hyman Bass	<i>ex officio</i>
	Felix E. Browder	<i>ex officio</i>
	Michael G. Crandall	1999
	Robert J. Daverman	<i>ex officio</i>
	John H. Ewing	<i>ex officio</i>
	Susan J. Friedlander	1999
	Frederick P. Gardiner	1999
	Jane M. Hawkins	2000
	Roger E. Howe	2000
Chair	Arthur M. Jaffe	<i>ex officio</i>
	M. Beth Ruskai	2001
	Daniel W. Stroock	2000
	Nolan R. Wallach	2001
	Efim I. Zelmanov	2001
	_____	2000
	_____	2001

4.7.7. Young Scholars Program, Interim Committee on the

	Leonore J. Cowen	2001
	Michael Sipser	2001
Chair	Joel H. Spencer	2001
	Karen Vogtmann	2001

4.8. Prizes and Awards

Standing Committees

4.8.1. Award for Public Service, Committee to Select the Winner of the

	Frederick W. Gehring	2002
	Ronald L. Graham	2000
	Peter D. Lax	2001
Chair	D. J. Lewis	2003
	Everett Pitcher	1999

4.8.2. Centennial Fellowships

Terms expire on June 30

	Frederic Davis Ancel	2001
	Richard T. Durrett	2000
	Robert Hardt	2001
	Janos Pach	2001
	Richard P. Stanley	2000
Chair	Nancy K. Stanton	2000
	Steven H. Weintraub	2000

4.8.3. Menger Prize Committee

Terms expire on May 31

	Gisele R. Goldstein	2001
	Mubenga Ngandu Nkashama	2000
Chair	Peter V. O'Neil	2000
	Julian I. Palmore	2002

4.8.4. National Awards and Public Representation

Chair	Felix E. Browder	<i>ex officio</i>
	Robert J. Daverman	<i>ex officio</i>
	Melvin Hochster	1999
	Arthur M. Jaffe	<i>ex officio</i>
	Joseph J. Kohn	2000
	John W. Milnor	2000
	Cathleen S. Morawetz	1999

4.8.5. Satter Prize, Committee to Select the Winner of the

Chair	Sun-Yung Alice Chang	2000
	Peter Sarnak	1999
	Bhama Srinivasan	2002

4.8.6. Steele Prizes

	Ciprian I. Foias	1999
	Bertram Kostant	2000
	Hugh L. Montgomery	2001
	Louis Nirenberg	1999
	Marc A. Rieffel	2000
Chair	Jonathan M. Rosenberg	2000
	John T. Tate	1999
	Francois Treves	2001
	S. R. S. Varadhan	2001

Special Committee

4.8.7. Automatic Theorem Proving, Committee to Recommend Winners of Prizes for

4.8.8. Cole Prize

	Simon K. Donaldson
	William Fulton
Chair	Efim I. Zelmanov

4.8.9. Veblen Prize

Chair	Mikhael Gromov
	Richard S. Hamilton
	Robion C. Kirby
	Gang Tian

4.9. Institutes and Symposia

Standing Committees

4.9.1. Liaison Committee with AAAS

Lenore Blum	<i>ex officio</i>
Ronald G. Douglas	<i>ex officio</i>
John H. Ewing	1999
Robert M. Fossum	<i>ex officio</i>
Gene H. Golub	<i>ex officio</i>
Evans M. Harrell	<i>ex officio</i>
Jerrold E. Marsden	2000
Warren Page	<i>ex officio</i>
Yum Tong Siu	1999
Ronny O. Wells	2000
_____	1999

4.9.2. Summer Institutes and Special Symposia

Terms expire on February 28

Lawrence Craig Evans	2001
János Kollár	2002
Krystyna M. Kuperberg	2002
Jeffrey B. Rauch	2000
Leon A. Takhtajan	2000
Clarence Eugene Wayne	2001

Chair

4.10. Joint Committees

4.10.1. AMS-ASA-AWM-IMS-MAA-NCTM-SIAM Committee on Women in the Mathematical Sciences

NCTM members' terms expire April 1 of the year given.

Susan R. Ackerman (ASA)	2000
Ann S. Almgren (SIAM)	1999
Mary E. Flahive (MAA)	2000
Ena Gross (NCTM)	1999
Diane L. Herrmann (AWM)	2000
Erica Jen (AMS)	2000
Deborah Lockhart (SIAM)	1998
Harriett M. Lord (MAA)	2000
Connie Page (IMS)	1998
Gail D. Ratcliff (AWM)	2001
Rosemary A. Renaut (AMS)	2001
Tamar Schlick (SIAM)	1999
Sanford Segal (MAA)	1998
Tara L. Smith (AWM)	1999
Elizabeth Stasy (IMS)	2000
Mary Wheeler (AMS)	2001
Patricia J. Wozniak (ASA)	1999
_____ (AMS)	2001

Chair

4.10.2. AMS-IMS-SIAM Committee on Joint Summer Research Conferences in the Mathematical Sciences

Terms expire on June 30

Alejandro Adem (AMS)	2000
Paul F. Baum (AMS)	2002
David Brydges (AMS)	2001
James W. Demmel (AMS)	2000
Dipak Dey (IMS)	2000
Tom DiCiccio (IMS)	2000
Steven Hurder (AMS)	2001
Alan F. Karr (AMS)	2000
Barbara L. Keyfitz (SIAM)	2000
W. Brent Lindquist (AMS)	2001
Andrzej Manitius (SIAM)	2000
Bart S. Ng (SIAM)	2000

Chair

4.10.3. AMS-MAA Committee on Cooperation

All members of this committee serve *ex officio*.

Gerald L. Alexanderson (MAA)
Thomas F. Banchoff (MAA)
Felix E. Browder (AMS)
Robert J. Daverman (AMS)
John H. Ewing (AMS)
Arthur M. Jaffe (AMS)
Martha J. Siegel (MAA)
Marcia P. Sward (MAA)

4.10.4. AMS-MAA Committee on Mathematicians with Disabilities

Lawrence W. Baggett (AMS)	2001
Robert Coleman (AMS)	2000
John D. Fulton (MAA)	2000
Carlos E. Kenig (AMS)	1999
Eileen L. Poiani (MAA)	2000
Jon Wilkin (MAA)	1999

4.10.5. AMS-MAA Committee on Research in Undergraduate Mathematics Education (CRUME)

George E. Andrews (AMS)	2000
Hyman Bass (AMS)	1999
Anne E. Brown (MAA)	2001
Ed Dubinsky (MAA)	2000
Joan Ferrini-Mundy (NCTM)	2001
Gregory D. Foley (AMATYC)	2001
Daniel L. Goroff (AMS)	1999
James J. Kaput (MAA)	1999
R. Bruce Lind (MAA)	2000
Herbert S. Wilf (AMS)	2001

Chair

4.10.6. AMS-MAA Committee on Teaching Assistants and Part-time Instructors (TA/PTI)

Curtis D. Bennett (AMS)	1999
Neil J. Calkin (AMS)	2000
Reuben Drake (MAA)	1998
John B. Garnett (AMS)	2001
James Kister (AMS)	2000
Teri J. Murphy (MAA)	2000
Stephen B. Rodi (MAA)	2000
Raymond O. Wells (MAA)	1998

4.10.7. AMS-MAA Joint Archives Committee

Robert M. Fossum (AMS)	2001
Victor Katz (MAA)	2000
John H. McCleary (MAA)	1999
Karen H. Parshall (AMS)	1999
Everett Pitcher (AMS)	2000
James J. Tattersall (MAA)	1998

Chair

4.10.8. AMS-MAA Joint Meetings Committee

All members of this committee serve *ex officio*.

Consultant	H. Hope Daly
	Robert J. Daverman
	John H. Ewing
	Marcia P. Sward
Chair	James J. Tattersall

4.10.9. AMS-MAA Exhibits Advisory Subcommittee

Donald J. Albers
 Paula Brister
 H. Hope Daly
 Co-Chair Robert J. Daverman
 Joe Fountain
 Annette Emerson
 Ruediger J. Gebauer
 Joyce Glynn
 Debbie Hamar
 David J. Lerner
 Fred Osborne
 Elaine Pedreira-Sullivan
 Penny Pina
 Co-Chair James J. Tattersall

4.10.10. AMS-MAA Arrangements Committee for the Washington, DC Meeting January 19–22, 2000

Chair Carole B. Lacampagne
 Ronald C. Rosier

4.10.11. AMS-MAA-SIAM Joint Program Committee for the Washington, DC Meeting

Chair Gerald Alexanderson (MAA)
 Jennifer Tour Chayes (AMS)
 Dan Freed (AMS)
 Barbara L. Keyfitz (SIAM)
 David Levermore (SIAM)
 Robert Osserman (MAA)

4.10.12. AMS-MAA Arrangements Committee for the New Orleans Meeting January 10–13, 2001

Chair Charles S. Rees

4.10.13. AMS-MAA-SIAM Joint Administrative Committee

All members of this committee serve *ex officio*.

Thomas F. Banchoff (MAA)
 James M. Crowley (SIAM)
 Robert J. Daverman (AMS)
 John H. Ewing (AMS)
 John M. Franks (AMS)
 Samuel Gubins (SIAM)
 Martha J. Siegel (MAA)
 Gilbert Strang (SIAM)
 Marcia P. Sward (MAA)

4.10.14. AMS-MAA-SIAM Joint Committee on Employment Opportunities

AMS staff contact: James W. Maxwell.

William G. Bade (AMS) 2000
 James W. Bond (AMS) 1999
 Neil J. Calkin (AMS) 2000
 J. Kevin Colligan (MAA) 2000
 James W. Daniel (MAA) 2000
 David A. Field (SIAM) 2000
 James W. Maxwell *ex officio*
 Chair Thomas W. Rishel (MAA) 1999
 David S. Ross (SIAM) 2000

4.10.15. AMS-MAA-SIAM Joint Policy Board for Mathematics (see 1999 Mathematical Sciences Professional Directory, page 31)

4.10.16. AMS-MAA-SIAM Morgan Prize Committee for Outstanding Research in Mathematics by an Undergraduate Student

Chair George E. Andrews (AMS) 2000
 Kelly J. Black (SIAM) 2000
 Catherine A. Roberts (SIAM) 1999
 Robert O. Robson (MAA) 1999
 Martha J. Siegel (MAA) 2000
 Trevor Wooley (AMS) 1999

4.10.17. AMS-SIAM Committee on Applied Mathematics

James W. Demmel 1998
 Tai-Ping Liu 1998
 Juan C. Meza 1997
 Tamar Schlick 1997
 _____ 1999
 _____ 1999

4.10.18. AMS-SIAM-SMB Committee on Mathematics in the Life Sciences

Stephen D. Ellner 2000
 Lisa Fauci 2000
 Michael C. Mackey 1999
 John M. Rinzel 1999
 Michael S. Waterman 1998
 Carla Wofsy 1998

4.10.19. AMS-SIAM Committee to Select the Winner of the Wiener Prize for 2000

Chair Hermann Flaschka
 Ciprian Ilie Foias
 Charles S. Peskin

4.10.20. Annual Survey Data Committee

AMS staff contact: James W. Maxwell.

Paul W. Davis (AMS) 1999
 Lorraine Denby (ASA) 2000
 Mary W. Gray (MAA) 1999
 Alfred W. Hales (AMS) 2000
 James Kister (AMS) 2001
 William James Lewis (AMS) 2001
 Chair Don O. Loftsgaarden (MAA) 1999
 James W. Maxwell (AMS) *ex officio*
 Yashaswini Mittal (IMS) 2001
 Ann E. Watkins (MAA) 1999
 _____(AMS) 2001

Special Committee

4.10.21. AMS-AMS (American Mathematical Society-Australian Mathematical Society) Joint Program Committee, Australia July 5–9, 1999

Chair Ezra Getzler
 William H. Jaco
 Richard B. Melrose
 Ruth J. Williams

4.10.22. AMS-Hong Kong Mathematical Society Joint Program Committee, Hong Kong, December 13–17, 2000

Chair Peter W. K. Li
 Bernard Russo *ex officio*
 Zhouping Xin
 Lai-Sang Young

Officers and Committee Members

4.10.23. AMS-Nordic Joint Program Committee, Denmark, June 12–15, 2000

William Browder
Robert M. Fossum
Karsten Grove
Berit Stenones

4.10.24. AMS-SMM Joint Program Committee, Denton Meeting May 19–22, 1999

Alfonso Castro
Monica Clapp
David McLaughlin
Rick Miranda
Victor Perez-Abreu
Eduardo Rivera-Campo
Ronald J. Stern
Rafael H. Villarreal

4.10.25. AMS-Société de Mathématique de France Joint Program Committee, France, July 17–20, 2001

L. Craig Evans
Robin Hartshorne
Lisa Jeffrey
Barry Mazur
Lesley M. Sibner

Chair

ex officio

5. Representatives

5.0.1. American Association for the Advancement of Science

Terms expire on February 21

Section A	Robert M. Fossum	2001
Section Q	Evans M. Harrell	2001

5.0.2. Commission on Professionals in Science and Technology

Ann K. Stehney 1999

5.0.3. Committee on the American Mathematics Competition

Term expires on June 30

Noam Elkies 2000

5.0.4. Canadian Mathematical Society

M. Beth Ruskai 2000

5.0.5. Conference Board of the Mathematical Sciences

Felix E. Browder 2000

5.0.6. Fulkerson Prize Committee

Ronald L. Graham

5.0.7. Joint Public Service Award Committee of the AAS-AMS-APS

Felix Browder	2000
Arthur M. Jaffe	2001

5.0.8. MAA Committee on Undergraduate Program in Mathematics

Amy Cohen Corwin	1999
Peter Hinman	1999

5.0.9. U.S. National Committee on Theoretical and Applied Mechanics

Term expires on October 31

Philip John Holmes 2000

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Add this Cover Sheet to all of your Academic Job Applications

How to use this form

1. Using the facing page or a photocopy, (or a T_EX version which can be downloaded from the e-math "Employment Information" menu, <http://www.ams.org/employment/>), fill in the answers which apply to *all* of your academic applications. Make photocopies.
2. As you mail each application, fill in the remaining questions neatly on one cover sheet and include it *on top of* your application materials.

The Joint Committee on Employment Opportunities has adopted the cover sheet on the facing page as an aid to job applicants and prospective employers. The form is now available on e-math in a T_EX format which can be downloaded and edited. The purpose of the cover form is to aid department staff in tracking and responding to each application.

Mathematics Departments in Bachelor's, Master's and Doctorate granting institutions have been contacted and are expecting to receive the form from each applicant, along with any other application materials they require. Obviously, not all departments will utilize the cover form information in the same manner. Please direct all general questions and comments about the form to: emp-info@ams.org or call the Professional Programs and Services Department, AMS, at 800-321-4267 extension 4105.

JCEO Recommendations for Professional Standards in Hiring Practices

The JCEO believes that every applicant is entitled to the courtesy of a prompt and accurate response that provides timely information about his/her status. Specifically, the JCEO urges all institutions to do the following after receiving an application:

- (1) Acknowledge receipt of the application—immediately; and
- (2) Provide information as to the current status of the application, as soon as possible.

The JCEO recommends a triage-based response, informing the applicant that he/she

- (a) is not being considered further;
- (b) is not among the top candidates; or
- (c) is a strong match for the position.

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Indicate the mathematical subject area(s) in which you have done research using, if applicable, the 1991 Mathematics Subject Classification printed on the back of this form. If listing more than one number, list first the one number which best describes your current primary interest.

Primary Interest _____

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Give a brief synopsis of your current research interests (e.g. finite group actions on four-manifolds). Avoid special mathematical symbols and please do not write outside of the boxed area.

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Indicate the position for which you are applying and position posting code, if applicable

If unsuccessful for this position, would you like to be considered for a temporary position?

Yes No If yes, please check the appropriate boxes.

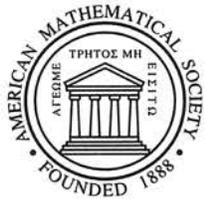
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List the names, affiliations, and e-mail addresses of up to four individuals who will provide letters of recommendation if asked. Mark the box provided for each individual whom you have already asked to send a letter.

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This cover sheet is provided as an aid to departments in processing job applications. It should be included with your application material.

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- 03 Logic and foundations
- 04 Set theory
- 05 Combinatorics
- 06 Order, lattices, ordered algebraic structures
- 08 General mathematical 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, optimal control
- 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
- 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
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The journal will publish papers presenting new mathematical results in mathematical physics, analysis, and geometry with particular reference to: – mathematical problems of statistical physics, fluids, etc. – complex function theory – operators in function space, especially operator algebras – ordinary and partial differential equations – differential and algebraic geometry.

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Algebras and Representation Theory

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Mathematics Calendar

The most comprehensive and up-to-date Mathematics Calendar information is available on e-MATH at <http://www.ams.org/mathcal/>.

November 1999

* 5-7 **9th Midwest Geometry Conference**, University of Missouri-Columbia, Columbia, Missouri.

Main Speakers: M. Culler, Univ. of Illinois at Chicago; T. Mrowka, M.I.T.; M. Choptuik, Univ. of Texas; G. Galloway, Univ. of Miami; V. Moncrief, Yale Univ.; Y. Ruan, Univ. of Wisconsin; Y-T. Siu, Harvard Univ.; J. Hartle, Univ. Calif. at Santa Barbara; R. Wald, Univ. of Chicago.

Information: <http://www.math.missouri.edu/conference/mgc.html>.

December 1999

* 3-4 **Perspectives in Applied Mathematics, Conference in Honor of Gilbert Strang**, MIT, Cambridge, MA.

Focus: The conference will focus on topics of current research interest in applied mathematics, emphasizing results which have been motivated by Gil Strang's work.

Speakers: Keynote Addresses by G. Golub, B. Kohn, P. Lax, C. Moler, N. Trefethen.

Organizers: A. Edelman, H. Matthies, D. Gorsich, V. Strela.

Program Committee: E. Christiansen, W. Hager, V. Strela, H. Matthies.

Information: <http://www-math.mit.edu/~gsfest/>.

* 8-10 **Workshop on Discrete Problems with Medical Applications**, DIMACS Center, Rutgers University, Piscataway, New Jersey.

Submission Deadline: Those interested in presenting papers should send an abstract to one of the organizers before October 1, 1999, by e-mail. Authors willing to contribute to the proceedings or special issue of the *Journal of Combinatorial Optimization* should send full papers before December 31, 1999.

Sponsor: DIMACS Center.

Organizers: D.-Z. Du (Univ. of Minnesota), P. Pardalos (Univ. of Florida), J. Wang (Univ. of North Carolina).

Aim: The study of computing in medical applications has opened many challenging issues and problems for both the medical computing community and the algorithm community. This workshop aims to foster communication and collaboration between the two groups of researchers. The objectives of the workshop are to provide a forum where worldwide researchers and practitioners may meet and exchange research ideas and interests, as well as discuss new trends and identify open problems in the development and deployment of this area.

Information: D.-Z. Du (Univ. of Minnesota), dzd@cs.umn.edu; local arrangements:

P. Pravato, DIMACS Center, pravato@dimacs.rutgers.edu, tel: 732-445-5929; <http://dimacs.rutgers.edu/Workshops/index.html>.

March 2000

* 6-10 **International Conference on Differential Geometry and Quantum Physics**, TU Berlin, Germany.

Topics Include: Differential geometry and geometric analysis, partial differential equations in mathematical physics, quantum mechanics and quantum field theory.

Speakers: J. Avron, W. Ballmann, J. Bourguignon, J. Cheeger, J.-M. Combes, L. Faddeev, J. Froehlich, E. Lieb, W. Mueller, S. Novikov, B. Simon, C.-L. Terng.

Information: Organizers: V. Bach, FB Mathematik (17), Universitaet Mainz, D-55099 Mainz, Germany, e-mail: bach@math.tu-berlin.de, vbach@mathematik.uni-mainz.de and Jochen Bruening, Institut fuer Mathematik, Humboldt-Universitaet zu Berlin, Unter den Linden 6, D-10117 Berlin, e-mail: bruening@mathematik.hu-berlin.de.

* 20-22 **DIMACS Workshop on Cryptography and Intractability**, DIMACS Center, Rutgers University, Piscataway, New Jersey.

Sponsor: DIMACS Center.

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 meetings and symposia devoted to specialized topics, as well as announcements of regularly scheduled meetings of national or international mathematical organizations. A complete list of meetings of the Society can be found on the last page of each issue.

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@ams.org or mathcal@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](telnet://e-math.ams.org); login and password e-math) and use the Lynx option from the main menu.)

Program: The goal of this workshop is to explore the tight relationship between cryptography and computational hardness. The workshop will be organized around the following themes: the minimal intractability assumptions required for various cryptographic tasks; the feasibility of basing cryptography on worst-case assumptions; the proper form for an intractability assumption; the relationship between cryptography and computational learning theory, proof complexity, game theory and combinatorial optimization. Presented under the auspices of the DIMACS Special Years on Computational Intractability and Networks.

Organizers: M. Naor, Weizmann Institute of Science, J. Kilian, NEC Research Institute, S. Goldwasser, MIT and Weizmann Institute of Science.

Contacts: M. Naor, Weizmann Institute of Science, naor@wisdom.weizmann.ac.il.

Local Arrangements: P. Pravato, DIMACS Center, pravato@dimacs.rutgers.edu, 732-445-5929.

Information: <http://dimacs.rutgers.edu/Workshops/index.html>.

April 2000

* 25–May 6 **NATO Advanced Study Institute, Nonlinear Dynamics in Life and Social Sciences**, Moscow, Russia.

Eligibility: To be eligible to attend this ASI, students must be permanent residents of a NATO, NATO Partner, or Mediterranean Dialogue country who are in full-time attendance at a recognized university or academic institute. Preference will be given to those at a doctoral or postdoctoral level with research interests related to the ASI. The languages of the ASI will be English and Russian, though the majority of lectures will be in English. Thus a knowledge of English is preferred. Prospective students are required to submit a copy of their CV and a brief letter outlining their reasons for wishing to attend this ASI.

NATO countries: Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Turkey, UK, USA.

NATO Partner countries: Albania, Armenia, Azerbaijan, Belarus, Bulgaria, Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Poland, Romania, Russian Federation, Slovak Republic, Slovenia, Tajikistan, the former Yugoslav Republic of Macedonia, Turkmenistan, Ukraine, Uzbekistan.

Mediterranean Dialogue countries: Egypt, Israel, Jordan, Mauritania, Morocco, Tunisia.

Invited Lecturers: The following invited lecturers will teach during the Institute: V. I. Arnold (Steklov Institute of Mathematics), Y. Bar-Yam (New England Complex Systems Institute, USA), D. S. Chernavsky (Physical Institute, Russian Academy of Sciences), M. Feigenbaum (Rockefeller Univ., USA), Yu. L. Klimantovich (Moscow State Univ.), S. P. Kurdyumov (Keldysh Inst. of

Applied Mathematics, Moscow), Ch. J. Lumsden (Inst. of Medical Science, Univ. of Toronto, Canada), D. Ruelle (Inst. des Hautes Études Science, France), V. A. Sadovnichiy (Lomonosov Moscow State Univ.), T. Sauer (George Mason Univ., USA), M. V. Sevryuk (Steklov Institute of Mathematics), W. H. Sulis (McMaster Univ., Canada), D. I. Trubetzkov (Saratov State Univ.), B. West (Univ. of Texas, Austin, USA), G. West (Santa Fe Inst., USA). Presentations by ASI students and poster sessions will be organized.

Expenses: There is no registration fee for eligible students. A limited number of NATO grants will be available to eligible students who are permanent residents of NATO countries and NATO Partner countries. These grants will include: accommodation expenses during the duration of the ASI - US\$220; travel expenses, for students from North America - US\$500; from Europe - US\$300; from elsewhere - US\$150.

Information: For information and application forms visit <http://www.cas.mcmaster.ca/~sulisw/asi.html>, or write to I. Trofimova, e-mail: ira@ritchie.cas.mcmaster.ca.

May 2000

* 15–18 **Representation Theory and Computational Algebra**, University of Georgia, Athens, Georgia.

Subject: The title of the conference is intended to include representation theory of finite groups and related finite dimensional algebras, classifying spaces and cohomology of finite groups, and computer calculations in these areas.

Principal Invited Speakers: A. Adem (Wisconsin), M. Broue (Paris), J. Cannon (Sydney). **Program Committee:** J. Alperin (Chicago), D. Benson (Georgia), G. Mason (Santa Cruz), J. Milgram (Stanford), J. Rickard (Bristol).

Information: D. Benson, djb@byrd.math.uga.edu or <http://www.math.uga.edu/~djb/conf2000.html>.

* 29–June 9 **Foliation: Geometry and Dynamics Revisited**, Banach Center, Warsaw, Poland. (Jun/Jul. 1999, p. 714)

Purpose: The purpose of the conference in 2000 is: to exchange scientific information among specialists in the theory of foliations and related topics.

Topics: The topics of invited lectures cover such areas as coarse geometry of foliations: foliations of knot complements, compact foliations, stability of leaves, topology of generic leaves, contact structures and confoliations, laminations, entropy and other invariants which measure complexity of foliations, geometric invariants of foliations on Riemannian manifolds, characteristic classes of foliations.

Information: <http://fol2000.math.uni.lodz.pl/>.

June 2000

* 22–24 **CUR 2000: Research in Undergrad-**

uate Education, The College of Wooster, Wooster, Ohio.

Focus: The Eighth National Conference will bring together 500–700 faculty, administrators, and representatives from private foundations and federal agencies. During the three-day conference, there will be a variety of plenary sessions, panel discussions, and workshops for participants to attend. Day-long programs for graduate students, new faculty, tenured faculty, and administrators are planned. This is an ideal time and setting for networking. The conference is designed for all those who are interested in undertaking or promoting undergraduate research.

Information: For more information, visit The Council on Undergraduate Research (CUR) Web site at <http://www.cur.org/>, and go to the meetings and events section; also visit The College of Wooster's Web site at <http://www.wooster.edu/cur/>.

* 26–28 **Heat Transfer 2000, Advanced Computational Methods in Heat Transfer**, Madrid, Spain.

Organized by: Wessex Institute of Technology, UK.

Information: For further details contact S. Hanley, e-mail: shanley@wessex.ac.uk; Web site: <http://www.wessex.ac.uk/conferences/2000/>; tel: 44 (0) 238 029 3223; fax: 44 (0) 238 029 2853.

July 2000

* 2–15 **First Announcement: NATO Advanced Study Institute 20th Century Harmonic Analysis—a Celebration**, Il Ciocco Resort Hotel, Tuscany, Italy.

Principal Lecturers: H. A. Hauptman, V. P. Havin, G. Janssen, J.-P. Kahane, T. W. Korner, Y. Meyer, B. Moran, N. Nikolski, A. Odlyzko, B. Saffari, H. S. Shapiro, E. M. Stein, M. Vetterli, G. Weiss, Y. Zeevi.

Information: Further details may be found on the Web site: <http://www.cs.umb.edu/~asi/analysis2000>.

* 5–7 **Scandinavian Workshop on Algorithm Theory**, Bergen, Norway.

Information: <http://www.ii.uib.no/swat2000> or send e-mail: telle@ii.uib.no.

* 6–8 **The 6th Barcelona Logic Meeting**, Barcelona, Spain.

Topics: All areas of mathematical logic, with an emphasis in algebraic logic, model theory and set theory. The scientific program will consist of several one-hour invited lectures and a number of twenty-minute contributed talks.

Invited Speakers: J. L. Balcázar, P. Del-lunde, P. Koepke, A. Pillay, Y. Venema, M. Zakharyashev.

Information: Further information will be available from the address above, or by e-mail from crm@crm.es or in the Web sites <http://www.mat.ub.es/~logica/news.html> and <http://www.crm.es/>.

INSTITUTE FOR MATHEMATICS AND ITS APPLICATIONS
ANNOUNCES A PROGRAM ON
Mathematics in Multimedia
2000-2001

ORGANIZING COMMITTEE: Michael Barnsley, Rosemary Chang, Tony Derose ,
Stu Geman, Peter Olver, Roni Rosenfeld, Larry Schumaker, Ahmed Tewfik

A one-year program with three parts:

Fall: September - December 2000, **VISION, SPEECH AND LANGUAGE**

Winter: January - March 2001, **COMPRESSION COMMUNICATION AND
RETRIEVAL**

Spring: April - June 2001, **GEOMETRIC DESIGN AND COMPUTER
GRAPHICS**

The mathematical methods for multimedia will be based on stochastic processes and differential equations. There will be a one-week course on Markov processes and statistical estimation at the beginning of the program.

