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Notices

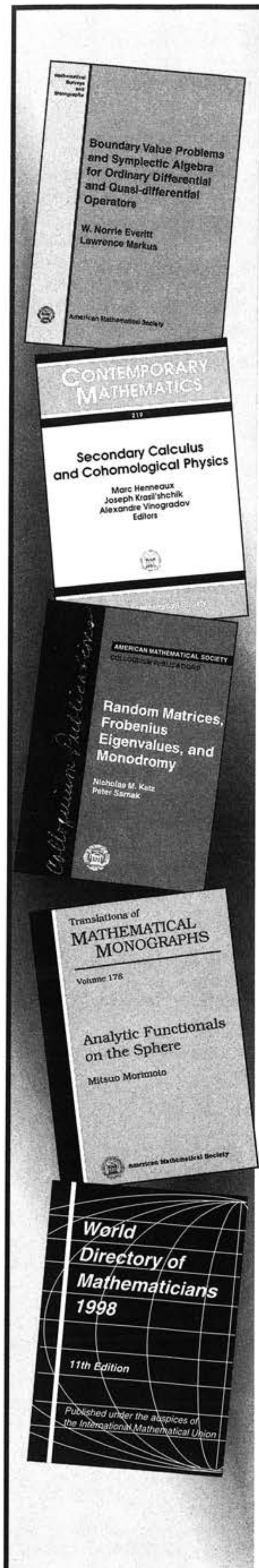
of the American Mathematical Society

September 1998

Volume 45, Number 8

A Collection of Mathematical Stamps *(See page 948)*

AMERICAN MATHEMATICAL SOCIETY



New Titles from the AMS

Boundary Value Problems and Symplectic Algebra for Ordinary Differential and Quasi-differential Operators

W. Norrie Everitt, *University of Birmingham, UK*, and **Lawrence Markus**, *University of Minnesota, Minneapolis*

In the classical theory of self-adjoint boundary value problems for linear ordinary differential operators there is a fundamental, but rather mysterious, interplay between the symmetric (conjugate) bilinear scalar product of the basic Hilbert space and the skew-symmetric boundary form of the associated differential expression. This book presents a new conceptual framework, leading to an effective structured method, for analyzing and classifying all such self-adjoint boundary conditions. The program is carried out by introducing innovative new mathematical structures which relate the Hilbert space to a complex symplectic space. This work offers the first systematic detailed treatment in the literature of these two topics: complex symplectic spaces—their geometry and linear algebra—and quasi-differential operators.

Features:

- Authoritative and systematic exposition of the classical theory for self-adjoint linear ordinary differential operators (including a review of all relevant topics in texts of Naimark, and Dunford and Schwartz).
- Introduction and development of new methods of complex symplectic linear algebra and geometry and of quasi-differential operators, offering the only extensive treatment of these topics in book form.
- New conceptual and structured methods for self-adjoint boundary value problems.
- Extensive and exhaustive tabulations of all existing kinds of self-adjoint boundary conditions for regular and for singular ordinary quasi-differential operators of all orders up through six.

Mathematical Surveys and Monographs; 1998; approximately 200 pages; Hardcover; ISBN 0-8218-1080-4; List $49; Individual member $29; Order code SURV-EVERITTNT89

Secondary Calculus and Cohomological Physics

Marc Henneaux, *Université Libre de Bruxelles, Brussels, Belgium*, **Joseph Krasil'shchik**, *Moscow Institute for Municipal Economy, Russia*, and **Alexandre Vinogradov**, *University of Salerno, Italy*, Editors

This collection of invited lectures (at the Conference on Secondary Calculus and Cohomological Physics, Moscow, 1997) reflects the state-of-the-art in a new branch of mathematics and mathematical physics arising at the intersection of geometry of nonlinear differential equations, quantum field theory, and cohomological algebra. This is the first comprehensive and self-contained book on modern quantum field theory in the context of cohomological methods and the geometry of nonlinear PDEs.

Contemporary Mathematics, Volume 219; 1998; 287 pages; Softcover; ISBN 0-8218-0828-1; List $60; Individual member $36; Order code CONM/219NT89

Random Matrices, Frobenius Eigenvalues, and Monodromy

Nicholas M. Katz and **Peter Sarnak**, *Princeton University, NJ*

The main topic of this book is the deep relation between the spacings between zeros of zeta and L-functions and spacings between eigenvalues of random elements of large compact classical groups. This relation, the Montgomery-Odlyzko law, is shown to hold for wide classes of zeta and L-functions over finite fields. The book draws on, and gives accessible accounts of, many disparate areas of mathematics, from algebraic geometry, moduli spaces, monodromy, equidistribution, and Weil conjectures, to probability theory on the compact classical groups in the limit as their dimension goes to infinity and related techniques from orthogonal polynomials and Fredholm determinants.

Colloquium Publications; 1998; approximately 416 pages; Hardcover; ISBN 0-8218-1017-0; List $69; Individual member $41; Order code COLL-KATZNT89

Analytic Functionals on the Sphere

Mitsuo Morimoto, *International Christian University, Tokyo, Japan*

This book treats spherical harmonic expansion of real analytic functions and hyperfunctions on the sphere. Because a one-dimensional sphere is a circle, the simplest example of the theory is that of Fourier series of periodic functions.

The author first introduces a system of complex neighborhoods of the sphere by means of the Lie norm. He then studies holomorphic functions and analytic functionals on the complex sphere. In the one-dimensional case, this corresponds to the study of holomorphic functions and analytic functionals on the annular set in the complex plane, relying on the Laurent series expansion. In this volume, it is shown that the same idea still works in a higher-dimensional sphere. The Fourier-Borel transformation of analytic functionals on the sphere is also examined; the eigenfunction of the Laplacian can be studied in this way.

Translations of Mathematical Monographs; 1998; approximately 170 pages; Hardcover; ISBN 0-8218-0585-1; List $65; Individual member $39; Order code MMONO-MORIMOTO2NT89

World Directory of Mathematicians 1998

This 11th edition of the *World Directory of Mathematicians 1998* incorporates updates and corrections to the 1994 edition, and includes nearly 30 percent more names. Published by the International Mathematical Union, 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. Listings for the directory are arranged both alphabetically and geographically and are based on information supplied by National Committees for Mathematics (or corresponding organizations). Libraries, mathematics departments, and individuals will find this new edition to be a valuable resource for its extensive coverage of the international mathematical community.

Contents: Preface; Ordering; List of Main Abbreviations; Members of the International Mathematical Union; List of Mathematical Organizations; Alphabetical List of Mathematicians; Geographical List of Mathematicians.

Published by the International Mathematical Union.

1998; 1093 pages; Softcover; List $65; All individuals $40; Order code WRLDIR/11NT89

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AMS
AMERICAN MATHEMATICAL SOCIETY

Table of Contents

September 1998

Feature Articles

Memorial Article

Communications

From the AMS

Departments

Notices

of the American Mathematical Society

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Editorial

Bibliographies in the *Notices*

Readers, particularly those who know ahead of time something about the topic of a *Notices* mathematics article, often wonder why the bibliography for the article seems so short and incomplete. Sometimes they are even driven to write a letter of complaint, pointing out references that they think should have been mentioned in the article.

The answer is that we ask authors to keep their lists of references very short. The intention is that articles in the *Notices* have large target audiences. As such, the articles cannot be written especially for experts, not even for would-be experts. Instead they are written for nonexperts in the field. For nonexperts a short bibliography is more useful than a long one. Such readers are often interested in some sketch of the history, but they are usually not interested in pursuing any detailed historical references. Their main interest in references is likely to be in having some suggestions from the author for further reading. Authors are told these facts early in their dealings with the *Notices*, and most of them are able to include this kind of secondary reference in their bibliographies.