TWO-YEAR POSTDOCTORAL MEMBERSHIPS

The second year of the appointment will provide a variety of options to enhance career development, including participation in the ANNUAL PROGRAM: 2001-2002
Mathematics in the Geosciences.

All requirements for a doctorate should be completed by September 1, 2000. Applicants must show evidence of mathematical excellence, but they do not need to be specialists in the field. The following materials must be submitted (all materials should arrive by January 14, 2000):

- (1) Personal statement of scientific interests, research plans, and reasons for wishing to participate in the PROGRAM.
- (2) Curriculum vitae and a list of publications.
- (3) Three letters of recommendation to be sent directly to the IMA.

SENIOR MEMBERSHIPS

Preference will be given to supplementary support for persons with sabbatical leaves, fellowships, or other stipends.

POSTDOCTORATES IN INDUSTRIAL MATHEMATICS

IMA announces two-year positions in Industrial Mathematics, effective September 1, 2000. These appointments are in addition to the regular program and are funded jointly by the NSF and participating industries. They are designed to prepare mathematicians for research careers involving industrial interaction. Applicants should have fulfilled all requirements for a Ph.D. in Mathematics, Applied Mathematics or Statistics by September 1, 2000. Postdoctorates will spend 50% effort working with industrial scientists and 50% effort in the regular IMA program. Requirements and application procedures are the same as for the postdoctoral memberships listed above.

The University of Minnesota is an equal opportunity educator and employer.

The application forms are available at <http://www.ima.umn.edu/docs/genapp.html>

e-mail: staff@ima.umn.edu, or call (612) 624-6066.

All correspondence should be sent to either
POSTDOC/VISITING MEMBERSHIP COMMITTEE

or

INDUSTRIAL MATHEMATICS POSTDOCTORATE MEMBERSHIP COMMITTEE

Institute for Mathematics and its Applications

University of Minnesota

400 Lind Hall

207 Church St. S.E.

Minneapolis, MN 55455-0436

Mathematics Calendar

* 31-August 5 **KNOTS 2000**, KAIST, Yongpyong Resort, Kangwon-do, Korea (South of).

Purpose: The purpose of the conference is to bring together people working in the field of knot theory, low-dimensional topology and related subjects, to exchange ideas and to present results of their current research.
Local Organizing Committee: G. T. Jin, K. H. Ko, S. Oh (secretary).

Information: <http://knot.kaist.ac.kr/2000/>.

September 2000

* 19-22 **SCAN 2000: 9th GAMM - IMACS International Symposium on Scientific Computing, Computer Arithmetic, and Validated Numerics**, University of Karlsruhe, Karlsruhe, Germany.

Focus: This conference continues the series of scan-symposia which have previously been held at Karlsruhe, Basel, Albena, Oldenburg, Wien, Wuppertal, Lyon, and Budapest under the joint sponsorship of GAMM and IMACS. These conferences have traditionally covered the numerical and algorithmic aspects of scientific computing, with a strong emphasis on validation and verification of computed results as well as on arithmetic, programming, and algorithmic tools for this purpose. The objectives are to propagate current applications and research as well as to promote a greater understanding and increased awareness of the subject matters.

Important Dates: March 31, 2000: Submission of abstracts; June 30, 2000: Notification of acceptance; July 31, 2000: Return of registration form.

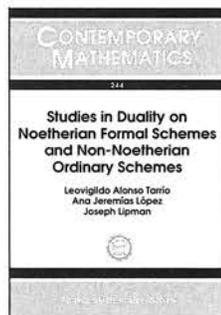
Conference Chairmen: W. Jüling (Univ. of Karlsruhe) and U. Kulisch (Univ. of Karlsruhe).

Local Organization: A. Facius, Institute for Applied Mathematics, Univ. of Karlsruhe, D-76128 Karlsruhe, Germany.

Information: For more information and subscription to a mailing list, send e-mail to: info@scan2000.de, or visit: <http://www.scan2000.de/>.

New Publications Offered by the AMS

Algebra and Algebraic Geometry



Studies in Duality on Noetherian Formal Schemes and Non-Noetherian Ordinary Schemes

Leovigildo Alonso and Ana Jeremías, *Universidade de Santiago de Compostela, Spain*, and Joseph Lipman, *Purdue*

University, West Lafayette, IN

This volume contains three papers on the foundations of Grothendieck duality on Noetherian formal schemes and on not-necessarily-Noetherian ordinary schemes.

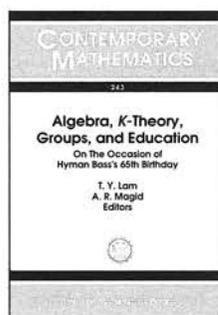
The first paper presents a self-contained treatment for formal schemes which synthesizes several duality-related topics, such as local duality, formal duality, residue theorems, dualizing complexes, etc. Included is an exposition of properties of torsion sheaves and of limits of coherent sheaves. A second paper extends Greenlees-May duality to complexes on formal schemes. This theorem has important applications to Grothendieck duality. The third paper outlines methods for eliminating the Noetherian hypotheses. A basic role is played by Kiehl's theorem affirming conservation of pseudo-coherence of complexes under proper pseudo-coherent maps.

This work gives a detailed introduction to the subject of Grothendieck Duality. The approach is unique in its presentation of a complex series of special cases that build up to the main results.

Contents: *Duality and Flat Base Change on Formal Schemes:* Duality and flat base change on formal schemes; *Greenlees-May Duality on Formal Schemes:* Greenlees-May duality on formal schemes; *Non-Noetherian Grothendieck Duality:* Non-noetherian Grothendieck duality; Index.

Contemporary Mathematics, Volume 244

November 1999, 126 pages, Softcover, ISBN 0-8218-1942-9, LC 99-42685, 1991 *Mathematics Subject Classification:* 14F99; 13D99, 14B15, 32C37, **Individual member \$20**, List \$33, Institutional member \$26, Order code CONM/244N



Algebra, K-Theory, Groups, and Education

On the Occasion of Hyman Bass's 65th Birthday

T. Y. Lam, *University of California, Berkeley*, and A. R. Magid, *University of*

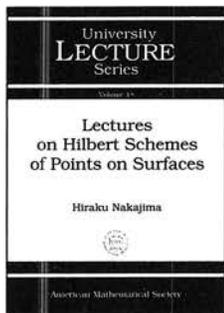
Oklahoma, Norman, OK, Editors

This volume includes expositions of key developments over the past four decades in commutative and noncommutative algebra, algebraic K -theory, infinite group theory, and applications of algebra to topology. Many of the articles are based on lectures given at a conference at Columbia University honoring the 65th birthday of Hyman Bass. Important topics related to Bass's mathematical interests are surveyed by leading experts in the field. Of particular note is a professional autobiography of Professor Bass, and an article by Deborah Ball on mathematical education. The range of subjects covered in the book offers a convenient single source for topics in the field.

Contents: J. Ewing, On the occasion of the 65th birthday of Hyman Bass; H. Bass, A professional autobiography; D. L. Ball, Crossing boundaries: Probing the interplay of mathematics and pedagogy in elementary teaching; E. Formanek, Bass's work on the Jacobian conjecture; R. M. Guralnick and C. J. Pappacena, Torsion in genus class groups; C. Huneke, Hyman Bass and ubiquity: Gorenstein rings; I. Kaplansky, A salute to Euler and Dickson on the occasion of Hy's 65th birthday; T. Y. Lam, Bass's work in ring theory and projective modules; A. Lubotzky, One for almost all: Generation of $SL(n, p)$ by subsets of $SL(n, \mathbb{Z})$; A. R. Magid, Deformations of representations; S. Mozes, Trees, lattices and commensurators; M. P. Murthy, A survey of obstruction theory for projective modules of top rank; A. S. Rapinchuk, The congruence subgroup problem; P. B. Shalen, Three-manifold topology and the tree for PSL_2 : The Smith conjecture and beyond; C. A. Weibel, The development of algebraic K -theory before 1980.

Contemporary Mathematics, Volume 243

November 1999, approximately 237 pages, Softcover, ISBN 0-8218-1087-1, LC 99-044937, 1991 *Mathematics Subject Classification:* 16-XX, 19-XX, 20-XX, 00-XX, **Individual member \$29**, List \$49, Institutional member \$39, Order code CONM/234N



Supplementary Reading

Lectures on Hilbert Schemes of Points on Surfaces

Hiraku Nakajima, *Kyoto University, Japan*

The Hilbert scheme $X^{[n]}$ of a surface X describes collections of n (not necessarily distinct) points on X . More precisely, it is the moduli space for 0-

dimensional subschemes of X of length n . Recently it was realized that Hilbert schemes originally studied in algebraic geometry are closely related to several branches of mathematics, such as singularities, symplectic geometry, representation theory—even theoretical physics. The discussion in the book reflects this feature of Hilbert schemes.

For example, a construction of the representation of the infinite dimensional Heisenberg algebra (i.e., Fock space) is presented. This representation has been studied extensively in the literature in connection with affine Lie algebras, the conformal field theory, etc. However, the construction presented in this volume is completely unique and provides the unexplored link between geometry and representation theory.

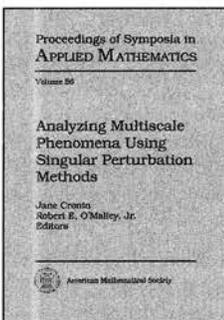
The book offers a nice survey of current developments in this rapidly growing subject. It is suitable as a text at the advanced graduate level.

Contents: Introduction; Hilbert scheme of points; Framed moduli space of torsion free sheaves on \mathbb{P}^2 ; Hyper-Kähler metric on $(\mathbb{C}^2)^{[n]}$; Resolution of simple singularities; Poincaré polynomials of the Hilbert schemes (1); Poincaré polynomials of Hilbert schemes (2); Hilbert scheme on the cotangent bundle of a Riemann surface; Homology group of the Hilbert schemes and the Heisenberg algebra; Symmetric products of an embedded curve, symmetric functions and vertex operators; Bibliography; Index.

University Lecture Series, Volume 18

October 1999, 132 pages, Softcover, ISBN 0-8218-1956-9, LC 99-39163, 1991 *Mathematics Subject Classification:* 14C05; 14F05, 14J17, 14J60, 17B65, 17B69, 16G20, 53C25, 81R10, 81T30, All AMS members \$17, List \$21, Order code ULECT/18N

Analysis



Analyzing Multiscale Phenomena Using Singular Perturbation Methods

Jane Cronin, *Rutgers University, New Brunswick, NJ*, and Robert E. O'Malley, Jr., *University of Washington, Seattle*, Editors

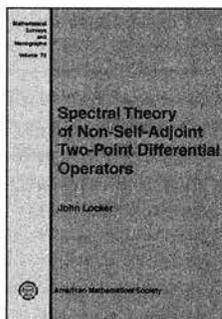
To understand multiscale phenomena, it is essential to employ asymptotic methods to construct approximate solutions and to

design effective computational algorithms. This volume consists of articles based on the AMS Short Course in Singular Perturbations held at the annual Joint Mathematics Meetings in Baltimore (MD). Leading experts discussed the following topics which they expand upon in the book: boundary layer theory, matched expansions, multiple scales, geometric theory, computational techniques, and applications in physiology and dynamic metastability. Readers will find that this text offers an up-to-date survey of this important field with numerous references to the current literature, both pure and applied.

Contents: R. E. O'Malley, Jr., Figuring out singular perturbations after a first course in ODEs; M. H. Holmes, The method of multiple scales; S. Adjerid, M. Aiffa, and J. E. Flaherty, Computational methods for singularly perturbed systems; T. J. Kaper, An introduction to geometric methods and dynamical systems theory for singular perturbation problems; J. Cronin, Analysis of cellular oscillations; M. J. Ward, Exponential asymptotics and convection-diffusion-reaction models; Index.

Proceedings of Symposia in Applied Mathematics, Volume 56

November 1999, 186 pages, Hardcover, ISBN 0-8218-0929-6, LC 99-13036, 1991 *Mathematics Subject Classification:* 34D15, 34E15, 34E20, 35B25, Individual member \$26, List \$44, Institutional member \$35, Order code PSAPM/56N



Spectral Theory of Non-Self-Adjoint Two-Point Differential Operators

John Locker, *Colorado State University, Fort Collins*

This monograph develops the spectral theory of an n th order non-self-

adjoint two-point differential operator L in the Hilbert space $L^2[0, 1]$. The mathematical foundation is laid in the first part, where the spectral theory is developed for closed linear operators and Fredholm operators. An important completeness theorem is established for the Hilbert-Schmidt discrete operators. The operational calculus plays a major role in this general theory.

In the second part, the spectral theory of the differential operator L is developed by expressing L in the form $L = T + S$, where T is the principal part determined by the n th order derivative and S is the part determined by the lower-order derivatives. The spectral theory of T is developed first using operator theory, and then the spectral theory of L is developed by treating L as a perturbation of T . Regular and irregular boundary values are allowed for T , and regular boundary values are considered for L . Special features of the spectral theory for L and T include the following: calculation of the eigenvalues, algebraic multiplicities and ascents; calculation of the associated family of projections which project onto the generalized eigenspaces; completeness of the generalized eigenfunctions; uniform bounds on the family of all finite sums of the associated projections; and expansions of functions in series of generalized eigenfunctions of L and T .

Contents: Unbounded linear operators; Fredholm operators; Introduction to the spectral theory of differential operators; Principal part of a differential operator; Projections and gener-

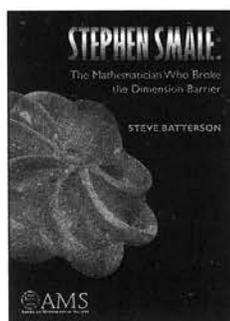
alized eigenfunction expansions; Spectral theory for general differential operators; Bibliography; Index.

Mathematical Surveys and Monographs, Volume 73

November 1999, 252 pages, Hardcover, ISBN 0-8218-2049-4, LC 99-44328, 1991 *Mathematics Subject Classification*: 34L05, 47E05; 34B27, 34L10, 34L20, 47A53, **Individual member \$39**, List \$65, Institutional member \$52, Order code SURV/73N

General and Interdisciplinary

Biography



Stephen Smale: The mathematician who broke the dimension barrier

Steve Batterson, *Emory University, Atlanta, GA*

In 1957 Stephen Smale startled the mathematical world by showing that it is possible to turn a sphere inside

out without cutting, tearing, or crimping. A few years later, from the beaches of Rio, he introduced the horseshoe map, demonstrating that simple functions could have chaotic dynamics. His next stunning mathematical accomplishment was to solve the higher-dimensional Poincaré conjecture, thus demonstrating that six or more dimensions are simpler than the more familiar three. In 1966 in Moscow, he was awarded the Fields Medal, the most prestigious prize in mathematics.

Smale's vision and influence extended beyond mathematics into two vastly different realms. In 1965 in Berkeley, he initiated a program with Jerry Rubin of civil disobedience directed at ending the Vietnam war. And as a mineral collector, he accumulated a museum-quality collection that ranks among the finest in the world. Despite these diverse accomplishments, Smale's name is virtually unknown outside mathematics and mineralogy. One of the objectives of this book is to bring his life and work to the attention of a larger community.

There are few good biographies of mathematicians. This makes sense when considering that to place their lives in perspective requires some appreciation of their theorems. Biographical writers are not usually trained in mathematics, and mathematicians do not usually write biographies. Though the author, Steve Batterson, is primarily a mathematician, he has long been intrigued by the notion of working on a biography of Smale. In this book, Batterson records and makes known the life and accomplishments of this great mathematician and significant figure in intellectual history.

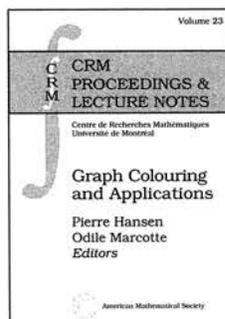
"Transparent Peach Eversion" cover art used with permission from the "Outside In" video project, generated at the Geometry Center (University of MN); distributed by A. K. Peters (Natick, MA).

Contents: One room schoolhouse; Marxism and mathematics at Ann Arbor; Early mathematical audacity; On the beaches of Rio; Berkeley to Columbia and back to Berkeley; The Lone Ranger of the antiwar movement; The summer of 1966; Smale versus the National Science Foundation; The aesthetic side: Minerals and photography; Adventure and physical risks; Other people; Smale the mathematician; Mathematical appendix A:

Smale's thesis; Mathematical appendix B: Everting the sphere; Mathematical appendix C: Chaos and the horseshoe; Mathematical appendix D: The higher dimensional Poincaré conjecture; Notes; Index.

February 2000, approximately 265 pages, Hardcover, ISBN 0-8218-2045-1, LC 99-38205, 1991 *Mathematics Subject Classification*: 01A70; 34-03, 55-03, 58-03, 65-03, **All AMS members \$28**, List \$35, Order code MBDBN

Discrete Mathematics and Combinatorics



Graph Colouring and Applications

Pierre Hansen, *École des Hautes Études Commerciales, Montréal, PQ, Canada*, and Odile Marcotte, *Université du Québec à Montréal, Canada*, Editors

This volume presents the proceedings of the CRM workshop on graph

coloring and applications. The articles span a wide spectrum of topics related to graph coloring, including: list-colorings, total colorings, colorings and embeddings of graphs, chromatic polynomials, characteristic polynomials, chromatic scheduling, and graph coloring problems related to frequency assignment. Outstanding researchers in combinatorial optimization and graph theory contributed their work. A list of open problems is included.

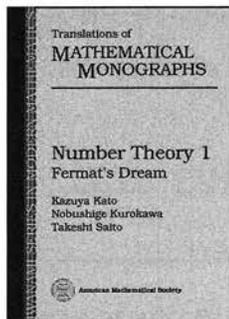
Contents: D. K. Arrowsmith and J. W. Essam, Chromatic polynomials and mod λ flows on directed graphs and their applications; K. L. Collins and J. P. Hutchinson, Four-coloring six-regular graphs on the torus; M. Dror, G. Finke, S. Gravier, and W. Kubiak, On the complexity of a restricted list-coloring problem; G. M. Hamilton, A. J. W. Hilton, and H. R. F. Hind, Totally critical graphs and the conformability conjecture; F. Harary and M. Plantholt, Graphs whose radio coloring number equals the number of nodes; O. Marcotte and P. Hansen, The height and length of colour switching; H. Sachs, Characteristic polynomials in the theory of polyhedra; T. R. Walsh, The number of edge 3-colourings of the n -prism; T. R. Walsh, The cost of radio-colouring paths and cycles; D. de Werra, Restricted graph coloring: Some mathematical programming models; Open problems.

CRM Proceedings & Lecture Notes, Volume 23

November 1999, 149 pages, Softcover, ISBN 0-8218-1955-0, LC 99-40201, 1991 *Mathematics Subject Classification*: 05C15, 05C90; 05C70, 68R10, **Individual member \$24**, List \$40, Institutional member \$32, Order code CRMP/23N

Number Theory

Supplementary Reading



Number Theory 1 Fermat's Dream

Kazuya Kato, *University of Tokyo, Japan*, **Nobushige Kurokawa**, *Tokyo Institute of Technology, Japan*, and **Takeshi Saito**, *University of Tokyo, Japan*

This is the English translation of the original Japanese book. In this volume, "Fermat's Dream", core theories in modern number theory are introduced. Developments are given in elliptic curves, p -adic numbers, the ζ -function, and the number fields. This work presents an elegant perspective on the wonder of numbers. *Number Theory 2* on class field theory, and *Number Theory 3* on Iwasawa theory and the theory of modular forms, are forthcoming in the series.

Contents: Introduction; Rational points on elliptic curves; Conics and p -adic numbers; ζ ; Algebraic number theory; Rudiments on Dedekind domains; Answers to questions; Answers to exercises; Index.

Translations of Mathematical Monographs (*Iwanami Series in Modern Mathematics*)

December 1999, approximately 165 pages, Softcover, ISBN 0-8218-0863-X, LC 99-33556, 1991 *Mathematics Subject Classification*: 11-XX, 14-XX, **All AMS members \$20**, List \$25, Order code MMONO-KATON

Previously Announced Publications

Supplementary Reading

Riemannian Geometry During the Second Half of the Twentieth Century

Marcel Berger, *Institut des Hautes Études Scientifiques, Bures-sur-Yvette, France*

Masterfully written and delightful to read. In addition to the numerous digressions for newly introduced concepts, the author adds to the value of the survey by providing fertile opinions, some of them his, others those of his close colleagues and of M. Gromov in particular. The wonderful effort of the author is shown partially by the long bibliography of thirty pages, with references updated right to the very end of the century. A person who wants to learn more about Riemannian geometry will certainly do him/herself a good service by reading Berger's work.

—*Mathematical Reviews*

During its first hundred years, Riemannian geometry enjoyed steady, but undistinguished growth as a field of mathematics. In the last fifty years of the twentieth century, however, it has exploded with activity. Berger marks the start of this period with Rauch's pioneering paper of 1951, which contains the first real pinching theorem and an amazing leap in the depth

of the connection between geometry and topology. Since then, the field has become so rich that it is almost impossible for the uninitiated to find their way through it. Textbooks on the subject invariably must choose a particular approach, thus narrowing the path. In this book, Berger provides a truly remarkable survey of the main developments in Riemannian geometry in the second half of the last fifty years.

One of the most powerful features of Riemannian manifolds is that they have invariants of (at least) three different kinds. There are the geometric invariants: topology, the metric, various notions of curvature, and relationships among these. There are analytic invariants: eigenvalues of the Laplacian, wave equations, Schrödinger equations. There are the invariants that come from Hamiltonian mechanics: geodesic flow, ergodic properties, periodic geodesics. Finally, there are important results relating different types of invariants. To keep the size of this survey manageable, Berger focuses on five areas of Riemannian geometry: Curvature and topology; the construction of and the classification of space forms; distinguished metrics, especially Einstein metrics; eigenvalues and eigenfunctions of the Laplacian; the study of periodic geodesics and the geodesic flow. Other topics are treated in less detail in a separate section.

While Berger's survey is not intended for the complete beginner (one should already be familiar with notions of curvature and geodesics), he provides a detailed map to the major developments of Riemannian geometry from 1950 to 1999. Important threads are highlighted, with brief descriptions of the results that make up that thread. This supremely scholarly account is remarkable for its careful citations and voluminous bibliography. If you wish to learn about the results that have defined Riemannian geometry in the last half century, start with this book.

Reprint arranged with the approval of the publisher B. G. Teubner, Stuttgart and Leipzig.

University Lecture Series

October 1999, approximately 217 pages, Softcover, ISBN 0-8218-2052-4, LC 99-32803, 1991 *Mathematics Subject Classification*: 53Axx, 53Bxx, 53Cxx, 58Axx, 58Cxx, 58Dxx, 58Exx, 58Fxx, **All AMS members \$27**, List \$34, Order code ULECT-BERGERT911

Supplementary Reading

Non-Euclidean Geometry in the Theory of Automorphic Functions

Jacques Hadamard, and **Jeremy J. Gray**, *Open University, Milton Keynes, UK*, and **Abe Shenitzer**, *Editors, York University, Toronto, ON, Canada*

This is the English translation of a volume originally published only in Russian and now out of print. The book was written by Jacques Hadamard on the work of Poincaré.

Poincaré's creation of a theory of automorphic functions in the early 1880s was one of the most significant mathematical achievements of the nineteenth century. It directly inspired the uniformization theorem, led to a class of functions adequate to solve all linear ordinary differential equations, and focused attention on a large new class of discrete groups. It was the first significant application of non-Euclidean geometry. The implications of these discoveries continue to be important to this day in numerous different areas of mathematics.

Hadamard begins with hyperbolic geometry, which he compares with plane and spherical geometry. He discusses the

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A Classic

corresponding isometry groups, introduces the idea of discrete subgroups, and shows that the corresponding quotient spaces are manifolds. In Chapter 2 he presents the appropriate automorphic functions, in particular, Fuchsian functions. He shows how to represent Fuchsian functions as quotients, and how Fuchsian functions invariant under the same group are related, and indicates how these functions can be used to solve differential equations. Chapter 4 is devoted to the outlines of the more complicated Kleinian case. Chapter 5 discusses algebraic functions and linear algebraic differential equations, and the last chapter sketches the theory of Fuchsian groups and geodesics.

This unique exposition by Hadamard offers a fascinating and intuitive introduction to the subject of automorphic functions and illuminates its connection to differential equations, a connection not often found in other texts.

This book is the second in an informal sequence of works called "History of Mathematics, Sources", to be included within the History of Mathematics series, co-published by the AMS and the London Mathematical Society. Volumes to be published within this subset are classical mathematical works that served as cornerstones for modern mathematical thought.

Co-published with the London Mathematical Society. Members of the LMS may order directly from the AMS at the AMS member price. The LMS is registered with the Charity Commissioners.

History of Mathematics, Volume 17

November 1999, 95 pages, Softcover, ISBN 0-8218-2030-3, LC 99-31709, 1991 *Mathematics Subject Classification*: 01-XX, 01A55, 01A60; 30-03, 30F35, 34A20, 51-03, **All AMS members \$15, List \$19, Order code HMATH/17RT911**

Advance Notice

Back in Print from the AMS

A Classic

Collected Papers of Srinivasa Ramanujan

G. H. Hardy, P. V. Sheshu Aiyar, and B. M. Wilson, with commentary by Bruce Berndt, *University of Illinois, Urbana, IL*, Editors

The influence of Ramanujan on number theory is without parallel in mathematics. His papers, problems and letters have spawned a remarkable number of later results by many different mathematicians. Here, his 37 published papers, most of his first two and last letters to Hardy, the famous 58 problems submitted to the *Journal of the Indian Mathematical Society*, and the commentary of the original editors (Hardy, Seshu Aiyar and Wilson) are reprinted again, after having been unavailable for some time.

In this, the third printing of Ramanujan's collected papers, Bruce Berndt provides an annotated guide to Ramanujan's work and to the mathematics it inspired over the last three-quarters of a century. The historical development of ideas is traced in the commentary and by citations to the copious references. The editor has done the mathematical world a tremendous service that few others would be qualified to do.

AMS Chelsea Publishing

February 2000, 355 pages, Hardcover, ISBN 0-8218-2076-1, LC 62-8326, 1991 *Mathematics Subject Classification*: 11-06, **All AMS members \$28, List \$31, Order code CHEL/159.HRT911**

Ramanujan

Twelve Lectures on Subjects Suggested by His Life and Work

G. H. Hardy

From the fact that practically all topics of analytic number theory are mentioned, briefly or extensively, in this book in connection with one or the other of Ramanujan's ideas, theorems, conjectures, we realize the far-reaching influence which his work has had on present-day mathematics ... the book is not only an homage to Ramanujan's genius; it is a survey of many branches of modern arithmetic and analysis and, altogether, a book which makes fascinating reading.

—Hans Rademacher, *Mathematical Reviews*

Ramanujan occupies a unique place in analytic number theory. His formulas, identities and calculations are still amazing three-quarters of a century after his death. Many of his discoveries seem to have appeared as if from the ether. His mentor and primary collaborator was the famous G. H. Hardy. Here, Hardy collects twelve of his own lectures on topics stemming from Ramanujan's life and work. The topics include: partitions, hypergeometric series, Ramanujan's τ -function and round numbers.

Hardy was the first to recognize the brilliance of Ramanujan's ideas. As one of the great mathematicians of the time, it is fascinating to read Hardy's accounts of their importance and influence.

AMS Chelsea Publishing

November 1999, 236 pages, Hardcover, ISBN 0-8218-2023-0, 1991 *Mathematics Subject Classification*: 11; 01, **All AMS members \$25, List \$28, Order code CHEL/136.HRT911**

Biography

John von Neumann

The Scientific Genius Who Pioneered the Modern Computer, Game Theory, Nuclear Deterrence, and Much More

Norman Macrae

I always thought [von Neumann's] brain indicated that he belonged to a new species, an evolution beyond man. Macrae shows us in a lively way how this brain was nurtured and then left its great imprint on the world.

—Hans A. Bethe, *Cornell University*

The book makes for utterly captivating reading. Von Neumann was, of course, one of this century's geniuses, and it is surprising that we have had to wait so long ... for a fully fleshed and sympathetic biography of the man. But now, happily, we have one.

Macrae nicely delineates the cultural, familial, and educational environment from which von Neumann sprang and sketches the mathematical and scientific environment in which he flourished. It's no small task to render a genius like von Neumann in ordinary language, yet Macrae manages the trick, providing more than a glimpse of what von Neumann accomplished intellectually without expecting the reader to have a Ph.D. in mathematics. Beyond that, he captures von Neumann's qualities

Previously Announced Publications

of temperament, mind, and personality, including his effortless wit and humor. And [Macrae] frames and accounts for von Neumann's politics in ways that even critics of them, among whom I include myself, will find provocative and illuminating.

—Daniel J. Kevles, *California Institute of Technology*

A lively portrait of the hugely consequential mathematician-physicist-et al., whose genius has left an enduring impress on our thought, technology, society, and culture. A double salute to Steve White, who started this grand book designed for us avid, nonmathematical readers, and to Norman Macrae, who brought it to a triumphant conclusion.

—Robert K. Merton, *Columbia University*

This volume is the reprinted edition of the first full-scale biography of the man widely regarded as the greatest scientist of the century after Einstein.

Born in Budapest in 1903, John von Neumann grew up in one of the most extraordinary of scientific communities. From his arrival in America in the mid-1930s—with bases in Boston, Princeton, Washington, and Los Alamos—von Neumann pioneered and participated in the major scientific and political dramas of the next three decades, leaving his mark on more fields of scientific endeavor than any other scientist. Von Neumann's work in areas such as game theory, mathematics, physics, and meteorology formed the building blocks for the most important discoveries of the century: the modern computer, game theory, the atom bomb, radar, and artificial intelligence, to name just a few.

From the laboratory to the highest levels of government, this definitive biography gives us a behind-the-scenes look at the politics and personalities involved in these world-changing discoveries. Written more than 30 years after von Neumann's untimely death at age 56, it was prepared with the cooperation of his family and includes information gained from interviewing countless sources across Europe and America. Norman Macrae paints a highly readable, humanizing portrait of a man whose legacy still influences and shapes modern science and knowledge.

October 1999, 406 pages, Hardcover, ISBN 0-8218-2064-8, LC 99-37303, 1991 *Mathematics Subject Classification*: 01A70, All AMS members \$28, List \$35, Order code JVNMR911

Supplementary Reading

Mirror Symmetry

Claire Voisin, *Université et Marie Curie, Paris, France*

This is the English translation of Professor Voisin's book reflecting the discovery of the mirror symmetry phenomenon. The first chapter is devoted to the geometry of Calabi-Yau manifolds, and the second describes, as motivation, the ideas from quantum field theory that led to the discovery of mirror symmetry.

The other chapters deal with more specialized aspects of the subject: the work of Candelas, de la Ossa, Greene, and Parkes, based on the fact that under the mirror symmetry hypothesis, the variation of Hodge structure of a Calabi-Yau threefold determines the Gromov-Witten invariants of its mirror; Batyrev's construction, which exhibits the mirror symmetry phenomenon between hypersurfaces of toric Fano varieties, after a combinatorial classification of the latter; the mathematical construction of the Gromov-Witten potential, and the proof of its crucial property (that it satisfies the WDVV equation), which makes it possible to construct a flat connection underlying a variation of Hodge structure in the Calabi-Yau case. The book concludes with the first "naive" Givental computation,

which is a mysterious mathematical justification of the computation of Candelas, et al.

SMF members are entitled to AMS member discounts.

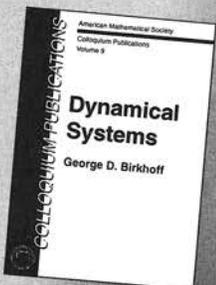
SMF/AMS Texts and Monographs, Volume 1

August 1999, 120 pages, Softcover, ISBN 0-8218-1947-X, LC 99-35675, 1991 *Mathematics Subject Classification*: 14D05, 14D07; 14J32, 14M25, 32G13, 32G20, 32L07, 81T30, 81T40, 53C23, 53C15, All AMS members \$22, List \$27, Order code SMFAMS/1RT911

PUBLICATIONS of CONTINUING INTEREST

Milestones in Mathematics

The AMS has published significant mathematical works all throughout the twentieth century. As the millennium approaches, we present to you these profound classics, marking highpoints of research and scholarship along the way.

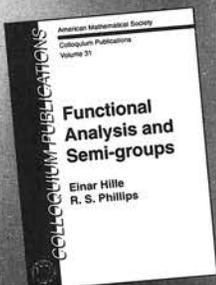


Dynamical Systems

George D. Birkhoff

His research in dynamics constitute the middle period of Birkhoff's scientific career, that of maturity and greatest power.
—Yearbook of the American Philosophical Society

Colloquium Publications, Volume 9; 1927; ISBN 0-8218-1009-X; 305 pages; Softcover; All AMS members \$23, List \$29, Order Code COLL/9CT911

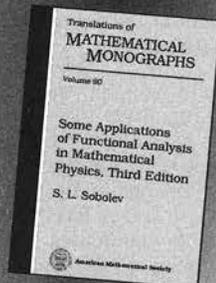


The Calculus of Variations in the Large

M. Morse

This monumental book is one of the most important and influential works written in mathematics in this century.
—Mathematical Reviews

Colloquium Publications, Volume 18; 1934; ISBN 0-8218-1018-9; 368 pages; Softcover; Individual member \$33, List \$55, Institutional member \$44, Order Code COLL/18CT911

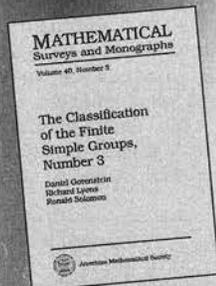


Foundations of Algebraic Geometry

André Weil †

This book has played an important role in establishing the mathematical foundations of Algebraic Geometry and in providing its accepted language.
—Monatshefte für Mathematik

Colloquium Publications, Volume 29; 1946; ISBN 0-8218-1029-4; 363 pages; Softcover; All AMS members \$24, List \$29, Order Code COLL/29CT911



Functional Analysis and Semi-groups

Einar Hille, and R. S. Phillips, Stanford University, CA

Colloquium Publications, Volume 31; 1957; ISBN 0-8218-1031-6; 808 pages; Softcover; All AMS members \$40, List \$50, Order Code COLL/31CT911

Structure and Representations of Jordan Algebras

N. Jacobson

A superb, extremely complete account of the foundations, techniques and results in a subject whose importance is perhaps only recently starting to be appreciated, written by one of the main developers of the theory.
—Mathematical Reviews

Colloquium Publications, Volume 39; 1968; ISBN 0-8218-1039-1; 453 pages; Hardcover; Individual member \$31, List \$52, Institutional member \$42, Order Code COLL/39CT911

Geometric Asymptotics

Victor Guillemin and Shlomo Sternberg

Mathematical Surveys and Monographs, Volume 14; 1977; ISBN 0-8218-1633-0; 480 pages; Softcover; Individual member \$47, List \$79, Institutional member \$63, Order Code SURV/14CT911

Some Applications of Functional Analysis in Mathematical Physics, Third Edition

S. L. Sobolev

This is a revised and augmented edition, prepared with the assistance of O. A. Oleinik, of the author's famous monograph which was first published in 1950 and reprinted in 1962.
—Mathematical Reviews

Translations of Mathematical Monographs, Volume 90; 1991; ISBN 0-8218-4549-7; 286 pages; Hardcover; Individual member \$100, List \$167, Institutional member \$134, Order Code MMONO/90CT911

The Classification of the Finite Simple Groups

Daniel Gorenstein †, Richard Lyons, Rutgers University, New Brunswick, NJ, and Ronald Solomon, Ohio State University, Columbus

The wait for this project to reach this stage has been worth it.
—Mathematical Reviews

Mathematical Surveys and Monographs, Volume 40; 1994; ISBN 0-8218-0334-4; 165 pages; Hardcover; Individual member \$30, List \$50, Institutional member \$40, Order Code SURV/40.1CT911

Number 2

A model of clarity and precision ... contains many gems of exposition and new proofs ... makes clear the very questions that could revolutionize the proof.
—Mathematical Reviews

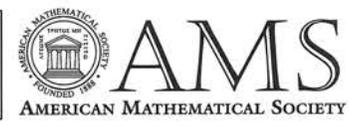
Mathematical Surveys and Monographs, Volume 40; 1996; ISBN 0-8218-0390-5; 218 pages; Hardcover; Individual member \$35, List \$59, Institutional member \$47, Order Code SURV/40.2CT911

Number 3

A valuable reference for future generations of mathematicians.
—Mathematical Reviews

Mathematical Surveys and Monographs, Volume 40; 1998; ISBN 0-8218-0391-3; 419 pages; Hardcover; Individual member \$47, List \$79, Institutional member \$63, Order Code SURV/40.3CT911

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For more publications in your subject area visit the AMS Bookstore: www.ams.org/bookstore/.

Classified Advertisements

Positions available, items for sale, services available, and more

ARIZONA

NORTHERN ARIZONA UNIVERSITY Department of Mathematics and Statistics

Tenure-track position in operations research. NAU is an Equal Opportunity/Affirmative Action Institute. Minorities, persons with disabilities, veterans, and women are encouraged to apply. See details at <http://odin.math.nau.edu/>.

CALIFORNIA

UNIVERSITY OF CALIFORNIA, DAVIS Regular and Visiting Faculty Positions in Mathematics

The Department of Mathematics at the University of California, Davis, is soliciting applications for a tenure-track/tenured position and several Visiting Research Assistant Professor (VRAP) positions starting July 1, 2000. These positions and appointments are contingent upon budgetary and administrative approval.

Appointment of the tenure-track/tenured position will be made commensurate with qualifications. It will normally be made at the level of assistant professor, but exceptional candidates will be considered for associate professorship with tenure. The Department of Mathematics plans to fill the tenure-track/tenured position in the area of applied mathematics. However, applications from exceptionally strong candidates with demonstrated excellence in

the following areas will also be considered: 1) analysis and partial differential equations; 2) discrete mathematics; 3) geometry and topology; 4) mathematical physics; and 5) numerical analysis and scientific computation. Minimum qualifications for this position include a Ph.D. degree in mathematical sciences and great promise in research and teaching. Duties include mathematical research, undergraduate and graduate teaching (4.0 quarter courses per year), and departmental and university service. Candidates for the associate professor position must have demonstrated outstanding attainment in research and teaching.

The VRAP positions are renewable for a total of three years with satisfactory performances in research and teaching. The VRAP applicants are required to have completed their Ph.D. no earlier than 1996. The department is interested in applicants in 1) analysis and partial differential equations; 2) applied mathematics; 3) discrete mathematics; 4) geometry and topology; 5) mathematical physics; and 6) numerical analysis and scientific computation.

Applications will be accepted until the positions are filled, but to receive full consideration, the application should be received by November 30, 1999. To initiate the application process, please request an application package by either sending an e-mail message to forms@math.ucdavis.edu or by writing to the Chair of Search Committee, Department of Mathematics, University of California, One Shields Avenue, Davis, CA 95616-8633. Our application form is identical to the

AMS Standard Cover Sheet.

Additional information on the department may be found on the World Wide Web at <http://math.ucdavis.edu/>.

The University of California, Davis, is an Affirmative Action/Equal Opportunity Employer. The university undertakes Affirmative Action to assure equal employment opportunity for minorities and women, for persons with disabilities, and for special disabled veterans, Vietnam war veterans, and any other veterans who served on active duty during a war or in a campaign or expedition for which a campaign badge has been authorized.

UNIVERSITY OF CALIFORNIA, LOS ANGELES Department of Mathematics Regular Positions in Pure and Applied Mathematics

The UCLA Department of Mathematics invites applications for three or more tenure-track positions in mathematics. Exceptional promise in research and teaching is required. Positions are generally 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 Staff Search, Department of Mathematics, University of California, Los Angeles, CA

Suggested uses for classified advertising are positions available, books or lecture notes for sale, books being sought, exchange or rental of houses, and typing services.

The 1999 rate is \$100 per inch or fraction thereof on a single column (one-inch minimum), calculated from top of headline. Any fractional text of $\frac{1}{2}$ inch or more will be charged at the next inch rate. No discounts for multiple ads or the same ad in consecutive issues. For an additional \$10 charge, announcements can be placed anonymously. Correspondence will be forwarded.

Advertisements in the "Positions Available" classified section will be set with a minimum one-line headline, consisting of the institution name above body copy, unless additional headline copy is specified by the advertiser. Headlines will be centered in boldface at no extra charge. Ads will appear in the language in which they are submitted.

There are no member discounts for classified ads. Dictation over the telephone will not be accepted for classified advertising.

Upcoming deadlines for classified advertising are as follows: December issue–September 24, 1999; January 2000 issue–October 25, 1999; February

issue–November 19, 1999; March issue–December 27, 1999; April issue–January 26, 2000; May issue–February 28, 2000.

U.S. laws prohibit discrimination in employment on the basis of color, age, sex, race, religion, or national origin. "Positions Available" advertisements from institutions outside the U.S. cannot be published unless they are accompanied by a statement that the institution does not discriminate on these grounds whether or not it is subject to U.S. laws. Details and specific wording may be found on page 1373 (vol. 44).

Situations wanted advertisements from involuntarily unemployed mathematicians are accepted under certain conditions for free publication. Call toll-free 800-321-4AMS (321-4267) in the U.S. and Canada, or 401-455-4084 worldwide, for further information.

Submission: Promotions Department, AMS, P.O. Box 6248, Providence, Rhode Island 02940, or via fax, 401-331-3842, or send e-mail to classes@ams.org. AMS location for express delivery packages is 201 Charles Street, Providence, Rhode Island 02904. Advertisers will be billed upon publication.

90095-1555. UCLA is an Equal Opportunity/Affirmative Action Employer.

Under federal law the University of California may employ only individuals who are legally authorized to work in the United States as established by providing documents specified in the Immigration Reform and Control Act of 1986.

**UNIVERSITY OF CALIFORNIA,
LOS ANGELES
Department of Mathematics
Temporary Positions**

Subject to availability of resources and administrative approval: Preference will be given to applications completed by January 7, 2000.

(1) Several E. R. Hedrick Assistant Professorships. Applicants must show very strong promise in research and teaching. Salary \$49,300. Three-year appointment. Teaching load: four quarter courses per year, which may include one advanced course in the candidate's field.

(2) One or two research assistant professorships in computational and applied mathematics (CAM). Applicants must show very strong promise in research and teaching. Salary \$49,300. Three-year appointment. Teaching load: normally is reduced to two quarter courses per year by research funding as available; may include one advanced course in the candidate's field.

(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 programming courses and one more advanced quarter course per year. One-year initial appointment, with the option of applying for renewal for a second year and possibly longer, up to a maximum service of four years. Salary \$52,900. 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 programming courses per year. One-year appointment, probably renewable one or more times, depending on the needs of the program. Salary is \$42,300 or more, depending on experience.

(4) An adjunct assistant professorship. One-year appointment, probably renewable once. Strong research and teaching background required. Salary \$45,500-\$48,000. Teaching load: five quarter courses per year.

(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: Staff Search, Department of Mathematics, University of California, Los Angeles, CA 90095-1555. UCLA is

an Equal Opportunity/Affirmative Action Employer.

Under federal law the University of California may employ only individuals who are legally authorized to work in the United States as established by providing documents specified in the Immigration Reform and Control Act of 1986.

**UNIVERSITY OF CALIFORNIA,
RIVERSIDE
Department of Mathematics
Assistant Professor Position in
Analysis/Geometry
Position in Algebra/Analysis
(Open Level)**

Applications and nominations are invited for the following positions:

1. Assistant Professor Position in Analysis/Geometry

2. Position in Algebra/Analysis (Open Level)

beginning July 1, 2000. A doctorate in mathematics is required, as is demonstrated excellence or strong promise in research and teaching. Responsibilities include teaching undergraduate and graduate-level courses and seminars, conducting scholarly research, and participating in service activities. Established criteria of the University of California determine salary and level of appointment. To assure full consideration, applicants should send their curriculum vitae, including a list of publications, and at least three letters of recommendation to:

2000 Faculty Search Committee
Department of Mathematics
University of California, Riverside
Riverside, CA 92521-0135

by Friday, December 10, 1999. The University of California, Riverside, is an Affirmative Action/Equal Opportunity Employer.

**UNIVERSITY OF CALIFORNIA,
SANTA CRUZ**

The department expects to have Visiting Assistant Professorships beginning fall 2000 (subject to the availability of funding). Appointees will be expected to teach and pursue their research. These positions are available for periods of one quarter to the full academic year, with a possible extension. Min. qualifications: Ph.D. (or equivalent) in mathematics or a closely related field and demonstrated achievements or potential for excellence in research and teaching. Salary: \$43,100. Available: Fall 2000. Application deadline: 1/14/00. Refer to #T99-2. Applicants should send a CV, a summary of their research and teaching experience, and three letters of recommendation with at least one letter addressing teaching experience and ability (all letters are treated as confidential documents) to: Recruitment Committee, Mathematics Department, University of California, Santa Cruz, CA 95064. Inquiries (not applica-

tions) can be sent to mathrcr@cats.ucsc.edu. UCSC is an AA/EEO Employer.

CONNECTICUT

**CONNECTICUT COLLEGE
Mathematics Department**

Connecticut College invites applications for a tenure-track position in applied mathematics. The rank is open; the position begins fall 2000. Applicants must have a Ph.D. in mathematics, applied mathematics, or statistics; a strong commitment to excellence in undergraduate teaching; and the potential to conduct research in a liberal arts setting. Candidates must have the ability to participate in the development of an applied mathematics program, which will include curricular expansion, student research, and collaborations with faculty and students in the natural and/or social sciences. Preference will be given to candidates with demonstrated experience in employing mathematical models in the natural and/or social sciences.

Connecticut College is a small, private, highly selective college with a strong commitment to the liberal arts tradition. Interdisciplinary teaching and research are encouraged. Dorm rooms and all offices are connected by ethernet to the campus network, enabling everyone to access the Connecticut College-Trinity College-Wesleyan University library consortium, the Internet, and the academic courseware server. The college has a strong program of integrating technology throughout the curriculum. Tenure-track faculty receive a research stipend for their first two summers and a semester's leave at full salary after their third year if they are reappointed for the full probationary period. Tenured faculty receive 80% salary during a sabbatical year or 100% salary during a one-semester sabbatical. The normal teaching load is 5 courses per year. Salary is competitive. Connecticut College is an Affirmative Action/Equal Opportunity Employer and is actively engaged in increasing faculty and staff diversity.

Applicants should send a letter of application, curriculum vitae, graduate transcripts, statements on teaching and research, and 3-5 letters of reference to:

Professor Kathleen A. McKeon
Connecticut College Box 5561
New London, CT 06320
tel: (860) 439-2012
fax: (860) 439-2700 (fax)
e-mail: math-dept@conncoll.edu

Applications received by December 1, 1999, will be given full consideration.

More information about this position and the college may be obtained at our Web page, <http://camel.conncoll.edu/ccacad/Math/job.html>.

FLORIDA

FLORIDA GULF COAST UNIVERSITY
Mathematics Faculty
College of Arts & Sciences

FGCU invites applications for two faculty positions in mathematics, available August 2000. The College of Arts and Sciences offers an innovative degree program in liberal studies and is dedicated to quality undergraduate teaching in an inquiry-based, interdisciplinary setting. Candidates for these positions will possess a commitment to excellence in teaching, the ability to teach a broad range of undergraduate mathematics courses, experience with computer algebra systems in teaching, experience or interest in developing distance learning courses, and the ability to interact positively with faculty across all Arts & Sciences disciplines and to contribute to interdisciplinary curriculum development. Appointments will be made on a 9-month, multiyear contract basis.

Assistant/Associate Professor, Pos. #12302. Req'd: Ph.D. in math conferred by August 2000. Prefer: Prior faculty experience. Area of specialization open. Ability to direct undergraduate research projects a plus. Continued scholarly activity is expected at a level commensurate with the mission of the university.

Assistant/Associate Professor, Pos. #11149. Req'd: Ph.D. in statistics conferred by August 2000, with specialty in statistics or operation research. Prefer: Prior faculty experience. Ability to direct undergraduate research projects a plus. Continued scholarly activity is expected at a level commensurate with the mission of the university. The successful candidate will work with science faculty on establishment of a new master's program in environmental studies; those with related expertise will receive priority consideration.

FGCU representatives will be at the Joint Meetings in Washington to meet with interested candidates. Under Florida's Public Records law, applications submitted are available for public review upon request.

Application Process: To apply, submit two packages (one original and one photocopy) for each position. Each package must include a letter of interest, curriculum vitae, and list of five references postmarked by the deadline date of January 15, 2000. Additional information about the above positions can be obtained by calling our 24-hr. jobline at 941-590-1111 or visiting our Web site at <http://admin.fgcu.edu/hr/index.html>. Mail materials to FGCU, HR Dept, Pos. # (state the position # for which you are applying), 10501 FGCU Blvd. South, Ft. Myers, FL 33965-6565.

FGCU is an Equal Opportunity/Equal Access/Affirmative Action Institution which has a commitment to cultural, racial, and ethnic communities and encourages women and minorities to apply. It is ex-

pected that successful candidates share in this commitment.

FLORIDA INTERNATIONAL UNIVERSITY

The Department of Mathematics invites applications for one or several tenure-track positions, subject to administrative approval, effective August 2000. The positions will probably be at the assistant professor level. Duties will include mathematical research, teaching, and service. Candidates must have a Ph.D. in mathematics.

Special consideration will be given to the areas of differential geometry, gauge theory, applied mathematics/PDE, number theory and several complex variables. The deadline for applications is January 14, 2000.

Florida International University is a member of the State University System of Florida, with over 30,000 students. The department offers bachelor's and master's degrees. Current faculty's research interests include algebra, number theory, analysis/PDE, numerical analysis, logic and differential geometry/topology.

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

For additional information please e-mail Dr. Enrique Villamor at villamor@fiu.edu. Florida International University is an Equal Opportunity/Equal Access Employer.

GEORGIA

GEORGIA INSTITUTE OF TECHNOLOGY

The School of Mathematics expects to have visiting and tenure-track positions at various levels beginning fall 2000 and will consider applications in pure and applied mathematics and statistics. The school intends to expand its areas of expertise and foresees the potential for 10-15 new appointments in the next five years. Candidates with strong research and teaching records or potential should arrange for a résumé, 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, GA 30332-0160. Georgia Tech, an institution of the University System of Georgia, is an Equal Opportunity/Affirmative Action Employer.

OGLETHORPE UNIVERSITY

Oglethorpe University invites applications for a tenure-track position at the rank of assistant professor beginning August 2000. A Ph.D. in mathematics and two years' full-time teaching experience are required. The successful candidate will be

expected to teach a broad range of undergraduate courses to both majors and nonmajors, maintain a program of scholarly activity, serve on college committees, and be involved in campus life. Salary is competitive. Oglethorpe University is a highly selective liberal arts college (1,300 students) located in Atlanta. Send letter of application, curriculum vitae, AMS cover sheet, and names only of at least three references by January 15 to Nora Krebs, Administrative Assistant to the Mathematics Search Committee, Oglethorpe University, 4484 Peachtree Road, Atlanta, GA 30319. EOE.

UNIVERSITY OF GEORGIA
Department of Mathematics
Regular Faculty Position

Applications are invited for one tenure-track position at or above the rank of assistant professor, to begin in August 2000. Candidates must have a Ph.D. in pure or applied mathematics and should exhibit outstanding research potential and a strong commitment to excellence in teaching. Applications from all areas of pure and applied mathematics will be considered. Special consideration will be given to applicants in areas where the department currently has strength.

Applicants should send a completed AMS Standard Cover Sheet, a curriculum vitae, and a brief statement about their current and future research plans to: Chair, Search Committee, Department of Mathematics, University of Georgia, Athens, GA 30602. They should also arrange to have three letters of recommendation concerning research and one concerning teaching sent directly to the above address. Review of applications will begin December 1, 1999; applications received by that date will be assured of consideration.

The University of Georgia is an Affirmative Action/Equal Opportunity Employer which is committed to increasing the diversity of its faculty. We especially encourage applications from women, minorities, and underrepresented groups.

ILLINOIS

NORTHWESTERN UNIVERSITY
Department of Mathematics
2033 Sheridan Road
Evanston, IL 60208-2730

Applications are invited for anticipated tenure-track or tenured positions starting September 2000. Priority will be given to exceptionally promising research mathematicians. Fields of interest within the department include algebra, algebraic geometry, analysis, dynamical systems, mathematical physics, probability, partial differential equations, and topology.

Application material should be sent to the Personnel Committee at the depart-

ment address and should include: (1) the American Mathematical Society's Application Cover Sheet for Academic Employment, (2) a curriculum vitae, and (3) at least four letters of recommendation, including one which discusses in some detail the candidate's teaching qualifications. Inquiries may be sent via e-mail to [hiring@math.nwu.edu](mailto: hiring@math.nwu.edu). Applications are welcomed at any time, but the review process starts in October 1999.

Northwestern University is an Affirmative Action/Equal Opportunity Employer committed to fostering a diverse faculty; women and minority candidates are especially encouraged to apply.

NORTHWESTERN UNIVERSITY
Department of Mathematics
2033 Sheridan Road
Evanston, IL 60208-2730
Boas Assistant Professor

Applications for two Ralph Boas assistant professorships of three years each starting in September 2000 are solicited from people whose research is related to dynamical systems. These positions are non-tenure-track and are part of the Emphasis Year in Dynamical Systems which the department will be sponsoring in 2000-01.

Applications should be sent to the Emphasis Year Committee at the department address and should include: (1) the American Mathematical Society's Application Cover Sheet for Academic Employment, (2) a curriculum vitae, and (3) three letters of recommendation, including one which discusses in some detail the candidate's teaching qualifications. Inquiries may be sent via e-mail to [hiring@math.nwu.edu](mailto: hiring@math.nwu.edu). Applications are welcomed at any time, but the review process starts December 1, 1999. 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 CHICAGO
Dept. of Mathematics, Statistics,
and Computer Science

The department has active research programs in all areas of pure mathematics, computational and applied mathematics, combinatorics and computer science, statistics, and mathematics education. See <http://www.math.uic.edu/> for more information.

Applications are invited for the following positions, effective August 21, 2000.

First, a tenure-track or tenured position. Candidates in all areas of interest to the department will be considered. The position is initially budgeted at the assistant professor level, but candidates with a sufficiently outstanding research record may be considered at higher levels. Applicants must have a Ph.D. or equivalent degree in mathematics, computer science, statistics,

mathematics education, or related field; an outstanding research record; and evidence of strong teaching ability. Salary negotiable.

Second, a research assistant professorship. This is a non-tenure-track position normally renewable annually to a maximum of three years. The position carries a teaching load of one course per semester, with the requirement that the incumbent play a significant role in the research life of the department. The salary for AY 2000-01 for this position is expected to be \$40,000. Applicants must have a Ph.D. or equivalent degree in mathematics, computer science, statistics, mathematics education, or related field; and evidence of outstanding research potential.

Send vita and direct 3 letters of recommendation, indicating the position being applied for, to Henri Gillet, Head, Dept. of Mathematics, Statistics, and Computer Science, University of Illinois at Chicago, 851 S. Morgan (M/C 249), Chicago, IL 60607. No e-mail applications will be accepted. To ensure full consideration, materials must be received by **December 21, 1999**. Minorities, persons with disabilities, and women are particularly encouraged to apply. UIC is an AA/EOE.

UNIVERSITY OF ILLINOIS AT CHICAGO
Dept. of Mathematics, Statistics,
and Computer Science

The department has active research programs in all areas of pure mathematics, computational and applied mathematics, combinatorics and computer science, statistics, and mathematics education. See <http://www.math.uic.edu/> for more information.