It is desirable also if the authors can find a way of meeting the needs of experts and would-be experts for a longer list of references without having that list appear in the *Notices*. Sometimes such a list appears in some convenient secondary source, and the author can point to that secondary source. Sometimes the author has written or is planning to write a longer, more detailed version of the *Notices* article and can point to that for the longer list of references. Sometimes the author can identify a short list of recent articles, possibly including some of the author's own papers, whose combined bibliographies can allow a person to assemble a long list of references.

But the *Notices* bibliography is still to be short. A long bibliographical list gives an incorrect message that the article is supposed to be comprehensive; it can discourage the reader and can put authors in the wrong frame of mind for the kind of exposition that the *Notices* seeks.

In view of the above policy, letters to the editor should not focus solely on adding references. Of course, letters that contain additional information of significance for nonspecialists are always welcome. Naturally, it is the *Notices* editorial board that has to make the judgment about significance.

—Anthony W. Knapp

In Future Issues

Upcoming Feature Articles

- K. Chandrasekharan, "The Autobiography of Laurent Schwartz"
- Elias M. Stein, "Singular Integrals: The Roles of Calderón and Zygmund"
- Edward Witten, "Magic, Mystery, and Matrix"
- Lai-Sang Young, "Developments in Chaotic Dynamics"

About the Cover

This month's cover image is the second in a series of collages of "mathematicians on stamps". The stamps used in this collage were chosen jointly with Robin Wilson who writes the "Stamp Corner" for the *Mathematics Intelligencer*. Starting in the upper left hand corner and proceeding clockwise, the mathematicians portrayed here are Euler, Russell, Bessel, Hamilton, Abel, Galois, Leibniz, and Gauss, with Poincaré in the center.

—Martin Golubitsky

In My Opinion

Institutes under Review

This year the National Science Foundation (NSF) has begun the process of deciding the future of NSF funding of the U.S. mathematical research institutes created under the auspices of the NSF (e.g., Mathematical Sciences Research Institute (MSRI) and the Institute for Mathematics and its Applications (IMA)). The NSF has called for proposals from other groups of mathematicians to be considered in competition with the existing institutes and has consulted various mathematical groups concerning the community's opinion on more/fewer, similar/different/innovative modes of institutes. My peripheral involvement with this discussion has led me to these thoughts about NSF funding and the role of research institutes.

Rightly so, much attention has been given to the miserable situation of young mathematicians with no secure job. But creating such a secure job is beyond the capabilities of the NSF or new or existing institutes. At best they can increase the number of postdoc positions and "pray" that in years to come the job situation will improve. The need for research support for mathematicians with tenure or tenure-track positions has been somewhat neglected, even though this group makes up the vast majority of active mathematicians. This situation is unique to mathematicians among the scientists supported by the NSF. As a community we have allowed grant support for individuals to erode to a pitiful state. Other sciences have fought this trend and now have a much higher percentage of their active members supported. For example, the top NSF priority of the Federation of American Societies of Experimental Biology is to emphasize the importance of individual investigator grants.

Many established research mathematicians could receive great benefits from a stay of a year or semester at one of the existing research institutes. However, other than sabbatical support from their own universities (which is drying up at a number of universities) the only award senior mathematicians can even apply for is a Guggenheim (and no more than half a dozen of these go to mathematicians each year).There are a few more possibilities for midcareer mathematicians, such as Sloan Fellowships, but such awards are also very limited in number. The research institutes themselves give little or no financial support to many of these very active (often grantless) mathematicians. Some can come on their own money (maybe half salary), but many just cannot afford to do so. These "more senior" mathematicians often carry the major load of work in their department in terms of teaching, committees, administrative chores, etc. A year at an institute allows them to escape and fully immerse themselves in research in a stimulating environment. Furthermore, the institute benefits from the maturity that such mathematicians can bring to their programs, including the vitality of established research and the mentoring of more junior mathematicians. At present there is just no possibility for many very able mathematicians to have such opportunities. This is a loss to the individuals, a loss to creation of research mathematics, and a deterrent to aspiring mathematicians considering their career paths.