Applications are invited for a tenure-track or tenured position, effective August 21, 2000, in computer science, broadly defined. Current areas of interest include algorithms, coding theory, combinatorial optimization, combinatorics, complexity, computational mathematics, computational statistics, cryptography, data mining, graph theory, language design, learning theory, logic, numerical analysis, and universal algebra. The position is initially budgeted at the assistant professor level, but candidates with a sufficiently outstanding research record may be considered at higher levels. Applicants must have a Ph.D. or equivalent degree in mathematics, computer science, or a related field; an outstanding research record; and evidence of strong teaching ability, with particular interest in programming and algorithms. Salary negotiable.

Send vita and direct 3 letters of recommendation, indicating the position being applied for, to Henri Gillet, Head, Dept. of Mathematics, Statistics, and Computer Science, University of Illinois at Chicago, 851 S. Morgan (M/C 249), Chicago, IL 60607. No e-mail applications will be accepted. To ensure full consideration, materials must

be received by **December 21, 1999**. Minorities, persons with disabilities, and women are particularly encouraged to apply. UIC is an AA/EOE.

UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN
Department of Mathematics
Tenure-Track Position

Applications are invited for one or more full-time faculty positions to commence August 21, 2000, at the tenure-track (assistant professor) level. Those faculty will be expected to pursue a vigorous research program and to teach graduate as well as undergraduate students. The department will consider applicants in all fields of mathematics, but we intend to show preference in applied mathematics, computational mathematics, mathematical physics, partial differential equations and global analysis, probability theory, algebraic geometry, and number theory. Salary and teaching load are competitive.

Applicants should have completed the Ph.D. (or equivalent) by the time the appointment begins and are expected to present evidence of excellence in research and teaching. Applicants should send a letter of application, a curriculum vitae and publication list, and three letters of reference to the address below. It is the responsibility of the tenure-track applicants to make sure that letters of recommendation are sent.

Joseph Rosenblatt, Chair
 Department of Mathematics
 University of Illinois at
 Urbana-Champaign
 1409 West Green Street
 Urbana, IL 61801-2975
 Tel. (217) 333-3352

E-mail: [search@math.uiuc.edu](mailto: search@math.uiuc.edu)

For full consideration, all materials, including letters of reference, should be received by November 30, 1999; however, applications will be accepted and interviews conducted until the positions are filled. We encourage use of the application cover sheet provided by the American Mathematical Society. Applications from women and minority candidates are especially encouraged. The University of Illinois is an Affirmative Action/Equal Opportunity Employer.

UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN
Department of Mathematics
Postdoctoral Positions as J. L. Doob
Research Assistant Professor

The Department of Mathematics of the University of Illinois at Urbana-Champaign is soliciting applications for postdoctoral positions. Three appointments will be made starting August 21, 2000; each appointment is for three years and is not renewable. These positions are for recent Ph.D. recipients (with a strong preference for

those not more than one year past the Ph.D. degree). The Department of Mathematics will provide an excellent scientific environment to pursue research in pure and applied mathematics. The position carries a salary of \$41,000 per year.

Applicants should send a letter of application, a curriculum vitae and publication list (please provide hard copies of your application and supporting documents), and three letters of reference to the address below. It is the responsibility of the applicants to make sure that letters of recommendation are sent.

Postdoctoral Search Committee
Department of Mathematics
University of Illinois at
Urbana-Champaign
1409 West Green Street
Urbana, IL 61801-2975
e-mail: postdocs@math.uiuc.edu

To insure full consideration, all materials, including letters of reference, should be received by November 30, 1999. We will review later applications until the search is closed. We encourage use of the application cover sheet provided by the American Mathematical Society and the indication of the subject area using the AMS subject classification numbers. Applications from women and minority candidates are especially encouraged. The University of Illinois is an Affirmative Action/Equal Opportunity Employer.

KANSAS

KANSAS STATE UNIVERSITY Department of Mathematics

Subject to budgetary approval, applications are invited for tenure-track and visiting positions commencing August 6, 2000; rank and salary commensurate with qualifications. The department seeks candidates whose research interests mesh well with current 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. A 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 at least three letters of reference evaluating research should be sent to:

Louis Pigno
Department of Mathematics
Cardwell Hall 138
Kansas State University
Manhattan, KS 66506

The department also requires that the candidate arrange for letters to be submitted evaluating teaching potential. Offers may begin by December 6, 1999, but applications for positions will be reviewed until February 1, 2000, or until positions are closed. AA/EOE.

MARYLAND

UNIVERSITY OF MARYLAND, COLLEGE PARK Department of Mathematics

Applications are invited for tenured and tenure-track positions in the Department of Mathematics. Strong preference will be given to candidates in (1) applied analysis, (2) applied and computational statistics, and (3) representation theory, but candidates from all areas will be considered.

Candidates at all levels will be considered. Priority will be given to applications received by November 1, 1999. Appointments will commence in fall 2000.

The University of Maryland is an Equal Opportunity and Affirmative Action Employer that strongly encourages applications from female and minority candidates.

Please send a curriculum vitae, AMS Standard Cover Sheet, and three letters of recommendation to:

The Hiring Committee
Department of Mathematics
University of Maryland
College Park, MD 20742

UNIVERSITY OF MARYLAND, COLLEGE PARK Computational Nonlinear Dynamics Faculty Position

A theoretical nonlinear dynamicist with strong interest in computation is sought for a tenured or tenure-track appointment in the Department of Mathematics, possibly joint with the Institute for Physical Science and Technology. An outstanding record of research accomplishments and a proven ability to attract research support are important for a senior position. Good teaching is a priority of the university.

Applications should be sent to: Chair's Office, Computational Nonlinear Dynamics, Department of Mathematics, University of Maryland, College Park, MD 20742-4015. Priority will be given to applications received by December 31, 1999. The University of Maryland is an Equal Opportunity/Affirmative Action Employer.

UNIVERSITY OF MARYLAND, COLLEGE PARK Lectureships in the Department of Mathematics

Applications are invited for Avron Douglis Lectureships, starting in fall 2000. These positions are for recent Ph.D. recipients, with a preference for those not more than one year past the Ph.D. degree. The Lectureship is for two years and is non-renewable. Candidates must have superior research potential and a strong commitment to teaching. The Department of Mathematics provides an excellent scientific

environment to foster the professional development of junior mathematicians. The teaching duties consist of three courses per year. The salary is \$43,000 per academic year, supplemented by a \$1,000 research stipend. Priority will be given to applications completed by December 15, 1999.

The University of Maryland is an Equal Opportunity and Affirmative Action Employer that strongly encourages applications from female and minority candidates.

Please send a curriculum vitae and AMS Standard Cover Sheet and direct three or more letters of recommendation, at least one of which speaks to the applicant's teaching credentials, to:

Douglis Lectureship Committee
Department of Mathematics
University of Maryland
College Park, MD 20742

MICHIGAN

CENTRAL MICHIGAN UNIVERSITY Statistics Position

The Mathematics Department is seeking qualified applicants for a tenure-track position at the assistant professor level in statistics starting in August 2000. Candidates should have a recent Ph.D. in statistics, show evidence of having conducted research in statistics, and have effective communication skills. The successful candidate will be expected to teach graduate and undergraduate statistics and mathematics courses, to conduct research in statistics, and to apply for external funding. We are especially interested in individuals with research interests that overlap existing research of the faculty. The usual teaching load is nine semester hours. Salary is competitive, and benefits include university-paid retirement, medical, dental, disability, and group life insurance.

Please send a letter of application, curriculum vitae, transcript, and three letters of reference to: Professor Sidney Graham, Chair, Department of Mathematics, Central Michigan University, Mt. Pleasant, MI 48859. Phone: 517-774-3596, fax: 517-774-2414, e-mail: math@cmich.edu, Web site: <http://www.cst.cmich.edu/units/mth/>. Screening will begin on October 15, 1999, but applications will be accepted until the position is filled.

CMU, an AA/EO Institution, is strongly and actively committed to increasing diversity within its community (see <http://www.cmich.edu/aaeo.html>).

MISSISSIPPI

MISSISSIPPI STATE UNIVERSITY Head Department of Mathematics

Nominations and applications are invited for the position of professor and head of the Department of Mathematics and Statistics at Mississippi State University, a Doctoral I land-grant institution. The department is housed in the College of Arts and Sciences and offers programs for the B.A., B.S., and M.S. in mathematics, the M.S. in statistics, and the Ph.D. in mathematical sciences. The department currently has 39 faculty members, some having cooperative research programs with faculty in the NSF Engineering Research Center. For more information, visit <http://www.msstate.edu/Dept/Math/>.

The applicant should have an earned doctorate in any area of mathematical sciences, strong administrative skills, an established research record, and a commitment to excellence in teaching, service, research, and other scholarly activities.

Screening of applicants will begin October 18, 1999, and will continue until the position is filled. The position is available July 1, 2000. Send nominations or applications and résumés, including names, addresses, and telephone numbers of at least three references, to:

Stephen B. Klein, Chair
Mathematics and Statistics Head
Search Committee
P.O. Box 6161
Mississippi State, MS 39762

Mississippi State University is an AA/EOE.

NEW HAMPSHIRE

DARTMOUTH COLLEGE

The Department of Mathematics anticipates two tenure-track openings with initial appointment in the 2000-01 academic year. The first is for an assistant professor of mathematics in the field of geometry. The second is for an assistant professor in applied mathematics. Current areas of applied interests include signal and image processing, informatics, and computational methods. The applied mathematics group enjoys close ties with computer science, cognitive neuroscience, engineering, and the medical school. Of particular interest are candidates who will be able to enhance some of these connections.

Candidates for either position must be committed to outstanding teaching at all levels of the undergraduate and graduate curriculum and must give evidence of a well-regarded research program that shows real promise for the future. Candidates with several years of experience should in addition be ready to direct Ph.D. theses. The applied mathematics candidate

should be someone who can and wants to help cover the undergraduate probability and statistics offerings of the department.

To create an atmosphere supportive of research, Dartmouth offers new faculty members grants for research-related expenses, a quarter of sabbatical leave for each three academic years in residence, and flexible scheduling of teaching responsibilities. The teaching responsibility in mathematics is four courses spread over two or three quarters. The department encourages good teaching with a combination of committed colleagues and bright, responsive students.

To apply, send a letter of application, curriculum vitae, and a brief statement of research results and interests. Also arrange for four letters of reference to be sent, at least one of which addresses teaching and, if the applicant's native language is not English, the applicant's ability to use English in a classroom. All application materials should be addressed to Betty Harrington, Recruiting Secretary, Department of Mathematics, Dartmouth College, 6188 Bradley Hall, Hanover, NH 03755-3551. Applications completed by January 15 will receive first consideration. Dartmouth is committed to Affirmative Action and encourages applications from African Americans, Asian Americans, Hispanics, Native Americans, and women. Inquiries about the progress of the selection process can be directed to Dwight Lahr, Recruiting Chair.

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 10-week courses spread over two or three quarters typically include at least one course in the instructor's specialty and include elementary, advanced, and (at instructor's option) graduate courses. Nine-month salary of \$41,000 supplemented by summer research stipend of \$9,111 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 3 or preferably 4 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.

RIVIER COLLEGE Mathematics Faculty Positions

The Department of Mathematics and Computer Science plans to hire two tenure-track positions in mathematics at the assistant professor level for August 2000. Responsibilities include teaching a wide range of courses, participation in departmental and college service, ongoing scholarship, and professional activity. A Ph.D. in mathematics or a related field is required. The candidates should also provide evidence of strong commitment to excellence in teaching, ability to work collaboratively within the department, willingness to integrate technology into mathematics courses, and familiarity with current trends in mathematics education.

The department offers bachelor's degrees in computer science, mathematics, and mathematics education; associate degrees in computer science; a Master of Science in Computer Science; and a Master of Arts in Teaching Mathematics. Teaching schedules include developmental, service, and liberal arts courses as well as courses for majors. Some classes are taught in the evenings and on Saturday.

Rivier College has the advantage of a central New England location in a thriving small city less than fifty miles from metropolitan Boston. With a student population of 2,800 undergraduate and graduate students, the college is recognized for academic excellence and a commitment to social justice coupled with professional career preparation in all its programs. The College welcomes women and men of all faiths to its faculty, staff, and student body. The candidates must demonstrate a personal and professional commitment to liberal arts education and to the promotion of the mission and traditions of a Catholic college.

Review of applications will begin December 15, 1999, and will continue until the position is filled. Submit a curriculum vitae, a letter of application that describes ability to contribute to our programs, and the names and telephone numbers of three references to: Office of Human Resources, Rivier College, 420 Main Street, Nashua, NH 03060-5086. For more information about Rivier College visit our Web site at <http://www.rivier.edu/>.

Rivier College is an Equal Opportunity Employer.

NEW JERSEY

RUTGERS UNIVERSITY

The Rutgers University Mathematics Department invites applications for the following positions which may be open beginning September 2000.

Tenure-Track and Tenure Positions. The department anticipates a few openings, mainly tenure-track assistant professorships. Strong candidates in all fields are encouraged to apply. Candidates must have Ph.D., outstanding research ability in pure or applied mathematics, and concern for teaching. Semester course load now averages 6 hours.

Hill Assistant Professorships (non-tenure-track). The Hill Assistant Professorships are three-year nonrenewable positions. Candidates should have received the Ph.D., show outstanding promise of research ability in pure or applied mathematics, and have concern for teaching. Semester course load now averages 6 hours.

NSF-VIGRE Postdoctoral Fellowships (non-tenure-track). Nonrenewable positions which include three years of academic year and summer support, a teaching load of one course per semester, and other special features. Restricted to citizens or permanent residents of the United States who are within 18 months of the award of their Ph.D. Candidates should show outstanding promise of research ability in pure or applied mathematics and have concern for teaching.

Non-Tenure-Track Assistant Professorships. These are three-year nonrenewable positions. Candidates should have a Ph.D., be able to document an active interest in and exceptional ability for mathematics instruction, and show promise of research ability. Preference will be given to applicants who have experience in the use of technology (such as graphing calculators and/or computer algebra systems) and group learning. Duties will consist of teaching three courses in the fall and two in the spring, mainly at the level of calculus.

Applicants should send résumé, with the AMS Application Cover Sheet attached, and direct at least three letters of recommendation to: Search Committee, Dept. of Math-Hill Center, Rutgers University, 110 Frelinghuysen Road, Piscataway, NJ 08854-8019. An electronic version of the AMS Application Cover Sheet should also be sent (see <http://www.math.rutgers.edu/> for details). The department will begin reviewing applications for tenure-track and tenure positions November 1, 1999, and for non-tenure-track positions December 1, 1999, and will continue its review until the positions are filled. Please indicate position(s) desired and give the AMS Subject Classification number of your area(s) of specialization.

Applicants who applied in 1998/99 may, if they wish, request to have their previous application reactivated and submit only new materials as they choose. An updated electronic version of the AMS Application Cover Sheet should also be sent. Rutgers is an Affirmative Action/Equal Opportunity Employer and encourages applications from women and minority-group

members. Updated details of these positions will appear on the Rutgers Mathematics Department Web page at <http://www.math.rutgers.edu/>.

NEW YORK

CORNELL UNIVERSITY School of Operations Research & Industrial Engineering Regular Faculty Positions

Cornell University's School of Operations Research and Industrial Engineering is seeking candidates for one or more regular faculty positions. The appointments are expected to be at the rank of tenure-track assistant professor; however, exceptional scholars at any rank are encouraged to apply. The search is open to all areas of specialization; specialization in one or more of financial engineering, applied probability, applied statistics, simulation, systems engineering, or information technology is of particular interest. Candidates should have a Ph.D. in operations research, industrial engineering, statistics, computer science, mathematics, or a related discipline and demonstrable excellence in teaching and research.

Applicants should send a CV with supporting materials and direct four letters of recommendation to Faculty Search Committee, School of ORIE, Rhodes Hall, Cornell University, Ithaca, NY 14853. We may be making several appointments over a three-year period; applicants who seek an appointment beginning by the fall of 2000 should apply as early as possible and no later than January 15, 2000.

Women and minority candidates are especially encouraged to apply.

Cornell University is an Affirmative Action/Equal Opportunity Employer.

UNIVERSITY AT BUFFALO STATE UNIVERSITY OF NEW YORK

The Department of Mathematics anticipates the appointment of a tenure-track assistant professor beginning September 1, 2000. The salary will be competitive. We seek applicants who have excellent research accomplishments/potential and a strong commitment to teaching. Our priority will be in applied mathematics, but highly qualified applicants in other areas may apply.

Applicants should send supporting information, including a CV with a list of research interests, **and four letters of recommendation to:**

Search Committee Chairman
Department of Mathematics
University of Buffalo, SUNY
Diefendorf Hall, Rm. 106
3435 Main Street, Bldg. 20
Buffalo, NY 14214-3093

No electronic applications will be accepted.

The deadline for applications is December 1, 1999. Late applications will be considered until positions are filled.

University at Buffalo, SUNY, is an Equal Opportunity/Affirmative Action Employer. We are interested in identifying prospective minority and women candidates. No person, in whatever relationship with the University at Buffalo, State University of New York, shall be subject to discrimination on the basis of age, creed, handicap, national origin, race, religion, sex, marital, or veteran status.

NORTH CAROLINA

UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL Chapel Hill, NC 27599

Applications are invited for a tenure-track assistant professorship in pure mathematics effective July 1, 2000. Applicants must have demonstrated a strong research potential, normally including substantial work beyond the dissertation. High-quality teaching, including interest and expertise in the use of instructional technology, is also expected. Strong preference will be shown to the areas of partial differential equations, representation theory, and geometry.

Send a curriculum vitae, brief statement of current research, statement of teaching goals, and four letters of recommendation to: Pure Search Committee, Dept. of Mathematics, CB #3250 Phillips Hall, UNC-Chapel Hill, Chapel Hill, NC 27599-3250. A copy of this ad may be found on our Web site at <http://www.math.unc.edu/General/Job.announcements/>. Further information about the mathematics dept. may be found at our Web site, <http://www.math.unc.edu/>. EO/AA Employer. Women and minorities are encouraged to apply and to identify themselves. Applications received by December 1 are assured of full consideration.

UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL Chapel Hill, NC 27599

Applications are invited for two tenure-track assistant professor positions in applied mathematics, with employment to begin July 1, 2000. A tenured appointment may be possible for an exceptional candidate. A strong research record and doctorate in mathematics, applied mathematics, or a closely related field are required. Preference is given to candidates with a commitment to interdisciplinary university research; collaborations with industry or government; and teaching, including development of applied math curricula at undergraduate and graduate levels. These positions contribute toward an aggressive plan to build a strong applied and

computational mathematics group interacting with existing strengths at UNC in mathematics and its applications in materials, marine, biomedical, life, environmental, and the computational sciences. A copy of this ad may be found on our Web site at <http://www.math.unc.edu/jobs/>. Further information about the applied mathematics program and the mathematics department may be found at the Web site <http://www.math.unc.edu/>. Send curriculum vitae, abstract of current research, and four letters of recommendation to: Applied Search Committee, Department of Mathematics, CB #3250 Phillips Hall, UNC at Chapel Hill, Chapel Hill, NC 27599-3250. EO/AA Employer. Women and minorities are encouraged to identify themselves voluntarily. Applicants are encouraged to submit a concise statement of current research plans and teaching goals. Completed applications received by December 1, 1999, are assured of full consideration.

WAKE FOREST UNIVERSITY
Department of Mathematics and
Computer Science

Applications are invited for a tenure-track position in statistics at the assistant professor level beginning August 2000. Duties include teaching statistics at the undergraduate and graduate levels and continuing research. A Ph.D. in statistics is required. Women and minorities are encouraged to apply. The department has 25 members and offers a B.S. and M.A. in mathematics, a B.S. and M.S. in computer science, and a B.S. in each of mathematical business and mathematical economics. 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.

OHIO

UNIVERSITY OF DAYTON
Department of Mathematics

Applications are invited for a tenure-track position at the assistant professor level starting in August 2000. A Ph.D. in mathematics is required with preference given to those working in the area of combinatorics. Applicants must have a strong commitment to research and the potential to become an effective teacher. Responsibilities include developing and maintaining a research agenda, teaching a broad range of courses, advising, and curriculum development in the undergraduate program. The applicant will also be expected to participate in mentoring students working on undergraduate research projects.

The selection process will begin on December 6, 1999. To receive full consider-

ation, all materials must be received by January 22, 2000. Please send a résumé, three letters of recommendation, a statement of research plans, and a statement of teaching philosophy to: Dr. Paul Eloe, Chair of the Combinatorics Search Committee, Department of Mathematics, University of Dayton, Dayton, OH 45469-2316. Both teaching and research abilities should be addressed in the letters. Please include an e-mail address in your correspondence. Further information can be obtained on our Web site, <http://www.udayton.edu/~mathdept/>. The University of Dayton is an Equal Opportunity and Affirmative Action Employer.

OKLAHOMA

OKLAHOMA STATE UNIVERSITY
Department of Mathematics

The department anticipates filling 3 or more **tenure-track or tenured** positions beginning fall 2000. Applicants should have outstanding research potential and have made major contributions beyond their doctoral research. Candidates should also be committed to excellence in undergraduate and graduate education; the usual teaching load is 5 or 6 hours each semester. The department seeks accomplished individuals in any field of mathematics, but preference may be given to strengthening one of our existing research groups. The department is also interested in branching out with a new group in an area such as: the mathematics of digital signal processing (building off our groups in analysis and number theory and the Signal Processing and Analysis Center in the College of Engineering), cryptography and other applications of number theory, combinatorial optimization and graph theory, computational and applied geometry, partial differential equations and differential geometry.

The department also invites applications from recent recipients of the Ph.D. for several temporary **postdoctoral positions** beginning fall 2000. These are one-year appointments which are typically renewed for a second year. Appointment to these positions does *not* preclude future consideration for a tenure-track position. The duties include research and teaching, with a teaching load of usually 5 or 6 hours each semester. Mathematicians with research interests close to those of the permanent faculty may receive preference.

All applicants should submit a curriculum vitae, abstracts of completed research, and a statement regarding teaching experience, and direct 4 letters of recommendation to the address below. One letter of recommendation should appraise the applicant's teaching abilities. 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. Full consideration will be given to applications **received by December 1, 1999**. Electronic applications are encouraged; information about this may be found at: <http://www.math.okstate.edu/~jobs/>.

Oklahoma State University is located in Stillwater in north central Oklahoma, about an hour by car from both Tulsa and Oklahoma City. The department boasts a dynamic faculty with 32 tenured or tenure-track members engaged in mathematics research and education. An active Ph.D. program, support for colloquium and other visitors, approximately 8-10 postdoctoral fellows, as well as involvement of undergraduates in research experiences, create a lively atmosphere in the department. The department has received national recognition for the faculty's contributions to mathematical research and education. More information on the department is available at <http://www.math.okstate.edu/>.

Oklahoma State University is an Equal Opportunity/Affirmative Action Employer. Women and minorities are encouraged to apply.

Appointments Committee Chair
Dept. of Math. 401 Math Science
Oklahoma State University
Stillwater, OK 74078-1058

OREGON

PORTLAND STATE UNIVERSITY
Department of Mathematical Sciences
Assistant Professor Positions

Applications are invited for assistant professor positions in applied mathematics, statistics, and a possible open position beginning September 16, 2000. Applicants are expected to have completed a doctoral degree in a mathematical science and show evidence of outstanding research potential and a strong commitment to excellence in teaching. Preference will be given to applicants with a commitment to interdisciplinary research and developing collaborations with industry. Further program information is available on our home page (<http://www.mth.pdx.edu/>). Qualified applicants' applications materials should include (1) the AMS Cover Sheet for Academic Employment, (2) a curriculum vitae, and (3) three letters of recommendation. Send materials to:

Search Committee
Department of Mathematical Sciences
Portland State University
P. O. Box 751
Portland, OR 97207-0751
E-mail: search@mth.pdx.edu

All materials should be received by January 15, 2000. Portland State University is an Affirmative Action/Equal Opportunity Institution. Applications from women and minorities are especially welcome.

UNIVERSITY OF OREGON Department of Mathematics

Applications are invited for tenure-track positions at all levels in mathematics or mathematical statistics beginning in September 2000. Qualifications are a Ph.D. in mathematics or statistics, an excellent record of research accomplishment, and evidence of teaching ability. Preference will be given to candidates with research interests that complement those currently represented. Competitive salary with good fringe benefits. Send complete résumé and at least three letters of recommendation to: Hiring Committee, Department of Mathematics, 1222 University of Oregon, Eugene, OR 97403-1222. Closing date is January 6, 2000. Women and minorities are encouraged to apply. The Univ. of Oregon is an EO/AA/ADA Institution committed to cultural diversity.

RHODE ISLAND

BROWN UNIVERSITY

J. D. Tamarkin Assistant Professorships:

Two three-year nontenured, nonrenewable appointments, beginning July 1, 2000. Teaching load: one to two courses per semester (3–6 hours per week). Candidates are required to have received a Ph.D. degree or equivalent by the start of this appointment, and they may have up to three years of academic and/or postdoctoral research experience by then.

VIGRE Postdoctoral Fellow: One or two three-year nontenured, nonrenewable appointments, beginning July 1, 2000. Teaching load: one course per semester (3 hours per week). The fellowship includes summer support and a \$2,500/year research fund. Candidates are required to have received a Ph.D. degree by the start of this appointment, and they may have up to 18 months of academic and/or postdoctoral research experience by then. Candidates must be U.S. citizens, nationals, or permanent residents to qualify for the VIGRE fellowships, which are NSF-supported positions.

Applicants should have strong research potential and a commitment to teaching. Field of research should be consonant with the current research interests of the department. For full consideration, a curriculum vitae, an AMS Standard Cover Sheet, and three letters of recommendation must be received by December 1, 1999. The cover letter should clearly indicate whether the candidate wishes to be considered for a J. D. Tamarkin Assistant Professorship, a VIGRE Postdoctoral Fellowship, or both. All inquiries and materials should be addressed to Junior Search Committee, Department of Mathematics, Brown University, Providence, RI 02912. To access the AMS Standard Cover Sheet, visit our Web site, <http://www.math.brown.edu/juniorsearch.html>. E-mail inquiries

can be addressed to juniorsearch@math.brown.edu. Brown University is an Equal Opportunity/Affirmative Action Employer and encourages applications from women and minorities.

SOUTH CAROLINA

CLEMSON UNIVERSITY Department of Mathematical Sciences

The Department of Mathematical Sciences of Clemson University invites applications for tenure-track positions at the assistant/associate professor level starting with the fall 2000 semester. Additional lecturer, postdoctoral, or temporary positions are anticipated. An earned doctorate or equivalent is required for the tenure-track positions. The department includes the areas of algebra, discrete mathematics, analysis, computational mathematics, operations research, and statistics. Well-qualified applicants in each of the above interest areas are solicited. Desirable attributes for candidates include an interdisciplinary research orientation in the mathematical sciences; postdoctoral, industrial, or practical experience; and an interest in innovative applications. Candidates should have strong potential or demonstrated capability for effective research and teaching. Review of applications will begin on November 1, 1999, and will continue until the positions are filled. Applicants should indicate in their cover letter their research specialties and interests. Vita and three reference letters should be sent to the address below. For further information regarding our department and its programs, please visit our Web site at <http://www.math.clemson.edu/>. CU is an AA/EO Employer and encourages applications from women and minorities.

Send applications to: Faculty Search Committee, Department of Mathematical Sciences, Box 340975, Clemson University, Clemson, SC 29634-0975.

COASTAL CAROLINA UNIVERSITY

The Department of Mathematics and Statistics at Coastal Carolina University invites applications for two (2) tenure-track positions in mathematics beginning August 2000 at the assistant professor level. Expertise in computational geometry, combinatorics, or applied mathematics is preferred, but strong applicants in all areas will be considered. The position will involve teaching both introductory and upper-level courses. The typical course load is 12 credits per semester.

Located near Myrtle Beach, South Carolina, Coastal Carolina University is primarily an undergraduate liberal arts institution with 4,500 students. Applicants must be committed to excellence in undergraduate classroom instruction, fos-

ter undergraduate research, and be active scholars. Candidates must have a Ph.D.

Applicants should send a letter of application and a curriculum vitae, and direct three (3) letters of recommendation, one of which must address teaching, to: Dr. Deborah A. Vrooman, Attn: Search Committee, Coastal Carolina University, Department of Mathematics and Statistics, P.O. Box 261954, Conway, SC 29528-6054. Deadline for applications: December 10, 1999.