My recommendation to the NSF to address this problem is not to fund more institutes, because the expense of creating new infrastructures will inevitably pull money away from the already too-limited pool. The structure of the existing institutes has many positive features and should continue while being open to new ideas and developments that could fruitfully involve both junior and senior mathematicians. If indeed new money can be obtained for institute activities, I would advocate setting up a program of sabbatical-type grants open to mathematicians at all stages of their careers to enable them to pursue their research in a peaceful but stimulating environment. This might be at a "classical" institute or might be at a research group at a university or maybe in an industrial or financial setting. The more flexible and broadly based the program, the more successful it is likely to be. I believe that giving mathematicians the chance to be intensively involved in their research for periods of three months or longer is the most valuable aspect of a mathematical research institute.

—Susan Friedlander
Associate Editor

Letters to the Editor

Of Frogs and Men

Mary Beth Ruskai fails to point out an important property of mathematical modelling in her May 1998 opinion column, "The Decline of Science". It, in any form, is the only way to calculate the consequences of actions and events. To optimize our outcomes, one must inevitably compare the state of the world as it is to all the states it possibly could be: i.e., to events that exist only in the abstract. Therefore, comparison of events is, by definition, an abstract process. Experimentation has nothing to do with this.

As an example, Ruskai mentioned the issue of what's to be done about dissection. The following questions could be formulated more precisely in terms of game theory and fair-division problems. Of course, I can't do that here in the "Commentary" section.

1) Maximize justice. Do all the billions of people who preach about personal responsibility deserve to reap whatever health benefits they think might come from dissecting frogs? No, especially non-vegetarians. They should take responsibility for their

own health. It is not the frog's responsibility.

2) Minimize number of frogs being dissected and maximize humans' knowledge about what frogs look like inside. After animal dissectors cut open the first frog to find out what's inside, and report on it, videotape it, or make a computer model of it, there is no need thereafter to deliberately breed millions more for dissection. Ruskai fails to ask whether we even need to know the notion of external world, objective reality, universality, or truth about organ positions of frogs.

If scientists had made the sorts of calculations that I have suggested above before breeding millions of animals and pursuing dissection, then millions would not be forced to suffer in laboratories each year, and millions of our tax dollars would have been saved. That is what mathematics is meant to do.

—John M. Nahay
Rutgers University

(Received April 27, 1998)

Science Funding and Granting Agencies

Though I, in principle, agree with Arthur Jaffe that "investigator-initiated projects" lie at the heart of our work (*Notices*, May 1998, p. 564), I remain highly skeptical that doubling (tripling, quadrupling, etc.) of science funding will bring much good unless it is accompanied by a fundamental overhaul of the grant distribution system itself.

Operations of major research-granting agencies, such as the National Science Foundation in the USA or the Natural Sciences and Engineering Research Council in Canada, are shrouded by secrecy (R. Gordon, *Grant agencies versus the search for truth*, Accountability in Research **2** (1992), 297–301). Claims that the process is based on objective peer review are of little merit because for all practical purposes it is impossible to verify that all applicants are treated equally and fairly. Thus, instead of the alleged impartiality, the system often degenerates to a notorious "old boys' network" whose members primarily care about arranging lavish funding for themselves. Naturally, such a system fiercely resists any genuine public accountability.

In place of the overblown and bureaucracy-loaded funding agencies, we need a much simpler funding mechanism which will fund many more researchers on a more equitable basis, even if it means lower average grants (e.g., A. A. Berezin and R. Gordon, *Smaller grants for more Canadians?*, Nature **386** (20 March 1997), 212). Only clear incompetence should be a sufficient reason to deny any operating funds. Without such a reform new research dollars (if obtained) are almost certainly largely adding more fat to the already overbuilt empires of the grantsmanship establishment instead of fostering true innovation and risk taking.

—Alexander A. Berezin
McMaster University, Canada

(Received May 24, 1998)

Analyzing the TIMSS 12th-Grade Exam

The reported results of our American twelfth-graders on the mathematics and physics portions of the Third International Mathematics and Science Study (TIMSS) are dismal, but even more depressing was the performance of our advanced students (honors and AP calculus) on the Advanced Mathematics Test. Of sixteen countries, all European, we were near the bottom in the three areas tested: numbers and equations, calculus, and geometry. If these students are our best, what does it say about our training of the rest?

I recently received an informal report from the Educational Testing Service (ETS) further analyzing the 65 questions on the Advanced Mathematics Test, and it is even more depressing. Some findings:

1. Only 13 of the 65 questions measure content from calculus, and these are at a basic level of the Advanced Placement Calculus AB course, not the more advanced BC course. The questions measure a minimal part of a basic first-semester course.

2. The remaining 52 questions measure topics from geometry, second-year algebra, and precalculus, which would include trigonometry, elementary functions, and analytical geometry.

3. It would be expected that our good Calculus AB or Calculus BC students would do well on the calculus portion of the test.

What this indicates is that our best students have a very poor preparation in the mathematics needed to do calculus. Some examples:

- Only 68% of U.S. advanced mathematics students could answer correctly a multiple choice question (five answers given) asking for the solution set of the inequality

$$5X + 5/3 \leq -2X - 2/3.$$

- Only 47% of U.S. advanced mathematics students could identify a triangle with vertices (1,2), (4,6), and (-4,12) as a right triangle with right angle at (4,6)—multiple-choice question (four answers given).

If you wonder about the gaps you encounter in your college or university calculus students' mathematics background, wonder no more.

A possible reason for our students' failing performance could be attributed to the prestige that AP has acquired. Schools get extra gold stars from their district or state for offering AP courses, there is a current clamor in some states for the creation of an AP diploma for students who have successfully passed a certain number of AP courses or tests, and colleges and universities have long given credit for high grades on AP tests. In the rush for status, are high schools pushing students into AP calculus courses before they have the necessary solid background in algebra and geometry? Our country's abysmal results strongly support an answer of "Yes".

The mathematics departments of research universities long ago gave up serious involvement in K–12 matters, including the training of teachers. I think that decision has come back to haunt us.

—David A. Sanchez
Texas A&M University

(Received May 6, 1998)

Chowla-Selberg Formula

In the May 1998 issue of the *Notices*, on page 596, Ayoub, Huard, and Williams say:

"In 1967 Selberg and Chowla discovered ..." and proceed to state the Chowla-Selberg formula. However, the result was first announced by Chowla and Selberg in *On Epstein's zeta function. I*, Proc. Nat. Acad. Sci. USA **35** (1949), 371–374. Their 1967 publication of a proof was the second proof: K. Ramachandra in *Some applications of Kronecker's limit formulas*, Ann. Math. (2) **80** (1964), 104–148, preceded them with essentially the same proof. This proof is given its most elegant form in chapter IX of A. Weil's *Elliptic Functions according to Eisenstein and Kronecker*, Springer, 1976.

From the article by Ayoub, Huard, and Williams it is perhaps not apparent why the Chowla-Selberg formula is so important. In 1978 B. H. Gross in *On the periods of abelian integrals and a formula of Chowla and Selberg*, Inv. Math. **45** (1978), 193–211, one of the most beautiful papers in modern mathematics, gave a new proof of the Chowla-Selberg formula.

Briefly put, Gross finds a family of abelian varieties with complex multiplication by the imaginary quadratic field in the formula. The left side of the formula is a period of one of these abelian varieties, and he shows that there exists a constant period family of abelian varieties, one of which is a factor of the Fermat curve Jacobian, where an explicit calculation gives the gamma function terms on the right side of the formula.

Gross's ideas helped inspire Deligne's work on periods of L functions and his later work on absolute Hodge cycles. See P. Deligne, *Valeurs de fonctions L et periodes d'integrales*, PSPM **33** (1979), 313–346. This is perhaps the true meaning of the Chowla-Selberg formula.