Coastal Carolina University is committed to Equal Employment Opportunity through Affirmative Action and is eager to identify minority persons and/or women with appropriate qualifications.

TEXAS

BAYLOR UNIVERSITY

The Department of Mathematics invites applications for a tenure-track position, at the assistant professor level, starting in August 2000. Excellence in teaching and research/scholarship is essential. Special consideration will be given to strong applicants in areas related to analysis or applied mathematics.

An application must include a current curriculum vitae, three recent letters of reference, a photocopy of each official transcript, and statements about your philosophy of teaching and of research. Applications will be reviewed beginning November 1, 1999, and will be accepted until the position is filled. To ensure full consideration, an application should be received by December 15, 1999.

Baylor is a Baptist university affiliated with the Baptist General Convention of Texas. As an Affirmative Action/Equal Employment Opportunity Employer, Baylor encourages minorities, women, veterans, and persons with disabilities to apply. The university offers generous benefits, including tuition remission for qualified family members.

Send all materials to Mathematics Search Committee, P. O. Box 97328, Waco, TX 76798-7328; e-mail address: Ed_Oxford@baylor.edu.

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, wavelets, combinatorics, and ergodic theory. Duties will include research and classroom teaching. Applications received by December 31, 1999, 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 on E-MATH) would be greatly appreciated.

SOUTHWEST TEXAS STATE UNIVERSITY Tenure-Track Position

The Department of Mathematics invites applications for an assistant professor tenure-track position starting September 1, 2000. We will consider applicants in the areas of combinatorics, discrete algebraic structures, and number theory. Applicants must have a doctorate in mathematics by August 2000 and must exhibit outstanding research potential as well as excellence in teaching. Starting salary will be competitive and will depend on qualifications.

To be considered, an applicant must include a cover letter, curriculum vitae, a research plan, and three references with phone numbers. All applications must be received by January 25, 2000. Apply to:

Prof. Xingdo Jia
Recruitment Committee Chair
Department of Mathematics
Southwest Texas State University
San Marcos, TX 78666
Phone: 512-245-2551
Fax: 512-245-3425
E-mail: math@swt.edu

Southwest Texas State University is an Affirmative Action/Equal Opportunity Employer.

TEXAS CHRISTIAN UNIVERSITY Department of Mathematics

Tenure-track position at the assistant professor level beginning August 2000. Applicants from all areas of mathematics are welcomed, but preference will be given to candidates in areas that are compatible with the current research interests of the department; these areas include number theory, index theory, operator theory, and differential geometry. A Ph.D. is required, and excellence in both teaching and research is expected. A complete application consists of a vita, a research abstract, a brief statement on teaching experience and philosophy, photocopies of undergraduate and graduate transcripts, and at least three letters of reference addressing research and teaching.

Two instructor positions beginning August 2000. A Ph.D. or master's degree in mathematics or statistics is required, as well as documented excellence in teaching. Instructors will typically teach four classes per semester. In addition, at least one of the instructors will be in charge of organizing and maintaining course offerings in statistics and probability. These instructorships are one-year positions, but are

renewable indefinitely, provided that the instructor continues to exhibit exceptional ability in the classroom. A complete application consists of a vita, a statement on teaching experience and philosophy, photocopies of undergraduate and graduate transcripts, and at least three letters of reference addressing teaching.

Texas Christian University is a major teaching and research university of approximately 7,000 students. The university is located in the Dallas-Fort Worth metropolitan area of 5 million people. TCU does not discriminate in admissions or hiring on the basis of religion. Send correspondence to: Search Committee, Department of Mathematics, Box 298900, Texas Christian University, Fort Worth, TX 76129. Consideration of applications will begin December 1, 1999, and will continue until the positions are filled. TCU is an Equal Opportunity/Affirmative Action Employer.

TRINITY UNIVERSITY

The Department of Mathematics invites applications for a tenure-track position at the rank of assistant professor to begin in August 2000. Responsibilities include teaching undergraduates and continued scholarly involvement. A Ph.D. in mathematics or related field is required. The department values both a commitment to excellence in teaching and potential for scholarly success. All research fields in mathematics will be considered.

Candidates should send a curriculum vitae, academic transcripts, three letters of reference (at least one of which addresses teaching), and statements of teaching philosophy and mathematical interests to:

Search Committee
Department of Mathematics
Trinity University
715 Stadium Drive
San Antonio, TX 78212-7200

To ensure full consideration, applications must be received by December 10, 1999. Inquiries (not applications) may be sent to math@trinity.edu. AA/EOE.

THE UNIVERSITY OF TEXAS OF THE PERMIAN BASIN

The University of Texas of the Permian Basin invites applications for a tenure-track position at the assistant professor level. The position begins January 2000 or August 2000. Required qualifications include a Ph.D. in mathematics and evidence of potential for effective teaching and research. All fields of mathematics will be considered. Each applicant should send a résumé, including a statement on teaching and research interests, and three letters of recommendation (at least one should address teaching effectiveness) to:

Dr. Paul Feit
Science and Mathematics
UT Permian Basin

4901 E. University Blvd.
Odessa, TX 79762

Documents may be submitted by e-mail to feit_p@utpb.edu. However, a signed hard copy of each letter of recommendation is required to complete the file. Review of applications will begin October 4, 1999, and will continue until the position is filled. The University of Texas of the Permian Basin UTPB is an Affirmative Action/Equal Opportunity Employer.

UTAH

BRIGHAM YOUNG UNIVERSITY

The Department of Mathematics at Brigham Young University is accepting applications for anticipated visiting and tenure-track positions beginning August 2000. The department has a strong commitment to undergraduate education and has a substantial doctoral program. Candidates will be evaluated on evidence of excellent teaching and potential to make significant research contributions. Research interests in the department include algebraic geometry, combinatorial and geometric group theory, combinatorics, dynamical systems, geometric analysis, mathematics education, matrix theory, number theory, numerical analysis, partial differential equations, and topology. Interested applicants should send an AMS Standard Cover Sheet and a curriculum vitae and direct three letters of recommendation to:

Search Committee
Department of Mathematics
292 TMCB
Brigham Young University
Provo, UT 84602-6539

Application review begins immediately; however, applications will be accepted until January 31, 2000, or until positions are filled. Brigham Young University, an Equal Opportunity Employer, is sponsored by the Church of Jesus Christ of Latter-day Saints and requires observance of Church standards. Strong preference is given to members in good standing of the sponsoring church.

UNIVERSITY OF UTAH

The Department of Mathematics at the University of Utah invites applications for the following positions. Availability of positions is contingent upon funding. The hiring committee will select candidates based on their teaching experience and research record.

1. **Up to three full-time tenure-track or tenure appointment** at the level of assistant associate or full professor. The department is primarily interested in applicants who work in the research areas represented in the department and who received their Ph.D. degrees prior to 1999.

2. **One or more nonrenewable three-year instructorships.** Persons of any age

receiving Ph.D. degrees in 1999 or 2000 are eligible. Starting salary will be at least \$40,000. Increases are given annually, but amounts vary from year to year. Teaching duties for the entire three-year instructorship are 9 one-semester courses.

3. **One or more Visiting Faculty positions** of one year or less in any of the professorial ranks, depending upon availability.

The deadline for applications is January 14, 2000. However, applications may be accepted until all positions are filled.

To apply for any of these positions, you are strongly encouraged to fill out an application at <http://www.math.utah.edu/jobs/> or send the AMS cover sheet. To complete your application, send a curriculum vitae, bibliography, and three letters of recommendation. Visiting Professor applicants should indicate the part of the year they wish to visit. Incomplete files will not be considered.

Please send this information to Committee on Staffing, Department of Mathematics, University of Utah, 155 S. 1400 E. JWB 233, Salt Lake City, UT 84112. The University of Utah is an Equal Opportunity/Affirmative Action Employer and encourages applications from women and minorities and provides reasonable accommodation to the known disabilities of applicants and employees.

CANADA

**UNIVERSITY OF TORONTO
Tenure-Stream Appointment
in Algebra, Number
Theory, and Geometry**

The University of Toronto solicits applications for a tenure-stream appointment in the fields of algebra, number theory, and geometry. Preference will be given to researchers in arithmetic geometry.

The appointment is at the downtown (St. George) campus at the level of assistant professor, to begin July 1, 2000. Candidates are expected to have demonstrated excellence in both teaching and research after the Ph.D.; in particular, a candidate's research record should show clearly the ability to make significant original and independent contributions to mathematics. Salary commensurate with experience.

Applicants should send their complete C.V., including a list of publications, a short statement describing their research program, and all appropriate material about their teaching. They should also arrange to have at least four letters of reference sent directly to:

Search Committee
Department of Mathematics
University of Toronto
100 St. George Street, Room 4072
Toronto, Canada M5S 3G3

At least one letter should be primarily concerned with the candidate's teach-

ing. In addition, it is recommended that applicants submit the electronic application form which is available from our World Wide Web Employment Opportunities page: <http://www.math.toronto.edu/jobs/>.

To ensure full consideration, this information should be received by December 1, 1999.

In accordance with its Employment Equity Policy, the University of Toronto encourages applications from qualified women or men, members of visible minorities, aboriginal peoples, and persons with disabilities.

**UNIVERSITY OF TORONTO
Tenure-Stream Appointment in
Applied Mathematics**

The Department of Mathematics, University of Toronto, solicits applications for a tenure-stream appointment for a mathematician working in the area of applied mathematics.

The appointment is at the downtown (St. George) campus at the level of assistant professor, to begin July 1, 2000. Candidates are expected to have demonstrated excellence in both teaching and research after the Ph.D.; in particular, a candidate's research record should show clearly the ability to make significant original and independent contributions to mathematics. Salary commensurate with experience.

Applicants should send their complete C.V., including a list of publications, a short statement describing their research program, and all appropriate material about their teaching. They should also arrange to have at least four letters of reference sent directly to:

Search Committee
Department of Mathematics
University of Toronto
100 St. George Street, Room 4072
Toronto, Canada M5S 3G3

At least one letter should be primarily concerned with the candidate's teaching. In addition, it is recommended that applicants submit the electronic application form which is available from our World Wide Web Employment Opportunities page: <http://www.math.toronto.edu/jobs/>.

To ensure full consideration, this information should be received by December 1, 1999.

In accordance with its Employment Equity Policy, the University of Toronto encourages applications from qualified women or men, members of visible minorities, aboriginal peoples, and persons with disabilities.

**UNIVERSITY OF TORONTO
Tenure-Stream Appointment in
Applied Mathematics - Computational
Science**

The Department of Mathematics, Univer-

sity of Toronto, solicits applications for a tenure-stream appointment for a mathematician working in the area of applied mathematics (computational science).

The appointment is at the downtown (St. George) campus at the level of assistant professor, to begin July 1, 2000. Candidates are expected to have demonstrated excellence in both teaching and research after the Ph.D.; in particular, a candidate's research record should show clearly the ability to make significant original and independent contributions to mathematics. Salary commensurate with experience.

Applicants should send their complete C.V., including a list of publications, a short statement describing their research program, and all appropriate material about their teaching. They should also arrange to have at least four letters of reference sent directly to:

Search Committee
Department of Mathematics
University of Toronto
100 St. George Street, Room 4072
Toronto, Canada M5S 3G3

At least one letter should be primarily concerned with the candidate's teaching. In addition, it is recommended that applicants submit the electronic application form which is available from our World Wide Web Employment Opportunities page: <http://www.math.toronto.edu/jobs/>.

To ensure full consideration, this information should be received by December 1, 1999.

In accordance with Canadian immigration requirements this advertisement is directed to Canadian citizens and to permanent residents of Canada. In accordance with its Employment Equity Policy, the University of Toronto encourages applications from qualified women or men, members of visible minorities, aboriginal peoples, and persons with disabilities.

**UNIVERSITY OF TORONTO
Limited Term Assistant Professorships**

The Department invites applications for one or more limited term assistant professorships which may, subject to budgetary approval, become available at the St. George (downtown), Scarborough, or Erindale campus for a period of one to three years, beginning July 1, 2000. Duties consist of teaching and research, and candidates must demonstrate clear strength in both. Preference will be given to candidates with recent doctoral degrees. Salaries commensurate with qualifications.

Applicants should send their complete C.V., including a list of publications, a short statement describing their research program, and all appropriate material about their teaching. They should also arrange to have at least three letters of reference sent directly to:

Search Committee
Department of Mathematics

University of Toronto
100 St. George Street
Toronto, Canada M5S 3G3

At least one letter should be primarily concerned with the candidate's teaching. In addition, it is recommended that applicants submit the electronic application form which is available on our World Wide Web Employment Opportunities page: <http://www.math.toronto.edu/jobs/>.

To ensure full consideration, all information should be received by December 1, 1999.

Further information about academic positions in the Department of Mathematics is available on the World Wide Web by accessing the above URL.

In accordance with Canadian immigration requirements, this advertisement is directed to Canadian citizens and to permanent residents of Canada. In accordance with its Employment Equity Policy, the University of Toronto encourages applications from qualified women or men, members of visible minorities, aboriginal peoples, and persons with disabilities.

**UNIVERSITY OF TORONTO
Tenure-Stream Appointment in
Mathematics**

The Physical Sciences Division, University of Toronto at Scarborough, invites applications for a tenure-stream appointment in mathematics. Preference will be given to candidates with interests in the areas of analysis or applied mathematics.

The appointment will be at the level of assistant professor, effective on or after July 1, 2000. The successful candidate will be cross-appointed to the graduate Department of Mathematics, University of Toronto, on the downtown (St. George) campus.

Candidates are expected to have demonstrated excellence in both teaching and research after the Ph.D.; in particular, a candidate's research record should show clearly the ability to make significant original and independent contributions to mathematics. Salary commensurate with experience.

Applicants should send their complete C.V., including a list of publications, a short statement describing their proposed research program, and all appropriate material about their teaching background. Applicants should also arrange for at least four letters of reference, including at least one primarily concerned with the candidate's teaching abilities and experience. All correspondence should be sent to:

Professor J. C. Thompson
Chair, Physical Sciences Division
University of Toronto at Scarborough
1264 Military Trail
Scarborough, Ontario M1C 1A4

In addition, it is recommended that applicants submit the electronic application form at <http://www.math.utoronto.ca/jobs/>.

Candidates who apply also for other appointments with the Department of Mathematics, University of Toronto, need only submit one application to that department, but should indicate clearly that they wish to be considered for this appointment as well.

To ensure full consideration, this information should be received by December 1, 1999.

In accordance with Canadian immigration requirements this advertisement is directed to Canadian citizens and to permanent residents of Canada. In accordance with its Employment Equity Policy, the University of Toronto encourages applications from qualified women or men, members of visible minorities, aboriginal peoples, and persons with disabilities.

Any inquiries about the application should be addressed to:

Professor R.-O. Buchweitz
Associate Chair Hiring
Department of Mathematics
University of Toronto
100 St. George Street, Room 4072
Toronto, Ontario M5S 3G3

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MATHEMATICS BOOKS PURCHASED

Pure & appl. adv. & research level, any age, usable cond. Reprints OK. One box to whole libraries sought. Contact: Collier Brown or Kirsten Berg @ **Powell's Technical Bks.**, Portland, OR. Call 800-225-6911, fax 503-228-0505, or e-mail kirsten@technical.powells.com.

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The Fellowship will support an outstanding new PhD pursuing research in an area of pure mathematics. It will cover 60 months full-time research as well as funds for travel and equipment. Mail applications and nominations to:

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360 Portage Ave.
Palo Alto, CA 94306

Materials should be received by December 1, 1999 for consideration of an award to be made January 15, 2000. This Fellowship is for new PhDs: candidates expecting to receive a PhD in the year 2000 are eligible to apply. An application consists of a cover letter, a vita, 3 letters of reference, and a research plan.

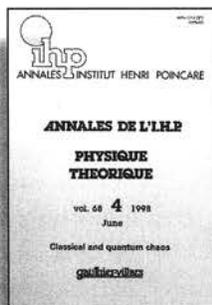
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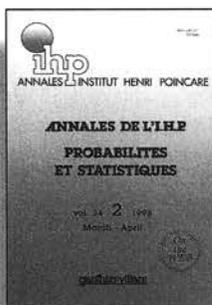
In 1999, the awarded articles from the three series of the
Annales de l'Institut Henri Poincaré are:



Vol. 68, 1998

Universality in the random matrix spectra in the regime of weak non-Hermiticity

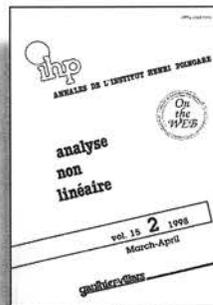
Y.V. Fyodorov,
B.A. Khoruzhenko,
H.-J. Sommers



Vol. 34, 1998

Percolation on Fuchsian groups

S.P. Lalley



Vol. 15, 1998

A kinetic formulation for multi-branch entropy solutions of scalar conservation laws

Y. Brenier, L. Corrias

The articles are available on the web: <http://www.gauthier-villars.fr>

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Articles awarded in

- 1998 > *Theoretical Physics*; Vol. 67, 1997
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> *Probability and Statistics*; Vol. 33, 1997
Local statistics of lattice dimers - **R. Kenyon**
> *Nonlinear Analysis*; Vol. 14, 1997
Nonlinear instability in an ideal fluid - **S. Friedlander, W. Strauss, M. Vishik**
- 1997 > *Theoretical Physics*; Vol. 64, 1996
Nonexistence of minimal blow-up solutions of equations $iu_t = -\Delta_u - k(x)|u|^{4n}u$ in \mathbb{R}^n - **F. Merle**
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• Rough large deviation estimates for the optimal convergence speed exponent of generalized simulated annealing algorithms - **A. Trounev**
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V. Jakšić, C.A. Pillet
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S. Brasseco, A. de Masi, E. Presutti
> *Nonlinear Analysis*; Vol. 12, 1995
Topological solutions in the self-dual Cherns-Simons theory: Existence and approximation
J. Spruck, Y. Yang
- 1995 > *Theoretical Physics*; Vol. 60, 1994
Drift and diffusion in phase space - **L. Chierchia, G. Gallavotti**
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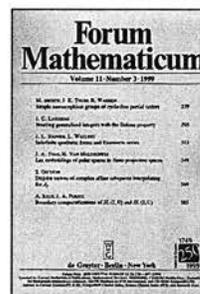
The *Journal für die reine und angewandte Mathematik* is the oldest mathematics periodical still in existence. Founded in Berlin by August Leopold Crelle in 1826 and edited by him until his death in 1855, it soon became widely known under the name of Crelle's Journal.



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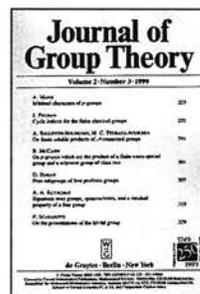
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Nikolai Saveliev

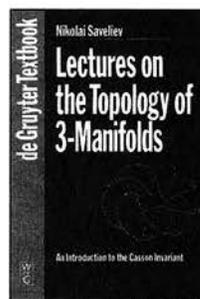
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2000

JANUARY—DECEMBER

Please read the "Membership Categories" section of this form to determine the membership category for which you are eligible. Then fill out this application and return it as soon as possible.

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Degrees, with institutions and dates _____

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| 20 Group theory and generalizations | 74 Mechanics of deformable solids |
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The annual dues for **reciprocity members** who reside outside the U.S. are \$66. 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. must pay ordinary member dues (\$99 or \$132).

The annual dues for **category-S members**, those who reside in developing countries, are \$16. Members can choose only one privilege journal. Please indicate your choice below.

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2000 Dues Schedule (January through December)

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Category-S member ⁴	<input type="checkbox"/> \$16
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¹ **Student Verification** (sign below)

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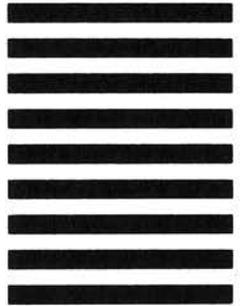
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Journal mailing lists must be printed four to six weeks before the issue date.

Therefore, in order to avoid disruption of service, members are requested to provide the required notice well in advance.

Besides mailing addresses for members, the Society's records contain information about members' positions and their employers (for publication in the Combined Membership List). In addition, the AMS maintains records of members' honors, awards, and information on Society service.

When changing their addresses, members are urged to cooperate by supplying the requested information. The Society's records are of value only to the extent that they are current and accurate.

If your address has changed or will change within the next two or three months, please fill out this form, supply any other information appropriate for the AMS records, and mail it to:

Customer Services

AMS

P.O. Box 6248

Providence, RI 02940

or send the information on the form by e-mail to:

amsmem@ams.org or

cust-serv@ams.org

Name _____

Customer code _____

Change effective as of _____

Old mailing address

New mailing address

New position _____

If mailing address is not that of your employer, please supply the following informations:

New employer _____

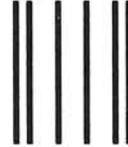
Location of employer (city, state, zip code, country)

Telephone number _____

e-mail _____

Recent honors and awards

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AMERICAN MATHEMATICAL SOCIETY
P. O. Box 6248
Providence, RI 02940-9943



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Staple here

1. Fill in the 3 pages of this form
2. Send 10 stapled, single-sided copies by U.S. mail to the AMS
3. Include only one copy of page 3
Note: If you prefer, a downloadable form is available
at www.ams.org/employment/UCLA-travel.html

Return on or before **January 31, 2000** to:
Professional Services Department
American Mathematical Society
P.O. Box 6248, Providence, RI 02940
email for inquiries only: mathchall@ams.org

TRAVEL GRANT APPLICATION

for Junior U.S. Mathematicians Attending the

“Mathematical Challenges of the 21st Century” Summer Meeting at UCLA, August 7 - 12, 2000

U.S. mathematicians are those affiliated with a U.S. institution or organization. Only graduate students or those who have received a Ph.D. in the Mathematical Sciences on or after January 1, 1994, are eligible. Funding by NSF for this program has been requested, and the awards will be made if funding for the program is approved. An award to attend the meeting under this program may NOT be supplemented by other NSF funds. Persons traveling under NSF grants must travel by U.S. flag carriers, if available.

Last name: _____ First and/or middle names: _____

Full mailing address (usable from now until Summer, 2000):

Line one: _____

Line two: _____

Line three: _____

City: _____ State: _____ Zip: _____

Telephone: _____ Email: _____

Present rank or position: _____

Current institution or organization: _____

Highest earned degree: _____

Institution: _____ Year: _____

Have you requested or been granted funds which might be used for travel to this meeting? If so, give details:

Please notify the American Mathematical Society if this information changes.

Mathematics specialties (use text or MR classification numbers):

Ph.D. thesis title and advisor, if applicable: _____

Other professional, scientific, teaching, or administrative positions held (specify institution or organization, position, and dates for each):

1. _____

2. _____

List up to five significant publications with title, journal, page, and date references (these may include recently accepted papers).

1. _____

2. _____

3. _____

4. _____

5. _____

Scholarships, fellowships, etc. (specify institution, dates held, and field of study):

List research support from all sources in the last five years, including any current support (specify sponsor, title or identification of award, and amount and duration dates):

List research proposals which have been submitted and/or are pending at this time (specify sponsor):

Further comments in support of your application, or other relevant professional contributions not already listed:

All applicants are urged to have senior professional mathematicians (no more than 2) write on their behalf concerning their ability and the value of their attendance at this meeting to the research and professional interests of such junior mathematicians. Submission of these letters is strongly encouraged but not required, except in the case of graduate students, who must have at least one letter in support of their attendance submitted. Letters should be sent to Professional Services, AMS, P.O. Box 6248, Providence, RI 02904. Letters ONLY (not applications) may be sent via email to mathchall@ams.org. The name of the applicant and "Math Challenges Meeting" should appear on the first line of the message. Deadline for receipt of letters is January 31, 2000.

All applicants should submit only ONE copy of this page.

The following information is optional. Your application will not be adversely affected if you choose not to provide this information.

Sex:

- Female
- Male
- Do not wish to provide

Ethnicity:

- Hispanic or Latino
- Not Hispanic or Latino
- Do not wish to provide

Citizenship:

- U.S. citizen
- U.S. permanent resident
- Other non-U.S. citizen
- Do not wish to provide

Disability:

- Hearing impairment
- Visual impairment
- Mobility/orthopedic impairment
- Other _____
- None
- Do not wish to provide

Race:

- American Indian or Alaska Native
 - Asian
 - Black or African American
 - Native Hawaiian or Other Pacific Islander
 - White
 - Do not wish to provide
-

Instructions for Applicant and Employer Forms

Applicant forms submitted for the Employment Center by the November 8 deadline will be reproduced in a booklet titled *Winter List of Applicants*. Employer forms submitted by the November 8 deadline will be reproduced for the *Winter List of Employers*.

Please use the electronic versions of Applicant and Employer forms (<http://www.ams.org/emp-reg/>). Paper forms should be submitted only by those who do not have access to e-MATH.

If submitting a paper form, please type carefully. **Do not type outside the box or beyond the lines indicated. Extra type will be omitted.**

All forms must be received by the Society by **November 8, 1999**, in order to appear in the *Winter List*. If you are attending the meeting, the Advance Registration/Housing Form printed in this issue should accompany the form.

- 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
- 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
- 86 Geophysics
- 90 Economics, operations research, programming, games
- 92 Biology and other natural sciences, behavioral sciences
- 93 Systems theory, control
- 94 Information and communication, circuits
- 97 Mathematics education

New Titles in General Interest

SUPPLEMENTARY READING

Riemannian Geometry During the Second Half of the Twentieth Century

Marcel Berger, Institut des Hautes Études Scientifiques, Bures-sur-Yvette, France

Masterfully written and delightful to read. In addition to the numerous digressions for newly introduced concepts, the author adds to the value of the survey by providing fertile opinions, some of them his, others those of his close colleagues and of M. Gromov in particular. The wonderful effort of the author is shown partially by the long bibliography of thirty pages, with references updated right to the very end of the century. A person who wants to learn more about Riemannian geometry will certainly do him/herself a good service by reading Berger's work.

—Mathematical Reviews

This supremely scholarly account is remarkable for its careful citations and voluminous bibliography. If you wish to learn about the results that have defined Riemannian geometry in the last half century, start with this book.

Reprint arranged with the approval of the publisher B. G. Teubner, Stuttgart and Leipzig.

University Lecture Series; 1999; approximately 217 pages; Softcover; ISBN 0-8218-2052-4; List \$34; All AMS members \$27; Order code ULECT-BERGERNA

BACK IN PRINT FROM THE AMS

A CLASSIC

Geometry and the Imagination

D. Hilbert and S. Cohn-Vossen

A fascinating tour of the 20th century mathematical zoo ... Anyone who would like to see proof of the fact that a sphere with a hole can always be bent (no matter how small the hole), learn the theorems about Klein's bottle—a bottle with no edges, no inside, and no outside—and meet other strange creatures of modern geometry will be delighted with Hilbert and Cohn-Vossen's book.

—Scientific American

Should provide stimulus and inspiration to every student and teacher of geometry.

—Nature

A mathematical classic ... The purpose is to make the reader see and feel the proofs ... readers can penetrate into higher mathematics with ... pleasure instead of the usual laborious study.

—Scientific American

Students, particularly, would benefit very much by reading this book ... they will experience the sensation of being taken into the friendly confidence of a great mathematician and being shown the real significance of things.

—Science Progress

A person with a minimum of formal training can follow the reasoning ... an important [book].

—Mathematics Teacher

This remarkable book has endured as a true masterpiece of mathematical exposition. There are few mathematics books

that are still so widely read and continue to have so much to offer—even after more than half a century has passed! The book is overflowing with mathematical ideas, which are always explained clearly and elegantly, and above all, with penetrating insight. It is a joy to read, both for beginners and experienced mathematicians.

It would be hard to overestimate the continuing influence Hilbert-Cohn-Vossen's book has had on mathematicians of this century. It surely belongs in the "pantheon" of great mathematics books.

AMS Chelsea Publishing; 1952; 357 pages; Hardcover; ISBN 0-8218-1998-4; List \$29; All AMS members \$26; Order code CHEL/87.HNA

BIOGRAPHY

John von Neumann
The Scientific Genius Who Pioneered the Modern Computer, Game Theory, Nuclear Deterrence, and Much More

Norman Macrae

I always thought [von Neumann's] brain indicated that he belonged to a new species, an evolution beyond man. Macrae shows us in a lively way how this brain was nurtured and then left its great imprint on the world.

—Hans A. Bethe, Cornell University

The book makes for utterly captivating reading. Von Neumann was, of course, one of this century's geniuses, and it is surprising that we have had to wait so long ... for a fully fleshed and sympathetic biography of the man. But now, happily, we have one.

Macrae nicely delineates the cultural, familial, and educational environment from which von Neumann sprang and sketches the mathematical and scientific environment in which he flourished. It's no small task to render a genius like von Neumann in ordinary language, yet Macrae manages the trick, providing more than a glimpse of what von Neumann accomplished intellectually without expecting the reader to have a Ph.D. in mathematics. Beyond that, he captures von Neumann's qualities of temperament, mind, and personality, including his effortless wit and humor. And [Macrae] frames and accounts for von Neumann's politics in ways that even critics of them, among whom I include myself, will find provocative and illuminating.

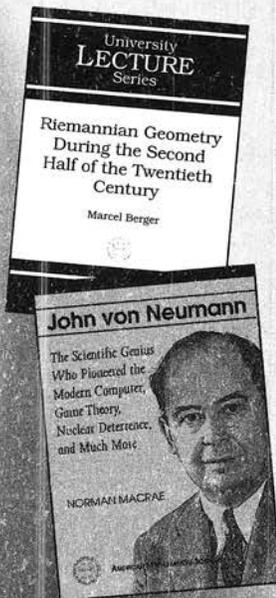
—Daniel J. Kevles, California Institute of Technology

A lively portrait of the hugely consequential mathematician-physicist-et al., whose genius has left an enduring impress on our thought, technology, society, and culture. A double salute to Steve White, who started this grand book designed for us avid, nonmathematical readers, and to Norman Macrae, who brought it to a triumphant conclusion.

—Robert K. Merton, Columbia University

This volume is the reprinted edition of the first full-scale biography of the man widely regarded as the greatest scientist of the century after Einstein.

1999; 406 pages; Hardcover; ISBN 0-8218-2064-8; List \$35; All AMS members \$28; Order code JVNMINA



All prices subject to change. Charges for delivery are \$3.00 per order. For optional air delivery outside of the continental U. S., please include \$6.50 per item. Prepayment required. Order from: American Mathematical Society, P. O. Box 5904, Boston, MA 02206-5904, USA. For credit card orders, fax 1-401-455-4046 or call toll free 1-800-321-4AMS (4267) in the U. S. and Canada, 1-401-455-4000 worldwide. Or place your order through the AMS bookstore at www.ams.org/bookstore/. Residents of Canada, please include 7% GST.



APPLICANT RÉSUMÉ FORM
MATHEMATICAL SCIENCES EMPLOYMENT CENTER
 JANUARY 19–22, 2000
 WASHINGTON, DC

1. Forms should be accessed and submitted electronically if possible. The URL for accessing Employment Center information and forms is <http://www.ams.org/emp-reg/>.
2. Paper or electronic forms are due, along with payment and your Advance Registration/Housing Form, by November 8 (to AMS, P. O. Box 6887, Providence, RI 02940) in order to be included in the *Winter List of Applicants*.
3. Forms will not be processed until registration and payment of fees have been received.

APPLICANT CODE:	Last name _____ First name _____		
	Mailing address (include zip code) _____		
	E-mail address (one only) _____		
	URL (or other contact info) _____		
	Specialties _____		
(use MR classification codes plus text if possible; applicants will be indexed by first number only)			
DESIRED POSITION:			
Academic:	<input type="checkbox"/> Research <input type="checkbox"/> University Teaching	College Teaching: <input type="checkbox"/> 4-year <input type="checkbox"/> 2-year	
Would you be interested in nonacademic employment? <input type="checkbox"/> Yes <input type="checkbox"/> No			
Available mo. _____ /yr. _____			
Significant requirements (or restrictions) which would limit your availability for employment _____			
PROFESSIONAL ACCOMPLISHMENTS:			
Significant achievements, research or teaching interests _____			

Paper to be presented at this meeting or recent publication _____			

Degree	Year (expected)	Institution	
_____	_____	_____	
_____	_____	_____	
_____	_____	_____	
		Number of refereed papers accepted/published _____	
PROFESSIONAL EMPLOYMENT HISTORY:			
	Employer	Position	Years
1.	_____	_____	_____ to _____
2.	_____	_____	_____ to _____
3.	_____	_____	_____ to _____
References (Name and Institution only)			

Work authorization status: (check one)			
		<input type="checkbox"/> U.S. Citizen	<input type="checkbox"/> Non-U.S. Citizen, authorized to work permanently in U.S.
		<input type="checkbox"/> Other	
This applicant will be using: <input type="checkbox"/> ALL Employment Center services <input type="checkbox"/> Message Center and Winter List ONLY			

AMERICAN MATHEMATICAL SOCIETY

Professional Resources from the AMS

Starting Our Careers

A Collection of Essays and Advice on Professional Development from the Young Mathematicians' Network

Curtis D. Bennett, *Bowling Green State University, OH*, and Annalisa Crannell, *Franklin & Marshall College, Lancaster, PA*, Editors

If you are the reader we envision for this book, you have just passed through the most crucial stage of your career—writing and defending your doctoral thesis in mathematics—only to discover what lies ahead is, yet again, the most crucial stage of your career: making the choice about what job to take.

—from the Introduction

This "how-to" book addresses all aspects of a young mathematician's early career development: How do I get good letters of recommendation? How do I apply for a grant? How do I do research in a small department that has no one in my field? How do I do anything meaningful if all I can get is a series of one-year jobs?

These articles paint a broad portrait of current professional development issues of interest from the Young Mathematician's Network—from finding jobs to organizing special sessions. There are chapters on applying for positions, working in industry and in academia, starting and publishing research, writing grant proposals, applying for tenure, and becoming involved in the academic community. The book offers timely and sound advice offered by recent doctorates through experienced mathematicians. The material originally appeared in the electronic pages of *Concerns of Young Mathematicians*. The book is devoted exclusively to the early stages of a mathematical career.

1999; 116 pages; Softcover; ISBN 0-8218-1543-1; List \$24; Individual member \$14; Order code SOCNA

Assistantships and Graduate Fellowships in the Mathematical Sciences, 1999–2000

Review of the previous annual edition:

What makes this directory unusual is the additional information provided about the department. The AMS has provided for each department the number of tenured faculty that have published within the last three years and a breakdown of the financial support available to graduate students as well as the kind of work required to obtain support. From a student's point of view, these additional data are vital in the selection process. The American Mathematical Society has provided a valuable aid to students in the mathematical sciences. This guide is highly recommended for any academic institution with an undergraduate mathematics major.

—American Reference Books Annual

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 available. 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.

Also listed are sources of support for graduate study and travel, summer internships, and graduate study 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.

1999; 129 pages; Softcover; ISBN 0-8218-2011-7; List \$20; Individual member \$12; Order code ASST/99NA

Combined Membership List 1999–2000

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.

The CML is distributed on request to AMS members in even-numbered years. MAA members can request the CML in odd-numbered years from the MAA.

1999; 376 pages; Softcover; ISBN 0-8218-1997-6; List \$62; Individual member \$37; Order code CML/1999/2000NA

Mathematical Sciences Professional Directory, 1999

This annual directory provides a handy reference to various organizations in the mathematical sciences community. Listed in the directory are the following: 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.

1999; 222 pages; Softcover; ISBN 0-8218-1090-1; List \$50; Order code PRODIR/99NA

Mathematics into Type Updated Edition

Ellen Swanson, *Director of AMS Editorial Services (Retired)*

This edition, updated by Arlene O'Sean and Antoinette Schleyer of the American Mathematical Society, brings Ms. Swanson's work up to date, reflecting the more technical reality of publishing today. While it includes information for copy editors, proofreaders, and production staff to do a thorough, traditional copyediting and proofreading of a manuscript and proof copy, it is increasingly more useful to authors, who have become intricately involved with the typesetting of their manuscripts.

1999; 102 pages; Softcover; ISBN 0-8218-1961-5; List \$24; Individual member \$14; Order code MIT/2NA

World Directory of Mathematicians 1998

A publication of International Mathematical Union.

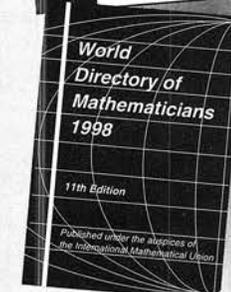
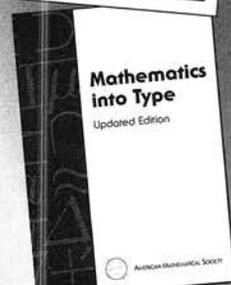
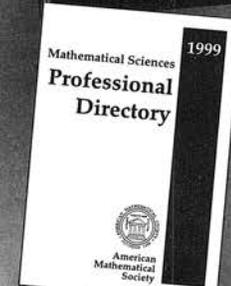
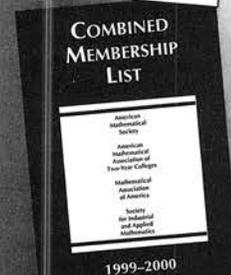
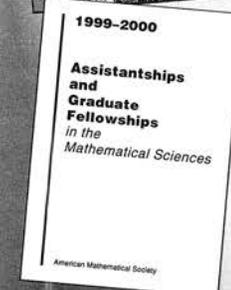
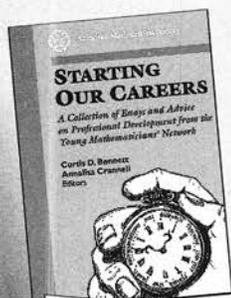
What is most impressive about this directory is its scope and size. It includes worldwide organizations of every type in the mathematical sciences. This title will be especially useful to academic libraries that support graduate programs in mathematics.

—American Reference Books Annual

This edition of the *World Directory of Mathematicians 1998* incorporates updates and corrections to the 1994 edition, and includes nearly 30 percent more names. This valuable reference contains the names and addresses of over 50,000 mathematicians from 69 countries. There is also an increase in the number of fax numbers and email addresses in this edition. Libraries, mathematics departments, and individuals will find this new edition to be a valuable resource for its extensive coverage of the international mathematical community.

Published by the International Mathematical Union.

1998; 1093 pages; Softcover; List \$65; All individuals \$40; Order code WRLDIR/11NA



All prices subject to change. Charges for delivery are \$3.00 per order. For optional air delivery outside of the continental U. S., please include \$6.50 per item. Prepayment required. Order from: American Mathematical Society, P. O. Box 5904, Boston, MA 02206-5904, USA. For credit card orders, fax 1-401-455-4046 or call toll free 1-800-321-4AMS (4267) in the U. S. and Canada, 1-401-455-4000 worldwide. Or place your order through the AMS bookstore at www.ams.org/bookstore/. Residents of Canada, please include 7% GST.



AMS

AMERICAN MATHEMATICAL SOCIETY

Joint Summer Research Conferences in the Mathematical Sciences

**Mount Holyoke College
South Hadley, Massachusetts
June 11–July 20, 2000**

The 2000 Joint Summer Research Conferences will be held at Mount Holyoke College, South Hadley, Massachusetts, from June 11–July 20, 2000. The topics and organizers for the conferences were selected by a committee representing the AMS, the Institute of Mathematical Sciences (IMS), and the Society for Industrial and Applied Mathematics (SIAM). Committee members at the time were Alejandro Adem, Paul Baum, David Brydges, James W. Demmel, Dipak Dey, Tom Diccio, Steven Hurder, Alan F. Karr, Barbara Keyfitz, W. Brent Lindquist, Andre Manitius, and Bart Ng.

It is anticipated that the conferences will be partially funded by a grant from the National Science Foundation and perhaps others. Special encouragement is extended to junior scientists to apply. A special pool of funds expected from grant agencies has been earmarked for this group. Other participants who wish to apply for support funds should so indicate; however, available funds are limited, and individuals who can obtain support from other sources are encouraged to do so.

All persons who are interested in participating in one of the conferences should request an invitation by sending the following information to Summer Research Conferences Coordinator, AMS, P.O. Box 6887, Providence, RI 02940, or by e-mail to wsc@ams.org **no later than March 3, 2000.**

Please type or print the following:

1. Title and dates of conference.
2. Full name.
3. Mailing address.
4. Phone numbers (including area code) for office, home, and FAX.
5. E-mail address.
6. Your anticipated arrival/departure dates.
7. Scientific background relevant to the Institute topics; please indicate if you are a student or if you received your Ph.D. on or after 7/1/93.
8. The amount of financial assistance requested (or indicate if no support is required).

All requests will be forwarded to the appropriate organizing committee for consideration. In late April all applicants will receive formal invitations (including specific offers of support if applicable), a brochure of conference

information, program information known to date, along with information on travel and dormitory and other local housing. All participants will be required to pay a nominal conference fee.

Questions concerning the scientific program should be addressed to the organizers. Questions of a nonscientific nature should be directed to the Summer Research Conferences coordinator at the address provided above. Please watch <http://www.ams.org/meetings/> for future developments about these conferences.

Lectures begin on Sunday morning and run through Thursday. Check-in for housing begins on Saturday. No lectures are held on Saturday.

Symbolic Computation: Solving Equations in Algebra, Geometry and Engineering

Sunday, June 11–Thursday, June 15, 2000

Edward Green, Virginia Tech (co-chair)
Serkan Hosten, George Mason University (co-chair)
Reinhard Laubenbacher, New Mexico State University (co-chair)
Victoria Powers, Emory University (co-chair)

Symbolic computation is an important tool in many areas of pure and applied mathematics and engineering and is also an interesting and fast-growing area of pure mathematical research. Pure mathematicians can use symbolic computation to explore examples that would be impossible to work with “by hand” and to gain insight into complicated mathematical objects. In applied mathematics and engineering, symbolic computation can provide a way to compute exactly in complex models, give insight into problems, and improve the accuracy of numerical solutions. One general area in which symbolic computation has had a big impact is solving systems of equations of many kinds, from systems of polynomials to systems of differential and difference equations.

The aim of the conference is to bring together pure and applied mathematicians and engineers who use symbolic computation to solve systems of equations and those who develop the theoretical background and tools needed for solving equations. Talks will be given by a broad range of researchers and will present new developments in both theory and applications, exhibit nontrivial computations, and supply practical problems from engineering and applied mathematics. Topics covered will include the following:

1. *Systems of polynomials.* The focus will be on homotopy methods, such as nonlinear and polyhedral homotopies, and algebraic methods, including Groebner basis methods, SAGBI bases, primary decomposition, and invariant theory. Also included will be applications of the above techniques in zero-dimensional systems and real root

finding and numerical issues such as approximate solutions and sensitivity of solutions to perturbation of the input.

2. *Systems of differential equations.* The use of symbolic techniques in solving systems of differential equations is growing rapidly. In this area one line of research follows differential ideal theory, for example, Groebner type techniques in differential ideal theory. Another line of research is differential Galois theory, where one tries to understand the structure of solution spaces of differential equations. Also included will be emerging research like Groebner deformations in Weyl algebras for solving hypergeometric systems.

3. *Noncommutative systems.* The use of noncommutative Groebner bases has shown great potential for important applications. The theory has been used in the simplification of matrix equations coming from systems of differential equations. Noncommutative questions arise naturally in the study of differential operators and differential equations. Finally, in the study of commutative questions, recent work has shown that it is sometimes helpful to view the problem in a noncommutative setting.

4. *Applications to engineering.* Many real-world problems are solved using symbolic computation. Topics to be addressed include applications of solving systems of polynomial equations and real root finding in mechanics and robotics, uses of computational algebraic geometry in computer vision, graphics and computer-aided modeling, and Groebner basis techniques in integer programming.

5. *Recent theoretical advances.* The conference will also focus on exciting developments that use or have an impact on symbolic computation. For example, computing free resolutions of monomial and toric ideals and computing cohomology of toric varieties.

The preliminary list of invited speakers includes Dave Bayer, Columbia University; David Cox, Amherst College; David Eisenbud, Mathematical Sciences Research Institute, Berkeley; Ioannis Emiris, INRIA Sophia-Antipolis, France; Karin Gatermann, Freie Universitaet Berlin; William Helton, University of California at San Diego; Theresa Krick, Universidad Buenos Aires; T. Y. Li, Michigan State University; Danesh Manocha, North Carolina State University; Gregory Reid, Okanagan University College, Canada; Bernard Roth, Stanford University; Joachim Rosenthal, University of Notre Dame; Fabrice Rouillier, INRIA Lorraine (LORIA), France; Thomas Sederberg, Brigham Young University; Michael Singer, North Carolina State University; Bernd Sturmfels, University of California at Berkeley; Rekha Thomas, Texas A&M University; and Lakshman Yagati, Bell Labs.

Dispersive Wave Turbulence

Sunday, June 11–Thursday, June 15, 2000

Paul Milewski, University of Wisconsin
 Leslie Smith, University of Wisconsin (co-chair)
 Esteban Tabak, New York University (co-chair)
 Fabian Waleffe, University of Wisconsin (co-chair)

Program Summary

Many physical systems support the propagation of *dispersive waves*: waves whose speed of propagation depends on the wavenumber (inverse wavelength). Important examples of dispersive waves are surface water waves and internal waves in stratified and/or rotating fluids. A linear superposition of dispersive waves usually describes well the small-amplitude departures from equilibrium of the given physical system for short time scales (time scales of the order of the inverse of wave frequency).

The description of the wave field for longer times (or larger amplitudes) requires the understanding of the energy transfer between waves due to nonlinearities. In dispersive waves this energy transfer is fundamentally different from nondispersive waves, since it will occur only amongst *resonant* sets of waves, usually triads or quartets of waves. The deterministic dynamics of isolated resonant triads and quartets is well understood and has proved invaluable in understanding a wide range of wave phenomena. The dispersive wave turbulence problem is to obtain a statistical description of a large set or continuum of dispersive waves over long times. Although this problem has an almost forty-year history, there are still fundamental questions that need to be answered, and these questions are the proposed focus of the conference.

The mathematical understanding of this problem is of great importance for many relevant problems in geophysical fluid dynamics, such as: the prediction of the spectrum of ocean waves, the understanding of the spectrum of atmospheric wave turbulence and its effect on the slower nonwave dynamics, and the evolution of the internal wave spectrum in the ocean. In addition, in certain mediums and at large amplitudes light waves can be dispersive, and the characterization of optical turbulence for large intensity light in optical fibers also requires a mathematical understanding of dispersive wave turbulence theory.

The primitive equations governing dispersive wave turbulence (also called weak turbulence) in the applications mentioned above are the appropriate inviscid fluid-dynamics equations. Thus, in the regime of interest the evolution is *conservative* (usually Hamiltonian). However, this is an approximation of the real physical situations in which there is usually some energy input (such as the wind stress in surface ocean waves) and dissipation (such as viscous damping for small-scale motion). Since there often is a scale separation between the input and dissipation mechanism (for ocean waves the energy is input at low wavenumbers and withdrawn at large wavenumbers), one considers the intermediate regime as conservative, and the central question is how it transports energy between the disparate scales. The most fundamental result that one seeks is the statistical power law spectrum (or Kolmogorov spectrum, a name borrowed from nonwave turbulence in fluid flows) for this *energy cascade*.

The conference will stimulate discussion and progress on the numerical, modeling, and analytical aspects of dispersive wave turbulence and related problems. There will be a limited number of invited full-length lectures focusing on the major aspects of the subject: Modeling, Numerics, Observation, Internal Waves in the Ocean, Surface

Ocean Waves, Atmospheric Wave Dynamics, etc. There will also be half-hour lectures and considerable time for interaction between the participants. Advanced graduate students and recent Ph.D.'s are especially encouraged to attend the conference.

Radon Transforms and Tomography

Sunday, June 18–Thursday, June 22, 2000

Leon Ehrenpreis, Temple University
 Adel Faridani, Oregon State University
 Fulton B. Gonzalez, Tufts University
 Eric L. Grinberg, Temple University
 Eric Todd Quinto, Tufts University (chair)

Radon transforms were developed at the beginning of this century by at least three independent researchers: P. Funk, G. Lorenz, and J. Radon. They were motivated by problems in differential geometry, mathematical physics, and partial differential equations. In the 1970s the medical applications of these transforms produced a flurry of breakthroughs in imaging technology that resulted in a Nobel Prize. Currently, integral geometry comes up in analysis, Lie groups, differential and symplectic geometry, complex and harmonic analysis, mathematical physics, inverse problems, numerical analysis, computation, and more. It is becoming a unifying theme in a broad spectrum of mathematics. The multifaceted nature of the subject was already manifested in its birth, and today the subject has substantial cross-disciplinary interactions in both pure and applied mathematics as well as in medicine and engineering.

In the past few years an important general framework has emerged for integral geometry, based on the theory of sheaves and D-modules. In terms of this framework, one can obtain both new and classical inversion formulae and range theorems for various Radon transforms. Radon transform concepts are also of increasing interest in representation theory as double-fibration methods are used with greater emphasis. These ideas are related to mathematics physics, the Penrose transform, and complex geometry. Radon transform methods are becoming more prevalent in research on classical integral geometry, such as Finsler geometry and Hilbert's fourth problem. This includes novel ways of defining distances between as measures of planes separating them. Integral geometric techniques are being used in other fields, including Lie groups, convexity theory, and complex analysis.

Researchers have recently proven that the X-ray transform is injective on a Riemannian manifold of nonpositive curvature. The general problem of understanding Radon transforms on manifolds without symmetry is exciting, and it is an important theoretical basis for geophysical and other inverse problems. The interplay between these theoretical results and algorithms is exciting and important to explore.

There are continuing breakthroughs in tomography in areas including local tomography in the plane and 3-D local tomography with sources on a curve, RADAR, im-

pedance CT, and ultrasound. Applied mathematicians are using Radon transforms previously considered to be only of abstract theoretical interest; for example, geodesic Radon transforms have important applications in impedance and geophysical CT. Radon transforms have been used in new ways to solve theoretical problems in SONAR, and researchers are working on practical algorithms using these ideas. Many of the most exciting inverse problems in medicine, physics, and P.D.E. have integral geometric models.

Our goal is to bring together researchers from different areas who might find commonality in their shared interest in integral geometry and tomography. Perhaps the most vital such interaction is that which links pure and applied aspects of the fields. There is a great deal of activity in each category, and it is important to expand communication between them so that collaborative development takes place in a larger venue. Because of this goal, all speakers will be actively encouraged to give talks with accessible introductions. We plan to have tutorial talks on pure and applied topics related to the specific topics presented in the conference. An introductory reading list will be on the conference Web site for interested people.

We are committed to having younger mathematicians actively involved in the field. We plan to have talks by junior mathematicians as well as short thesis talks by graduate students.

Preliminary list of possible speakers: M. Agranovsky, J. Alvarez, C. Berenstein, M. Cheney, R. Clackdoyle, A. d'Agnolo, L. Ehrenpreis, S. Gindikin, A. Greenleaf, A. Gruenbaum, S. Helgason, D. Isaacson, P. Kuchment, A. Louis, P. Maass, F. Natterer, V. Sharafutdinov, G. Uhlmann, and L. Zalcman.

Noncommutative Geometry

Sunday, June 18–Thursday, June 29, 2000

Alain Connes, IHES (chair)
 Nigel Higson, Penn State University
 John Roe, Penn State University
 Guoliang Yu, University of Colorado

The purpose of this conference is to present to a broad audience an up-to-date account of Alain Connes's noncommutative geometry.

It is an old idea that noncommutative algebras should be studied as if they were the function algebras of "noncommutative spaces". The remarkable work of Alain Connes has transformed this metaphor into a powerful and substantial mathematical theory. Connes's inspiration came from functional analysis, but the theory he constructed has reached out to homological algebra, differential geometry, and quantum theory for its basic constructions. Connes's well-known book (Academic Press, 1994) and the spirited discussion it has engendered provide an ample introduction to the subject.

Recent work has brought noncommutative geometry into lively contact with number theory, dimension theory, and renormalization in quantum field theory, to name

some striking examples. Many of these developments have taken noncommutative geometry beyond the plan laid out in Connes's book. They have yet to be integrated into the literature and are indeed located at a rapidly advancing frontier. This meeting will transport participants to this frontier and equip them as independent prospectors there.

There will be particular emphasis on the following topics:

1. Noncommutative geometry and number theory.

In his book, Connes, in collaboration with J.-B. Bost, constructed a one-parameter C^* -dynamical system which is intimately related to classical questions on the distribution of prime numbers. Since then Connes has developed the theory considerably, emphasizing the central importance of a beautiful but conjectural trace formula in noncommutative geometry (special cases of this formula are now known). One reviewer described Connes's work as producing a "feeling of intense jubilation"; but its breadth and depth have meant that this jubilation has so far been experienced only by a few. A series of introductory lectures will give participants the chance to acquaint themselves with this formidably deep and exciting area of mathematics.

2. Noncommutative geometry and geometric topology.

In Connes' book the guiding examples of noncommutative spaces arise from group actions or foliations. Recently a new kind of example has become important: noncommutative spaces arising from controlled topology. These are the ideas which underly, for example, the dimension-theoretic approach to the Novikov Conjecture given by G. Yu and refined by S. Dranishnikov in his 1998 ICM address. Most of the development in this area so far has been at the level of K -theory, but a more refined geometric analysis is just beginning. A series of lectures will survey the area, and recent advances will be presented.

In addition to these areas of emphasis and to the presentation of current research, the conference will include an Introduction to Noncommutative Geometry minicourse aimed at mathematicians and graduate students with only a general acquaintance with functional analysis. It will enable outside specialists in, for instance, number theory to interact profitably with researchers in noncommutative geometry. It will also provide an introduction to noncommutative geometry for graduate students.

Bayes Frequentist and Likelihood Inference: A Synthesis

Sunday, July 9–Thursday, July 13, 2000

Gauri Sankar Datta, University of Georgia (co-chair)
 Nancy Reid, University of Toronto (co-chair)
 Dongchu Sun, University of Missouri (co-chair)
 James Berger, Duke University
 Malay Ghosh, University of Florida
 Elizabeth Slate, Cornell University

Bayes and frequentist approaches to statistics are the two main paradigms for statistical inference. Recently, likeli-

hood-based methods are also being proposed in many inferential problems. Each approach has its own advantage for some problems, but none is superior to the other. While the differences in the philosophy of these schools have generated a lot of debates and controversies in the past, there has been an effort in recent years to look for a synthesis of these various concepts. Although many statisticians feel that the frequentist and Bayesian views are different both on philosophical and operational grounds, a unification or synthesis of these ideas is much needed, at least for pragmatic reasons involving applications. It is indeed disappointing to have different Bayes and frequentist conclusions in applications while both approaches use the same evidence and beliefs about a scientific investigation. Thus a synthesis of the philosophy of the two schools should be attempted, and the interface where they produce similar conclusions and where they differ dramatically should be explored. As the area is very broad, the proposed conference will focus on a few selected topics. Some of the important topics are model selection, hypothesis testing, semiparametric inference for models with infinite-dimensional nuisance parameters, survey sampling, longitudinal data, and Bayesian and frequentist higher-order asymptotics, including probability matching priors and Bartlett corrections.

Statistical modeling is an indispensable tool in analyzing data and drawing valid inference. Two important areas where there are extensive ongoing efforts to discover the relationship between default Bayes and likelihood approaches to these problems are model selection and hypothesis testing. Development of default Bayesian analysis in these two problems is very challenging, because the use of any improper priors makes no sense due to the fact that such priors have an indeterminate multiplicative constant so that the pivotal quantity, the Bayes factor, remains undetermined. Many recent advances in Bayesian model selection will be presented in the conference.

Comparison of two models is equivalent to testing a null hypothesis against an alternative hypothesis. Hypothesis testing has been a main source of disagreement between the Bayesian and frequentist approaches to inference. While the reporting of Type I error and Type II error probabilities is a standard practice in the classical frequentist approach, it is not entirely satisfactory, as it fails to reflect the strength of evidence provided by given data. The use of P -value as a data-dependent measure is not entirely satisfactory either. Bayesians are not comfortable in using P -value in model selection or hypothesis testing. Although the P -value is in general agreement with posterior probabilities in testing a one-sided null hypothesis against a one-sided alternative hypothesis, it has dramatic conflict with the Bayes factor in testing point null and precise hypothesis. In the recent Bayesian literature there are a few modifications of the P -value such as the predictive, posterior predictive, and conditional predictive P -values, which are suggested as tools in measuring surprise. The main reason for devising many of these alternative measures is that the likelihood, not the tail area as used in P -value, should be the basis in measuring any statistical evidence. Extensive discussion on these alternative measures and their cal-

ibration were recently discussed by researchers who have already expressed their willingness to participate in the conference.

Semiparametric models or models with infinite-dimensional parameter space provide a large class of models that enhance the scope of statistical modeling. Neyman-Scott problems and the Cox regression model are some examples of such models. Despite an added flexibility, the asymptotic theory of inference for such models requires nontrivial extensions of results for usual parametric models. This is a growing area of research, and it appears that the Bayesian, likelihood, and frequentist paradigms all have a place for such inference.

Survey sampling plays an important role in providing reliable government and business statistics. A design-based approach is dominant in classical survey sampling. However, in recent years there has been a growing popularity of model-based approaches in sampling. Model-based approaches explicitly use auxiliary variables from administrative records or other surveys and are very popular in small area estimation. Small area estimation, an important topic in survey sampling, is gaining increasing popularity in government agencies due to a growing demand for reliable small area statistics from both public and private sectors. While a frequentist view is more dominant in small area estimation, the Bayesian approach to small area estimation is receiving favorable attention from the governments of the USA, Canada, and other countries. Although practitioners of small area estimates are less receptive to use of arbitrary priors in Bayes estimates, they feel comfortable when such estimates have a dual justification. In view of the importance of model-based inference in sampling generated by growing use of model-based estimates by the practitioners, it is really important to compare both the frequentist and the Bayesian methods that are currently in use. A synthesis of the two schools of thought will serve the survey samplers by presenting the current state of research in survey sampling. Such synthesis may result in estimates with an associated measure of uncertainty which have both frequentist and Bayesian justification.

Longitudinal models arise frequently in many statistical investigations. Such data occur often in clinical, environmental, and other scientific studies. Even in many repetitive surveys such models are found useful. Statistical analyses in longitudinal studies are based on models that express a relationship between the response and covariates that evolves in time. Besides handling unbalanced series and unequally spaced observations, recent longitudinal methods have focused on connections to survival analysis, detections of change points, and identification of latent classes. Bayesian and frequentist analyses of these models often use mixed linear models or generalized linear models. Transition models, which are useful generalizations of longitudinal models, explicitly represent the response for a subject at a given observation time as dependent not only on the subject's covariates at that time but also on the history of response values for that subject. MCMC methods play a powerful role in the analysis of these models.

Higher-order asymptotics play a crucial role in the unification of Bayesian and frequentist approaches to inference. In particular, frequentist validation of noninformative Bayesian solutions is attained through higher-order asymptotics. Noninformative priors which provide Bayes credible sets with approximate frequentists validity for moderate sample size are known as probability matching priors. Higher-order asymptotics are also useful in the comparison of different adjusted versions of the profile likelihood. These modifications to the usual likelihood play an important role in providing improved inference in likelihood-based inference in the presence of nuisance parameters. These adjustments and their interface with higher-order Bayesian asymptotics have received a lot of attention from researchers.

The five-day conference will focus on the topics discussed above and many other related topics in an effort to present a synthesis of the available Bayes, frequentist, and likelihood methods. Many leading and young researchers of international reputation have already expressed their interest in participating and presenting many stimulating research discussions in the conference.

Algorithms, Computational Complexity, and Models of Computation for Nonlinear and Multivariate Problems

Sunday, July 16–Thursday, July 20, 2000

Eugene Allgower, Colorado State University
Kurt Georg, Colorado State University
Christopher Sikorski, University of Utah (chair)
Frank Stenger, University of Utah

Nonlinear systems of equations arise in practically all areas of scientific computation. In some cases, such as the polynomial systems arising in the modelling of robotics problems or complementarity problems, the modelling equations are immediately finite dimensional. In other instances the systems derive from the discretizations of operator equations which model a physical system. In general, nonlinear systems are solved by iterative algorithms. Some examples are quasi-Newton methods, inexact Newton methods, interior point methods, continuation methods, etc. In addition, generalizations of bisection and some simplicial methods have been applied for systems which lack smoothness. Aspects of the effectiveness of algorithms for solving nonlinear systems include their convergence and complexity. The issue of complexity has been examined from differing viewpoints by investigators in scientific computation (who work with floating point computations) and, e.g., by groups of scientists who often work from the standpoint of the real number model of computation or a general theory of information-based complexity.

The aim of the proposed conference is to bring together some of the leading investigators presently working on algorithms for solving nonlinear systems and multivariate problems deriving from various areas of applications and



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to allow them an opportunity to discuss and compare their concepts and models of complexity.

Though scientists always had a concept of convergence and efficiency for numerical algorithms, the modern complexity theory has its origins in the work of J. Kiefer in 1953 and J. Traub in 1961. In the 1980s Traub and Wozniakowski initiated a general complexity theory for solving continuous problems, presently known as information-based complexity. In the late 1980s a new vein of research on models of continuous computation was originated by the work of Blum, Shub, and Smale, and their joint work with Cucker. More recently, Sikorski summarized some optimal complexity results for nonlinear equations and published a bibliography of this field.

Multivariate problems play a very important role in many applications. For instance, in financial applications there is a need to approximate integrals of functions of hundreds of variables. It is a challenging problem to design and analyze algorithms for such high-dimensional problems. Sloan and Wozniakowski provided a first step of a new theory for understanding tractability of high-dimensional problems.

The complexity theory complements the more traditional ideas of convergence and computational efficiency and stability. The latter, for example, is less formal but more practically oriented e.g., rounding effects are included. However, all address the fundamental problem of optimally (in some sense) computing approximate solutions to problems of science and engineering. They utilize the real number (or the floating point number) model of computation to address the optimality issues.

The focus of our conference will be to examine these issues and the relationships of the various efficiency concepts in the context of some important current examples of nonlinear and multivariate problems, in particular:

1. Nonlinear algebraic equations and fixed points
2. Nonlinear optimization
3. Quasi Monte Carlo techniques for multivariate integration
4. Models of continuous computation

The speakers will address the issues of optimal or nearly optimal algorithms, as well as the fastest known methods for computing approximate solutions to the above problems.

For further information, please visit the Web site maintained by the organizers at <http://www.cs.utah.edu/~sikorski/joint.html>.

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Call for Proposals for 2001 Conferences

Call for Proposals for Joint Summer Research Conferences in the Mathematical Sciences for 2001

The American Mathematical Society, the Institute of Mathematical Statistics, and the Society for Industrial and Applied Mathematics welcome proposals from mathematicians, either singly or in groups, for conferences to take place in the summer of 2001 as part of the Joint Summer Research Conferences. For almost twenty years these conferences have played a vital role in disseminating the latest research to more than 8,000 mathematicians whose research interests span the breadth of the mathematical sciences. Individuals willing to serve as organizers should be aware that staff of the sponsoring societies handle the logistical details of the conferences, thus making it possible for the organizers to focus almost exclusively on the scientific aspects of their conference. In particular:

- Core funding for the conferences is provided by a grant from the National Science Foundation. It is anticipated that future funding will provide approximately \$20,000 for direct support of conference participants for each of 6–8 one-week conferences.
- The professional conference coordinators in the AMS office will provide full logistical support and assistance before, during, and after the conference, thereby freeing the organizers to concentrate on providing a high-quality scientific program.
- Organizers are strongly encouraged to publish conference proceedings with one of the sponsoring societies. The sponsoring societies are committed to the rapid and widest possible dissemination of these proceedings as a means of sharing the conference research with those unable to attend.

Conferences emulate the scientific structure of those held at Oberwolfach, although this structure is flexible. The proposals to be selected will represent diverse areas of mathematical activity, with emphasis on areas currently especially active. Conferences typically run for one week with forty-five to sixty-five participants. Conferences of longer duration are possible.

All proposals must include (1) the names and affiliations of proposed members and the chair(s) of the Organizing Committee; (2) a three- to four-page narrative addressing the focus of the topic, including the importance and timeliness of the topic; (3) a list of the proposed principal speakers, the majority of whom have agreed to participate; (4) estimated total attendance and a tentative list of individuals to be invited to participate; (5) a list of the recent conferences in the same or closely related areas; and (6) the curriculum vitae of the chair and co-chair(s) of the Organizing Committee.

Organizers are expected to make a vigorous attempt to include qualified women, underrepresented minorities, and junior scientists (advanced graduate students and recent Ph.D.'s) as participants in their conference. Additional information on submitting a proposal, including examples of recent successful proposals, is available at <http://www.ams.org/meetings/topics.html> or may be requested by contacting the Meetings and Conferences Department as indicated below.

A list of the conferences scheduled for the summer of 2000 may be viewed at <http://www.ams.org/meetings/src.html>.

Do you see being a conference organizer as part of your future? Then begin preparation of your proposal soon! The deadline for receipt of all proposals is February 1, 2000. Proposals will be evaluated by the AMS-IMS-SIAM Committee on Joint Summer Research Conferences in the Mathematical Sciences. (The committee is listed at <http://www.ams.org/meetings/srcscomm.html>.) Members of this committee are willing to provide guidance on the preparation of proposals. In addition, they are willing to provide feedback on preproposals which address items (1) and (2) above and which include a tentative list of principal speakers who will be contacted if a complete proposal is submitted. Preproposals should be submitted by November 12, 1999. Conference proposers will be notified of the committee's decisions in early spring of 2000.

Submit preproposals and proposals to: Joint Summer Research Conferences, AMS Meetings and Conferences Department, P.O. Box 6887, Providence, RI 02940; fax: 401-455-4004; e-mail: meet@ams.org.

Meetings & Conferences of the AMS

IMPORTANT NEW PROGRAM INFORMATION: In order that AMS meeting programs include the most timely information for each speaker, abstract deadlines have been moved to dates much closer to the meeting. As a result, Sectional Meeting programs have been appearing in the *Notices* *after* the meeting takes place. The Secretariat of the AMS has observed that this arrangement does not provide an adequate service to the reader. So, beginning with the Gainesville meeting (March 12-13, 1999), AMS Sectional Meeting programs will no longer appear in the print version of the *Notices*. However, prior to the meeting date, comprehensive and continually updated meeting and program information with links to the abstract for each talk can be found on e-MATH. See <http://www.ams.org/meetings/>. Programs and abstracts will continue to be displayed on e-MATH in the Meetings and Conferences section until about three weeks after the meeting is over. Final programs for Sectional Meetings will be archived on e-MATH in the next electronic issue of the *Notices* which follows the meeting. See the entry "Program issue of electronic *Notices*" listed below for each meeting to identify the specific issue.

Austin, Texas

University of Texas, Austin

October 8-10, 1999

Meeting #948

Central Section

Associate secretary: Susan J. Friedlander

Announcement issue of *Notices*: June 1999

Program first available on eMATH: August 25, 1999

Program issue of electronic *Notices*: December 1999

Issue of *Abstracts*: Volume 20, Issue 4

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions: Expired

For abstracts: Expired

Invited Addresses

Mikhail M. Kapranov, Northwestern University, *Derived deformation theory*.

John Roe, Penn State University, *Large scale geometric invariants of elliptic operators*.

Catherine Sulem, University of Toronto, *The nonlinear Schrödinger equation: Self-focusing and wave collapse*.

Tatiana Toro, University of Washington, *Characterization of non-smooth domains via potential theory*.

Special Sessions

Advances in the Mathematics and Applications of Finite Elements, **J. Tinsley Oden**, University of Texas, Austin.

Aperiodic Tiling, **Charles Radin** and **Lorenzo Sadun**, University of Texas, Austin.

Banach and Operator Spaces: Isomorphic and Geometric Structure, **Edward Odell** and **Haskell P. Rosenthal**, University of Texas, Austin.

DNA Topology, **Isabel K. Darcy**, University of Texas, Austin, and **Makkuni Jayaram**, University of Texas, Austin.

Dehn Surgery and Kleinian Groups, **John Luecke** and **Alan Reid**, University of Texas, Austin.

Dynamical Systems, **David Delatte**, **R. Daniel Mauldin**, **Mariusz Urbanski**, and **Luca Quardo Zamboni**, University of North Texas.

Free Surface Interfaces and PDEs, **Kirk Lancaster**, Wichita State University, and **Thomas Vogel**, Texas A&M University.

Harmonic Analysis and PDEs, **William Beckner** and **Luis A. Caffarelli**, University of Texas, Austin, **Toti Daskalopoulos**, University of California, Irvine, and **Tatiana Toro**, University of Washington.

Interconnections Among Diophantine Geometry, Algebraic Geometry, and Value Distribution Theory, **William Cherry**, University of North Texas, **Min Ru**, University of Houston, and **Felipe Voloch**, University of Texas, Austin.

Mathematical Problems in Transport Phenomena, **Jose Antonio Carrillo** and **Irene M. Gamba**, University of Texas, Austin.

Mathematical and Computational Finance, **Stathis Tompaidis**, University of Texas, Austin.

Nonlinear Dynamics, **Robert J. McCann** and **Catherine Sulem**, University of Toronto.

Recent Developments in Index Theory, **Daniel S. Freed**, University of Texas, Austin, and **John Roe**, Pennsylvania State University.

The Development of Topology in the Americas, **Cameron Gordon**, University of Texas, Austin, and **Ioan Mackenzie James**, University of Oxford.

The Diverse Mathematical Legacy of Jean Leray, **Eric M. Friedlander**, Northwestern University, and **Susan J. Friedlander**, University of Illinois, Chicago.

Theoretical, Computational and Experimental Aspects of Mechanics, **Jerry Bona**, **Steven Levandosky**, and **Jiahong Wu**, University of Texas, Austin.

Topology of Continua, **Wayne Lewis** and **Carl Seaquist**, Texas Tech University.

Wavelets and Approximation Theory, **Don Hong**, Eastern Tennessee State University, and **Michael Prophet**, Murray State University.

Charlotte, North Carolina

University of North Carolina at Charlotte

October 15–17, 1999

Meeting #949

Southeastern Section

Associate secretary: John L. Bryant

Announcement issue of *Notices*: August 1999

Program first available on eMATH: September 1, 1999

Program issue of electronic *Notices*: December 1999

Issue of *Abstracts*: Volume 20, Issue 4

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions: Expired

For abstracts: Expired

Invited Addresses

Valery Alexeev, University of Georgia, *Stable maps between varieties with group action*.

Béla Bollobás, University of Memphis and Cambridge University, *Phase transitions in combinatorial structures*.

Konstantin M. Mischaikow, Georgia Institute of Technology, *From time series to symbolic dynamics: An algebraic topological approach*.

Yakov Sinai, Princeton University, *Recent results in mathematical and statistical hydrodynamics*.

Special Sessions

Algebraic Geometry, **Valery Aleeev**, **William Graham**, **Roy C. Smith**, and **Robert Varley**, University of Georgia.

Applied Probabilistic Combinatorics, **Bela Bollobás**, University of Memphis and Cambridge University, and **Gregory Sorkin**, IBM T. J. Watson Research Center.

Commutative Algebra, **Sarah Glaz**, University of Connecticut, and **Evan G. Houston** and **Thomas G. Lucas**, University of North Carolina at Charlotte.

Contemporary Methods in Dynamics and Differential Equations, **Robert W. Ghrist** and **Konstantin M. Mischaikow**, Georgia Institute of Technology.

Gauge Theory and Low-Dimensional Topology, **Eric P. Klassen**, Florida State University, and **Paul A. Kirk**, Indiana University.

Geometric Function Theory, **David A. Herron**, University of Cincinnati, and **Shanshuang Yang**, Emory University.

Knot Theory and Its Applications, **Yuanan Diao**, University of North Carolina at Charlotte.

Operator Theory, Including Applications in Operator Algebras and Wavelets, **Alan L. Lambert** and **Xingde Dai**, University of North Carolina at Charlotte.

Optimal Control and Computational Optimization, **Mohammed A. Kazemi**, University of North Carolina at Charlotte, and **Gamal N. Elnagar**, University of South Carolina Spartanburg.

Set-Theoretic Topology, **Ronald F. Levy**, George Mason University.

Spectral Theory of Differential Operators and Applications, **Boris R. Vainberg** and **Stanislav Molchanov**, University of North Carolina at Charlotte.

Stochastic PDEs and Turbulence, **Weinan E.**, Courant Institute, New York University.

Stochastic Processes and Control, **Volker Wihstutz** and **Alexander A. Yushkevich**, University of North Carolina at Charlotte.

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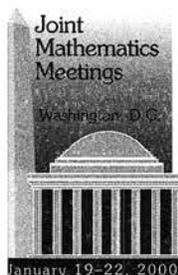
Marriott Wardman Park Hotel and Omni Shoreham Hotel

January 19–22, 2000

Meeting #950

Joint Mathematics Meetings, including the 106th Annual Meeting of the AMS, 83rd Meeting of the Mathematical Association of America (MAA), with minisymposia and other special events contributed by the Society for Industrial and Applied Mathematics (SIAM), the 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.

Associate secretary: Bernard Russo
Announcement issue of *Notices*: October 1999
Program first available on eMATH: November 1, 1999
Program issue of electronic *Notices*: January 2000
Issue of *Abstracts*: Volume 21, Issue 1



Note: This is a World Math Year 2000 (WMY2000) event.

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 Additions or Changes

Joint Invited Address

The AMS-MAA-MSEB address to be given by Bruce Alberts, National Academy of Sciences, on Wednesday afternoon has been cancelled.

MAA Sessions

Special Presentation for Chairs of Mathematics Departments in Comprehensive Universities, Four-Year Liberal Arts and Two-Year Colleges, Saturday 2:30 p.m.–4:00 p.m., organized by Gerald L. Alexanderson, Santa Clara University. This session will consist mainly of breakouts into discussion groups organized around the three types of institutions.

Minicourse #16: *Construction projects and the imagination*, has been cancelled.

Minicourse #14: *Modern physics and the mathematical world*, has been moved from Wednesday afternoon and Friday evening to Thursday and Saturday afternoons.

SIAM Invited Address

Alan C. Newell, University of Arizona and University of Warwick, *Natural patterns*, Friday, 10:05 a.m.

SIAM Minisymposia

Discrete Methods in Information Technology will take place on Thursday, 8:00 a.m.–10:00 a.m.

3D Navier-Stokes and Euler Equations will take place on Thursday, 8:00 a.m.–10:00 a.m.

Analysis of Krylov Space Methods in Numerical Linear Algebra will take place on Thursday, 1:00 p.m.–3:00 p.m.

The minisymposium organized by Kathleen T. Alligood and James A. Yorke is titled *Nonlinear Dynamics Theory for the Scientist* and will take place on Friday, 1:00 p.m.–5:00 p.m.

An additional minisymposium is *Applications of Inverse Problems in Partial Differential Equations*, organized by C. Maeve McCarthy, Murray State University, and will take place on Friday, 8:00 a.m.–10:00 a.m.

Social Events

Dinner in Honor of Retiring MAA Executive Director Marcia P. Sward, Saturday, 7:00 p.m.–10:00 p.m. Marcia P. Sward served as executive director of the MAA from 1989 to 1999. Her service has been of great benefit to the MAA and the larger mathematical community. Come wish Marcia well on the next chapter of her life. Cocktails at 7:00 p.m. (cash bar) followed by dinner at 7:30 p.m. Tickets are \$46, including tax and gratuity.

Santa Barbara, California

University of California, Santa Barbara

March 11–12, 2000

Meeting #951

Western Section

Associate secretary: Bernard Russo

Announcement issue of *Notices*: January 2000

Program first available on eMATH: February 1, 2000

Program issue of electronic *Notices*: May 2000

Issue of *Abstracts*: Volume 21, Issue 2

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions: November 23, 1999

For abstracts: January 18, 2000

Invited Addresses

Dietmar Bisch, University of California, Santa Barbara, *Title to be announced*.

Special Sessions

Automorphic Forms (Code: AMS SS D1), **Ozlem Imamoglu** and **Jeffrey Stopple**, University of California, Santa Barbara.

Geometric Analysis (Code: AMS SS C1), **Doug Moore**, **Guofang Wei**, and **Rick Ye**, University of California, Santa Barbara.

Geometric Methods in 3-manifolds (Code: AMS SS B1), **Daryl Cooper**, **Darren Long**, and **Martin Scharlemann**, University of California, Santa Barbara.

History of Mathematics (Code: AMS SS A1), **James Tattersall**, Providence College.

Subfactors and Free Probability Theory (Code: AMS SS E1), **Dietmar Bisch**, University of California, Santa Barbara, and **Sorin Popa**, University of California, Los Angeles.

Lowell, Massachusetts

University of Massachusetts, Lowell

April 1–2, 2000

Meeting #952

Eastern Section

Associate secretary: Lesley M. Sibner

Announcement issue of *Notices*: February 2000

Program first available on eMATH: February 24, 2000

Program issue of electronic *Notices*: June 2000

Issue of *Abstracts*: Volume 21, Issue 2

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions: December 14, 1999

For abstracts: February 8, 2000

Invited Addresses

Walter Craig, Brown University, *Title to be announced.*

Erwin Lutwak, Polytechnic University, *Title to be announced.*

Alexander Nabutovsky, Courant Institute of Mathematical Sciences, NYU, *Title to be announced.*

Mary Beth Ruskai, University of Massachusetts, Lowell, *Title to be announced.*

Special Sessions

Combustion Theory (Code: AMS SS D1), **James Graham-Eagle**, University of Massachusetts, Lowell, and **Daniel A. Schult**, Colgate University.

Ergodic Theory and Dynamical Systems (Code: AMS SS C1), **Stanley J. Eigen**, Northeastern University, and **Vidhu S. Prasad**, University of Massachusetts, Lowell.

Invariance in Convex Geometry (Code: AMS SS A1), **Daniel A. Klain**, Georgia Institute of Technology, and **Elisabeth Werner**, Case Western Reserve University.

Quantum Information Theory (Code: AMS SS B1), **M. Beth Ruskai**, University of Massachusetts, Lowell, and **Christopher K. King**, Northeastern University.

Szygies (Code: AMS SS E1), **Irena Peeva**, Cornell University.

Vorticity in Fluid Flows: Analysis and Methods (Code: AMS SS F1), **Louis F. Rossi**, University of Massachusetts at Lowell, **Richard B. Pelz**, Rutgers University, and **John Grant**, Naval Undersea Warfare Center.

Notre Dame, Indiana

University of Notre Dame

April 7–9, 2000

Meeting #953

Central Section

Associate secretary: Susan J. Friedlander

Announcement issue of *Notices*: February 2000

Program first available on eMATH: February 24, 2000

Program issue of electronic *Notices*: June 1999

Issue of *Abstracts*: Volume 21, Issue 2

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions: December 21, 1999

For abstracts: February 15, 2000

Invited Addresses

Peter Bates, Brigham Young University, *Title to be announced.*

Andras Nemethi, Ohio State University, *Title to be announced.*

Charles Radin, University of Texas, Austin, *Title to be announced.*

David Sattinger, University of Minnesota, *Title to be announced.*

Special Sessions

Algebraic Coding Theory (Code: AMS SS K1), **Judy Walker**, University of Nebraska, and **Jay Wood**, Purdue University Calumet.

Algebraic Geometry (Code: AMS SS F1), **Karen Chandler** and **Scott Nollet**, University of Notre Dame.

Applications of Invariant Manifold Theory (Code: AMS SS M1), **Peter Bates**, Brigham Young University, and **Clarence Eugene Wayne**, Boston University.

Commutative Algebra (Code: AMS SS A1), **Juan Migliore**, University of Notre Dame, and **Chris Peterson**, Washington University.

Cooperative Learning in Undergraduate Mathematics Education (Code: AMS SS T1), **Nahid Erfan**, University of Notre Dame, and **Vic Perera**, Kent State University.

Differential Geometry and its Applications (Code: AMS SS B1), **Jianguo Cao**, **Brian Smyth**, and **Frederico Xavier**, University of Notre Dame.

Differential Inequalities and Applications (Code: AMS SS N1), **Paul W. Eloe**, University of Dayton.

Homotopy Theory (Code: AMS SS H1), **William G. Dwyer**, University of Notre Dame, and **Michele Intermont**, Kalamazoo College.

Index Theory and Topology (Code: AMS SS Q1), **John Roe**, Pennsylvania State University, and **Stephan Stolz** and **Bruce Williams**, University of Notre Dame.

Integrable Systems and Nonlinear Waves (Code: AMS SS E1), **Mark S. Alber** and **Gerard Misiolek**, University of Notre Dame.

Microlocal Analysis and Partial Differential Equations (Code: AMS SS D1), **Nicholas Hanges**, CUNY, Lehman College, and **Alex Himonas**, University of Notre Dame.

Nonlinear Partial Differential Equations (Code: AMS SS J1), **Qing Han** and **Bei Hu**, University of Notre Dame, and **Hong-Ming Yin**, Washington State University.

Number Theory, Algorithms, and Cryptography (Code: AMS SS R1), **Eric Bach**, University of Wisconsin, Madison, and **Jonathan Sorenson**, Butler University.

Optimization and Numerical Analysis (Code: AMS SS C1), **Leonid Faybusovich**, University of Notre Dame.

Quasigroups and Loops and their Applications (Code: AMS SS P1), **Michael K. Kinyon**, Indiana University South Bend, and **J. D. Phillips**, Saint Mary's College of California.

Representations of Groups and Related Objects (Code: AMS SS S1), **Chris Bendel**, University of Wisconsin, Stout, and **George McNinch**, University of Notre Dame.

Several Complex Variables (Code: AMS SS G1), **Jeffrey Diller**, University of Notre Dame, and **Nancy Stanton**, University of Notre Dame.

Singularities in Algebraic Geometry (Code: AMS SS L1), **Sandor Kovacs**, University of Chicago, and **Andras Nemethi**, Ohio State University.

Symbolic Dynamics (Code: AMS SS U1), **William Geller**, Indiana University-Purdue University Indianapolis, and **Nicholas S. Ormes** and **Charles Radin**, University of Texas, Austin.

Lafayette, Louisiana

University of Southwestern Louisiana

April 14–16, 2000

Meeting #954

Southeastern Section

Associate secretary: John L. Bryant

Announcement issue of *Notices*: February 2000

Program first available on eMATH: March 2, 2000

Program issue of electronic *Notices*: June 2000

Issue of *Abstracts*: Volume 21, Issue 2

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions: December 28, 1999

For abstracts: February 22, 2000

Special Sessions

Continuum Theory (Code: AMS SS F1), **Thelma R. West**, University of Southwestern Louisiana.

Mathematical Models in the Biological and Physical Sciences (Code: AMS SS B1), **Azmy S. Ackleh**, **Lan Ke**, and **Robert D. Sidman**, University of Southwestern Louisiana.

Nonlinear Differential Equations and Their Applications (Code: AMS SS C1), **C. Y. Chan**, **Keng Deng**, and **A. S. Vatsala**, University of Southwestern Louisiana.

Quantum Topology (Code: AMS SS E1), **Patrick M. Gilmer**, Louisiana State University.

Rings and Their Generalizations (Code: AMS SS A1), **Gary F. Birkenmeier** and **Henry E. Heatherly**, University of Southwestern Louisiana.

Scientific Computing (Code: AMS SS D1), **R. Baker Kearfott**, **Qin Sheng**, and **Christo Christov**, University of Southwestern Louisiana.

Odense, Denmark

Odense University

June 13–16, 2000

Meeting #955

First AMS-Scandinavian International Mathematics Meeting. Sponsored by the AMS, Dansk Matematisk Forening, Suomen matemaattinen yhdistys, Icelandic Mathematical Society, Norsk Matematisk Forening, and Svenska matematikersamfundet.

Associate secretary: Robert M. Fossum

Announcement issue of *Notices*: To be announced

Program first available on eMATH: N/A

Program issue of electronic *Notices*: N/A

Issue of *Abstracts*: N/A

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced



Note: This is a World Math Year 2000 (WMY2000) event.

Invited Addresses

Tobias Colding, Courant Institute, New York University, *Title to be announced.*

Johan Håstad, Stockholm, *Title to be announced.*

Nigel J. Hitchin, University of Oxford, *Title to be announced.*

Elliott Lieb, Princeton University, *Title to be announced.*

Pertti Mattila, University of Jyväskylä, *Title to be announced.*

Curtis T. McMullen, Harvard University, *Title to be announced.*

Alexei N. Rudakov, Norwegian University of Science & Technology, *Title to be announced.*

Dan Voiculescu, University of California, Berkeley, *Title to be announced.*

Special Sessions

Algebraic Groups and Representation Theory, **Henning Haahr Andersen** and **Niels Lauritzen**, Aarhus University.

Complex Analysis in Higher Dimensions, **Finnur Larusson**, University of Western Ontario, and **Ragnar Sigurdsson**, University of Iceland.

Differential Geometry, **Claude R. LeBrun**, State University of New York at Stony Brook, and **Peter Petersen**, University of California, Los Angeles.

Discrete Mathematics, **Iiro S. Honkala**, University of Turku, and **Carsten Thomassen**, Technical University of Denmark.

Dynamical Systems, **Michael Benedicks**, Royal Institute of Science, Stockholm, and **Carsten Lunde Petersen**, Roskilde.

Geometric Analysis/PDE, **Gerd Grubb**, University of Copenhagen, and **Bent Ørsted**, Odense University.

Joint EWM and AWM Session, **Lisbeth Fajstrup**, Aalborg University, **Tinne Hoff Kjeldsen**, Roskilde, and **Christina Wiis Tønnesen-Friedman**, Aarhus University.

K-Theory and Operator Algebras, **Soren Eilers**, University of Copenhagen, and **Nigel D. Higson**, Pennsylvania State University.

Linear Spaces of Holomorphic Functions, **Peter L. Duren**, University of Michigan, Ann Arbor, **Michael Stessin**, State University of New York at Albany, and **Harold S. Shapiro**, Royal Institute of Technology, Stockholm.

Mathematical Physics, **Bergfinnur Durhuus**, University of Copenhagen, and **Kurt Johansson**, Royal Institute of Technology, Stockholm.

Mathematics Education, **Claus Michelsen**, Odense, and **Martti E. Pesonen**, University of Joensuu.

Stochastic DE and Financial Mathematics, **Tomas Björk**, University of Stockholm, and **Bernt Øksendal**, University of Oslo.

Los Angeles, California

University of California-Los Angeles

August 7–12, 2000

Meeting #956

Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: May 2000
Program first available on eMATH: May 24, 2000
Program issue of electronic *Notices*: October 2000
Issue of *Abstracts*: Volume 21, Issue 3



Note: This is a World Math Year 2000 (WMY2000) event.

Deadlines

For abstracts: May 10, 2000

Note: There will be no Special Sessions at this meeting, only sessions for contributed papers.

Invited Addresses

James G. Arthur, University of Toronto, *will speak on automorphic forms and the Langlands program.*

Alexander A. Beilinson, University of Chicago, *will speak on the geometric Langlands conjecture.*

Michael V. Berry, H. H. Wills Physics Laboratory, *will speak on waves, geometry, and arithmetic.*

Haim Brezis, University of Paris XI and Rutgers University, *will speak on nonlinear partial differential equations.*

Alain Connes, Collège de France, *will speak on noncommutative geometry.*

David L. Donoho, Stanford University, *will speak on interactions among harmonic analysis, statistical analysis, and information theory.*

Charles L. Fefferman, Princeton University, *will speak on a subject to be announced.*

Michael H. Freedman, Microsoft Research, *will speak on a subject to be announced.*

Ronald L. Graham, AT&T Labs, *will speak on a subject to be announced (MAA Invited Address).*

Helmuth W. Hofer, New York University - Courant Institute, *will speak on symplectic geometry/dynamical systems.*

Richard M. Karp, University of Washington, *will speak on computational molecular biology.*

Sergiu Klainerman, Princeton University, *will speak on partial differential equations.*

Maxim Kontsevich, Institut des Hautes Etudes Scientifiques, *will speak on deformations, supermanifolds, and homotopical algebra.*

Peter D. Lax, New York University - Courant Institute, *will speak on mathematics and computing.*

Simon A. Levin, Princeton University, *will speak on complexity of biology.*

László Lovász, Yale University, *will speak on discrete mathematics and algorithms.*

David Mumford, Brown University, *will speak on models of perception and inference.*

Peter Sarnak, Princeton University, *will speak on a subject to be announced.*

Peter W. Shor, AT&T Labs, *will speak on quantum computing/quantum information theory.*

Yakov G. Sinai, Princeton University, *will speak on dynamical systems.*

Richard P. Stanley, Massachusetts Institute of Technology, *will speak on algebraic combinatorics.*

Dennis P. Sullivan, The CUNY Graduate School, *will speak on applications of combinatorial topology to geometry.*

Clifford Taubes, Harvard University, *will speak on geometry and topology of the future.*

Jean E. Taylor, Rutgers University, *will speak on applications of geometric analysis.*

William P. Thurston, University of California - Davis, *will speak on three-dimensional topology and geometry.*

Karen Uhlenbeck, University of Texas, Austin, *will speak on a subject to be announced.*

S. R. S. Varadhan, New York University - Courant Institute, *will speak on a subject to be announced.*

Edward Witten, Institute for Advanced Study, *will speak on the mathematical impact of quantum fields and strings.*

Shing-Tung Yau, Harvard University, *will speak on geometry and its relation to physics.*

Don B. Zagier, Max-Planck Institut fur Mathematik, *will speak on number theory: modular forms.*

Toronto, Ontario Canada

University of Toronto

September 22–24, 2000

Meeting #957

Central Section

Associate secretary: Susan J. Friedlander

Announcement issue of *Notices*: August 2000

Program first available on eMATH: August 10, 2000

Program issue of electronic *Notices*: November 2000

Issue of *Abstracts*: Volume 21, Issue 3

Deadlines

For organizers: February 2, 2000

For consideration of contributed papers in Special Sessions: June 6, 2000

For abstracts: August 1, 2000

San Francisco, California

San Francisco State University

October 21–22, 2000

Meeting #958

Western Section

Associate secretary: Bernard Russo

Announcement issue of *Notices*: August 2000

Program first available on eMATH: September 11, 2000

Program issue of electronic *Notices*: November 2000

Issue of *Abstracts*: Volume 21, Issue 4

Deadlines

For organizers: March 21, 2000

For consideration of contributed papers in Special Sessions: June 21, 2000

For abstracts: August 29, 2000

Special Sessions

Algebraic and Geometric Combinatorics (Code: AMS SS A1), **Jesus De Loera**, University of California, Davis, and **Frank Sottile**, University of Wisconsin.

New York, New York

Columbia University

November 3–5, 2000

Meeting #959

Eastern Section

Associate secretary: Lesley M. Sibner

Announcement issue of *Notices*: September 2000

Program first available on eMATH: September 28, 2000

Program issue of electronic *Notices*: To be announced

Issue of *Abstracts*: Volume 21, Issue 4

Deadlines

For organizers: April 3, 2000

For consideration of contributed papers in Special Sessions: July 18, 2000

For abstracts: September 12, 2000

Invited Addresses

Paula Cohen, Université des Sciences et Technologies de Lille, France, *will speak on geometry and its relation to physics.*

Brian Greene, Columbia University, *Title to be announced.*

Sergey Novikov, University of Maryland-College Park and Landau Institute for Theoretical Physics, *Title to be announced.*

Alexander I. Suci, Northeastern University, *Title to be announced.*

Special Sessions

Arrangements of Hyperplanes (Code: AMS SS C1), Michael J. Falk, Northern Arizona University, and Alexander I. Suci, Northeastern University.

Combinatorial Group Theory (Code: AMS SS A1), Gilbert Baumslag, Alexei Myasnikov, and Vladimir Shpilrain, City College (CUNY).

The Topology of 3-Manifolds (Code: AMS SS B1), Joan S. Birman and Brian S. Magnus, Columbia University, and Walter D. Neumann, University of Melbourne.

Birmingham, Alabama

University of Alabama-Birmingham

November 10–12, 2000

Meeting #960

Southeastern Section

Associate secretary: John L. Bryant

Announcement issue of *Notices*: September 2000

Program first available on eMATH: October 5, 2000

Program issue of electronic *Notices*: To be announced

Issue of *Abstracts*: Volume 21, Issue 4

Deadlines

For organizers: April 10, 2000

For consideration of contributed papers in Special Sessions: July 25, 2000

For abstracts: September 19, 2000

Hong Kong, People's Republic of China

December 13–17, 2000

Meeting #961

First Joint International Meeting between the AMS and the Hong Kong Mathematical Society.

Associate secretary: Bernard Russo

Announcement issue of *Notices*: To be announced

Program first available on eMATH: To be announced

Program issue of electronic *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

New Orleans, Louisiana

New Orleans Marriott and 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*: October 2000

Program first available on eMATH: To be announced

Program issue of electronic *Notices*: To be announced

Issue of *Abstracts*: Volume 22, Issue 1

Deadlines

For organizers: April 11, 2000

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

Columbia, South Carolina

University of South Carolina

March 16–18, 2001

Southeastern Section

Associate secretary: John L. Bryant

Announcement issue of *Notices*: To be announced

Program first available on eMATH: To be announced

Program issue of electronic *Notices*: To be announced

Issue of *Abstracts*: To be announced

Deadlines

For organizers: August 15, 2000

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

Lawrence, Kansas

University of Kansas

March 30–31, 2001

Central Section

Associate secretary: Susan J. Friedlander

Announcement issue of *Notices*: To be announced

Program first available on eMATH: To be announced

Program issue of electronic *Notices*: To be announced

Issue of *Abstracts*: To be announced

Deadlines

For organizers: June 28, 2000

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

Hoboken, New Jersey

Stevens Institute of Technology

April 28–29, 2001

Eastern Section

Associate secretary: Lesley M. Sibner

Announcement issue of *Notices*: To be announced

Program first available on eMATH: To be announced

Program issue of electronic *Notices*: To be announced

Issue of *Abstracts*: To be announced

Deadlines

For organizers: September 28, 2000

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

Lyon, France

July 17–20, 2001

First Joint International Meeting between the AMS and the Société Mathématique de France.

Associate secretary: Lesley M. Sibner

Announcement issue of *Notices*: To be announced

Program first available on eMATH: To be announced

Program issue of electronic *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

Williamstown, Massachusetts

Williams College

October 13–14, 2001

Eastern Section

Associate secretary: Lesley M. Sibner

Announcement issue of *Notices*: To be announced

Program first available on eMATH: To be announced

Program issue of electronic *Notices*: To be announced

Issue of *Abstracts*: To be announced

Deadlines

For organizers: March 11, 2001

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

San Diego, California

San Diego Convention Center

January 6–9, 2002

Joint Mathematics Meetings, including the 108th Annual Meeting of the AMS and 85th Meeting of the Mathematical Association of America (MAA).

Associate secretary: John L. Bryant

Announcement issue of *Notices*: To be announced

Program first available on eMATH: To be announced

Program issue of electronic *Notices*: To be announced

Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 4, 2001

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

Washington, DC Advance Registration/Housing Form

Name _____
(please write name as you would like it to appear on your badge)

Mailing Address _____

Telephone _____ Fax _____

Email Address _____
(Acknowledgment of this registration will be sent to the email address given here,
unless you check this box: *Send by US Mail*)

Badge Information: Affiliation for badge _____
Nonmathematician guest badge name _____
(please note charge below)

- Membership**
✓ all that apply
- AMS
 - ASA
 - ASL
 - AWM
 - CMS
 - MAA
 - NAM
 - SIAM
 - YMN



I DO NOT want my program and badge to be mailed to me on 12/15/99.

Registration Fees

Joint Meetings	by Dec 20	at mtg	Subtotal
<input type="checkbox"/> Member AMS, ASL, CMS, MAA, SIAM	\$ 165	\$ 215	
<input type="checkbox"/> Nonmember	\$ 256	\$ 332	
<input type="checkbox"/> Graduate Student	\$ 35	\$ 45	
<input type="checkbox"/> Undergraduate Student	\$ 20	\$ 26	
<input type="checkbox"/> High School Student	\$ 2	\$ 5	
<input type="checkbox"/> Unemployed	\$ 35	\$ 45	
<input type="checkbox"/> Temporarily Employed	\$ 125	\$ 140	
<input type="checkbox"/> Developing Countries Special Rate	\$ 35	\$ 45	
<input type="checkbox"/> Emeritus Member of AMS or MAA	\$ 35	\$ 45	
<input type="checkbox"/> High School Teacher	\$ 35	\$ 45	
<input type="checkbox"/> Librarian	\$ 35	\$ 45	
<input type="checkbox"/> Nonmathematician Guest	\$ 5	\$ 5	

AMS Short Course: Quantum Computation (1/17-1/18)

<input type="checkbox"/> Member, Nonmember	\$ 80	\$ 95
<input type="checkbox"/> Student, Unemployed, Emeritus	\$ 35	\$ 45

AMS Short Course: Environmental Mathematics (1/17-1/18)

<input type="checkbox"/> Member, Nonmember	\$ 80	\$ 95
<input type="checkbox"/> Student, Unemployed, Emeritus	\$ 35	\$ 45

MAA Short Course: Fuzzy Mathematics (1/17-1/18)

<input type="checkbox"/> Member of MAA	\$ 125	\$ 140
<input type="checkbox"/> Nonmember	\$ 175	\$ 190
<input type="checkbox"/> Student, Unemployed, Emeritus	\$ 50	\$ 60

MAA Minicourses (see listing in text)
I would like to attend: One Minicourse Two Minicourses
Please enroll me in MAA Minicourse(s) # _____ and/or # _____
In order of preference, my alternatives are: # _____ and/or # _____
Prices: \$80 for Minicourses #1-6 and \$55 for Minicourses #7-16

Employment Center
Applicant résumé forms and employer job listing forms will be on e-MATH and in *Notices* in September.

Employer—First Table	\$ 200	\$ 250
<input type="checkbox"/> Regular <input type="checkbox"/> Self-scheduled <input type="checkbox"/> Information Table		
Employer—Second Table	\$ 50	\$ 75
<input type="checkbox"/> Regular <input type="checkbox"/> Self-scheduled <input type="checkbox"/> Information Table		
<input type="checkbox"/> Employer—Posting Only	\$ 50	N/A
<input type="checkbox"/> Applicant (all services)	\$ 40	\$ 75
<input type="checkbox"/> Applicant (Winter List & Message Ctr only)	\$ 20	\$ 20

Events with Tickets

Opening Banquet	\$43	# ___ Regular	# ___ Veg	# ___ Kosher
Hope Daly Luncheon	\$28	# ___ Regular	# ___ Veg	# ___ Kosher
Marcia Sward Dinner	\$46	# ___ Regular	# ___ Veg	# ___ Kosher

Other Events (no charge)
 Workshop: *Teaching Assistant Trainers* (1/21)
 MAA Student Workshop: *Theorems in Stone & Bronze* (1/20)
 Graduate Student Reception (1/19)

Total for Registrations and Events \$ _____

Payment

Registration & Event Total (total from other column) \$ _____
 Hotel Deposit (only if paying by check) \$ _____

Total Amount To Be Paid \$ _____

(Note: A \$5 processing fee will be charged for each returned check or invalid credit card.)

Method of Payment

- Check. Make checks payable to the AMS. Checks drawn on foreign banks must be in equivalent foreign currency at current exchange rates.
- Credit Card. VISA, MasterCard, AMEX, Discover (no others accepted).

Card number: _____

Exp. date: _____ Zipcode of credit card billing address: _____

Signature: _____

Name on card: _____

Purchase order # _____ (please enclose copy)

Registration for the Joint Meetings is not required for the Short Courses, but it is required for the Minicourses and the Employment Center.

Other Information

Mathematical Reviews field of interest # _____

How did you hear about this meeting? Check one: Colleague(s) Focus
 Notices SIAM News Special Mailing WWW

I am a mathematics department chair.

Please do not include my name on any promotional mailing list.

Please ✓ this box if you have a disability requiring special services.

Mail to:

Mathematics Meetings Service Bureau (MMSB)
P. O. Box 6887
Providence, RI 02940-6887
 Fax: 401-455-4004
 Questions/changes call: 401-455-4143 or 1-800-321-4267 x4143

Deadlines

- For room lottery and/or résumés/job descriptions printed in the *Winter Lists*, return this form by: **Nov. 8, 1999**
- For housing reservations, badges/programs mailed: **Nov. 22, 1999**
- For housing changes/cancellations through MMSB: **Dec. 17, 1999**
- For advance registration for the Joint Meetings, Employment Center, Short Courses, MAA Minicourses, & Tickets: **Dec. 20, 1999**
- For 50% refund on banquets, cancel by: **Jan 5, 2000***
- For 50% refund on advance registration, Minicourses & Short Courses, cancel by: **January 14, 2000***

***no refunds after this date**

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 14.5% sales occupancy tax. **Guarantee requirements: First night deposit by check (add to payment on reverse of form) or a credit card guarantee.**

Deposit enclosed Hold with my credit card Card Number _____ Exp. Date _____ Signature _____

Date and Time of Arrival _____ **Date and Time of Departure** _____

Name of Other Room Occupant _____ **Arrival Date** _____ **Departure Date** _____ **Spouse** **Child** _____ (give age)

Order of choice	Hotel	Single	Double 1 bed	Double 2 beds	Triple 2 beds	Triple 2 beds w/cot	Quad 2 beds	Quad 2 beds w/cot	Suites Starting rates
	Marriott Wardman Park (co-headquarters)								
	Superior	\$139	\$149	\$149	\$169	\$169	\$189	\$189	\$350
	Regular	\$126	\$136	\$136	\$156	\$156	\$176	\$176	\$350
	Student	\$114	\$114	\$114	\$134	\$134	\$154	\$154	N/A
	Omni Shoreham (co-headquarters)								
	Regular	\$119	\$119	\$119	\$139	\$164	\$139	\$164	\$229
	Student	\$108	\$108	\$108	\$128	\$153	\$128	\$153	N/A
	Hotel Sofitel	\$99	\$99	\$99	\$119	\$119	\$139	\$139	\$155
	Doyle Washington	\$99	\$99	\$99	\$114	\$129	\$129	\$144	\$400
	Washington Plaza								
	Regular	\$92	\$92	\$92	\$112	\$132	\$132	\$152	\$165
	Student	\$82	\$82	\$82	\$102	\$122	\$122	\$142	N/A
	Howard Johnson Plaza Hotel & Suites	\$79	\$79	\$79	\$89	\$100	\$99	\$110	(all suites)
	Doyle Normandy	\$79	\$79	\$79	\$94	\$104	\$109	\$119	N/A
	Days Inn Connecticut Avenue	\$79	\$79	\$79	\$89	\$99	\$99	\$109	\$134

Special Housing Requests:

- I have disabilities as defined by the ADA that require a sleeping room that is accessible to the physically challenged. My needs are: _____
- Other requests: _____
- If you are a member of a hotel frequent-travel club and would like to receive appropriate credit, please include the hotel chain and card number here: _____

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.
- I plan to share a room with _____, who is making reservations.

New Titles in Graduate Studies in Mathematics

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Foliations I

Alberto Candel, *California Institute of Technology, Pasadena, and Lawrence Conlon*, *Washington University, St. Louis, MO*

This is the first of two volumes on the qualitative theory of foliations. This volume is divided into three parts. The book is extensively illustrated throughout and provides a large number of examples.

Part 1 is intended as a "primer" in foliation theory. A working knowledge of manifold theory and topology is a prerequisite. Fundamental definitions and theorems are explained to prepare the reader for further exploration of the topic. This section places considerable emphasis on the construction of examples, which are accompanied by many illustrations.

Part 2 considers foliations of codimension one. Using very hands-on geometric methods, the path leads to a complete structure theory (the theory of levels), which was established by Conlon along with Cantwell, Hector, Duminy, Nishimori, Tsuchiya, et al. Presented here is the first and only full treatment of the theory of levels in a textbook.

Part 3 is devoted to foliations of higher codimension, including abstract laminations (foliated spaces). The treatment emphasizes the methods of ergodic theory: holonomy-invariant measures and entropy. Featured are Sullivan's theory of foliation cycles, Plante's theory of growth of leaves, and the Ghys, Langevin, Walczak theory of geometric entropy.

This comprehensive volume has something to offer a broad spectrum of readers: from beginners to advanced students to professional researchers. Packed with a wealth of illustrations and copious examples at varying degrees of difficulty, this highly-accessible text offers the first full treatment in the literature of the theory of levels for foliated manifolds of codimension one. It would make an elegant supplementary text for a topics course at the advanced graduate level.

2000; 394 pages; Hardcover; ISBN 0-8218-0809-5; List \$54; All AMS members \$43; Order code GSM-CONLONNA

A Course in Operator Theory

John B. Conway, *University of Tennessee, Knoxville*

Operator theory is a significant part of many important areas of modern mathematics: functional analysis, differential equations, index theory, representation theory, mathematical physics, and more. This text covers the central themes of operator theory, presented with the excellent clarity and style that readers have come to associate with Conway's writing.

Early chapters introduce and review material on C^* -algebras, normal operators, compact operators and non-normal operators. The topics include the spectral theorem, the functional calculus and the Fredholm index. Also, some deep connections between operator theory and analytic functions are presented.

Later chapters cover more advanced topics, such as representations of C^* -algebras, compact perturbations and von Neumann algebras. Major results, such as the Sz.-Nagy Dilation Theorem, the Weyl-von Neumann-Berg Theorem and the classification of von Neumann algebras, are covered, as is a treatment of Fredholm theory. These advanced topics are at the heart of current research.

The last chapter gives an introduction to reflexive subspaces, i.e., subspaces of operators that are determined by their invariant subspaces. These, along with hyperreflexive spaces, are one of the more successful episodes in the modern study of asymmetric algebras.

Professor Conway's authoritative treatment makes this a compelling and rigorous course text, suitable for graduate students who have had a standard course in functional analysis.

Volume 21; 2000; 372 pages; Hardcover; ISBN 0-8218-2065-6; List \$49; All AMS members \$39; Order code GSM/21NA

4-Manifolds and Kirby Calculus

Robert E. Gompf, *University of Texas, Austin, and András I. Stipsicz*, *ELTE, TTK, Budapest, Hungary*

The past two decades have brought explosive growth in 4-manifold theory. Many books are currently appearing that approach the topic from viewpoints such as gauge theory or algebraic geometry. This volume, however, offers an exposition from a topological point of view. It bridges the gap to other disciplines and presents classical but important topological techniques that have not previously appeared in the literature.

Part I of the text presents the basics of the theory at the second-year graduate level and offers an overview of current research. Part II is devoted to an exposition of Kirby calculus, or handlebody theory on 4-manifolds. It is both elementary and comprehensive. Part III offers in depth a broad range of topics from current 4-manifold research. Topics include branched coverings and the geography of complex surfaces, elliptic and Lefschetz fibrations, h -cobordisms, symplectic 4-manifolds, and Stein surfaces.

Applications are featured, and there are over 300 illustrations and numerous exercises with solutions in the book.

Volume 20; 1999; 558 pages; Hardcover; ISBN 0-8218-0994-6; List \$65; All AMS members \$52; Order code GSM/20NA

Growth of Algebras and Gelfand-Kirillov Dimension

Revised Edition

Günter R. Krause, *University of Manitoba, Winnipeg, Canada, and Thomas H. Lenagan*, *University of Edinburgh, Scotland*

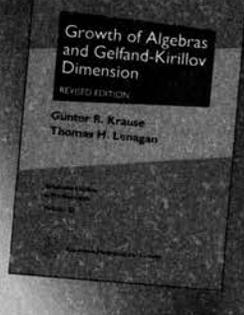
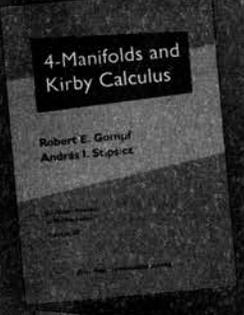
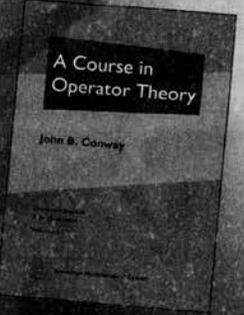
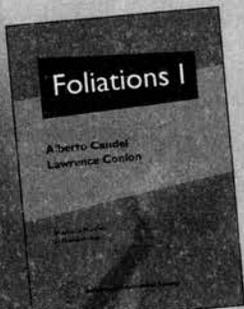
During the two decades that preceded the publication of the first edition of this book, the Gelfand-Kirillov dimension had emerged as a very useful and powerful tool for investigating non-commutative algebras. At that time, the basic ideas and results were scattered throughout various journal articles. The first edition of this book provided a much-needed reliable and coherent single source of information. Since that time, the book has become the standard reference source for researchers.

For this edition, the authors incorporated the original text with only minor modifications. Errors have been corrected, items have been rephrased, and more mathematical expressions have been displayed for the purpose of clarity.

The newly added Chapter 12 provides broad overviews of the new developments that have surfaced in the last few years, with references to the literature for details. The bibliography has been updated and accordingly, almost double the size of the original one.

The faithful revision and contemporary design of this work offers time-honored expertise with modern functionality. A keenly appealing combination. So, whether for the classroom, the well-tended mathematical books collection, or the research desk, this book holds unprecedented relevance.

Volume 22; 2000; 212 pages; Hardcover; ISBN 0-8218-0859-1; List \$39; All AMS members \$31; Order code GSM/22NA



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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. **Information in this issue may be dated. Up-to-date meeting and conference information is available on the World Wide Web at www.ams.org/meetings/.**

Meetings:

1999

October 8-10	Austin, Texas	p. 1332
October 15-17	Charlotte, North Carolina	p. 1333

2000

January 19-22	Washington, DC Annual Meeting	p. 1333
March 11-12	Santa Barbara, California	p. 1334
April 1-2	Lowell, Massachusetts	p. 1335
April 7-9	Notre Dame, Indiana	p. 1335
April 14-16	Lafayette, Louisiana	p. 1336
June 13-16	Odense, Denmark	p. 1336
August 7-12	Los Angeles, California	p. 1337
September 22-24	Toronto, Ontario, Canada	p. 1338
October 21-22	San Francisco, California	p. 1338
November 3-5	New York, New York	p. 1338
November 10-12	Birmingham, Alabama	p. 1339
December 13-17	Hong Kong, People's Republic of China	p. 1339

2001

January 10-13	New Orleans, Louisiana Annual Meeting	p. 1339
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March 16-18	Columbia, South Carolina	p. 1339
March 30-31	Lawrence, Kansas	p. 1339
April 28-29	Hoboken, New Jersey	p. 1340
July 17-20	Lyon, France	p. 1340
October 13-14	Williamstown, MA	p. 1340
2002		
January 6-9	San Diego, California Annual Meeting	p. 1340

Important Information Regarding AMS Meetings

Potential organizers, speakers, and hosts should refer to page 106 in the January 1999 issue of the *Notices* for general information regarding participation in AMS meetings and conferences.

Abstracts

Several options are available for speakers submitting abstracts, including an easy-to-use interactive Web form. No knowledge of LaTeX is necessary to submit an electronic form, although those who use LaTeX or AMS-LaTeX may submit abstracts with such 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 emailed 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 Meetings & Conferences Department, AMS, P.O. Box 6887, Providence, RI 02940. There is a \$20.00 processing fee for each paper abstract. There is no charge for electronic abstracts. 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.

Conferences: (See <http://www.ams.org/meetings/> for the most up-to-date information on these conferences.)

2000:

January 17-18, 2000: Short Course on Quantum Computation: The Grand Mathematical Challenge for the Twenty-First Century and the Millenium; Short Course on Environmental Mathematics; Washington, DC. (See pages 1171-1176, October issue, for details.)

June 11-July 20, 2000: Joint Summer Research Conferences in the Mathematical Sciences, Mt. Holyoke College, South Hadley, MA. (See pages 1325-1330, this issue, for details.)

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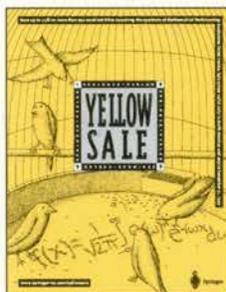
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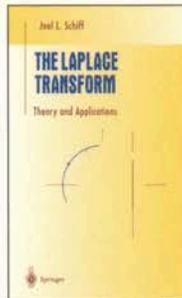
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