—Oisin McGuinness
New York, NY

(Received May 25, 1998)

Huard and Williams Reply

The Chowla-Selberg formula given in our article on p. 596 was first given by Chowla and Selberg in this form in their 1967 paper (formula (2), p. 110) but not in their 1949 paper, which was simply an announcement of results. However, in the 1967 paper it is asserted that the paper was written in the spring of 1949. Therefore, it would have been more accurate for us to have stated that the formula was discovered in 1949 but first published by Chowla and Selberg in 1967. It was not our intention in the article to give a detailed history of each result quoted, as some of them have complicated histories: for example, the Bruck-Chowla-Ryser theorem and the Chowla-Selberg formula. Moreover, we also did not discuss in any detail any further developments inspired by Chowla's results.

—James G. Huard
Canisius College
—Kenneth S. Williams
Carleton University

(Received June 4, 1998)

Russo's Speculative Interpretations

I have not yet seen L. Russo's book *La Rivoluzione Dimenticata*, which was so enthusiastically reviewed in the May *Notices*. But I have read the earlier presentation (in *Vistas in Astronomy*) of its startling claim that Hipparchus had a heliocentric dynamical gravitational theory of planetary motion. On this point, at least, I fear that the author's enthusiasm for his ideas has led him to rely on quite speculative interpretations of isolated bits in the texts he cites.

Let me illustrate this with Russo's interpretations of two bits from the few pages Vitruvius devotes to astronomy in his work on architecture. First, he says that "Vitruvius' exposition of the motions of Mercury and Venus is explicitly heliocentric." The words he cites do indeed say that the the paths of Mercury and Venus "circle the rays of the Sun as a sort of center." But Vitruvius immediately goes on to say that this is particularly clear for Venus, because it is prominent as the Evening Star when it follows the Sun and prominent as the Morning Star when it precedes the Sun. Obviously Vitruvius is describing the observed positions of Venus, not some theory of how they arise. Any possible doubt of this is dispelled when we read (two paragraphs later) that Venus completes its circuit "on the 485th day"; that must refer to the observed position on the ecliptic.

Second, Vitruvius says that the outer planets begin retrograde motion when they are in the trigon of the Sun ["cum in trigono fuerint, quod is inierit, ...regressus facientes morantur"]. A bit later he asks why this happens in the fifth sign rather than in the second or third signs, which are closer to the Sun. His suggestion is that the force of the Sun runs along a shape like the equal sides of a trigon. Russo decides that "fifth sign" here must mean the fifth point in some geometric diagram, even though it means "zodiac sign" in all the surrounding sentences. He also decides that "equal sides of the trigon" refers to isosceles triangles, despite the fact that "trigon" in this context almost always refers to an equilateral triangle formed by three points on the ecliptic (the second of which thus lies in the fifth sign from the first). He goes on to spend several pages inventing a diagram that resembles something in Newton, though he admits that in his diagram the second and third "signs" are not actually closer to the Sun (he calls this "a natural consequence of Vitruvius' misunderstanding"). Russo's treatment here has obviously lost all contact with the basic observational fact that the outer planets begin retrograde motion when they are roughly 120 degrees away from the Sun.

—William C. Waterhouse
Pennsylvania State University

(Received May 28, 1998)

Symplectic Structures— A New Approach to Geometry

Dusa McDuff

Introduction

Symplectic geometry is the geometry of a closed skew-symmetric form. It turns out to be very different from the Riemannian geometry with which we are familiar. One important difference is that, although all its concepts are initially expressed in the smooth category (for example, in terms of differential forms), in some intrinsic way they do not involve derivatives. Thus symplectic geometry is essentially topological in nature. Indeed, one often talks about symplectic topology. Another important feature is that it is a 2-dimensional geometry that measures the *area* of complex curves instead of the *length* of real curves.

The classical geometry over the complex numbers is Kähler geometry, the geometry of a complex manifold with a compatible Riemannian metric. This is a very rich geometry with a detailed local structure. In contrast, symplectic geometry is flabby, though as should become clear, not completely flabby—there are interesting elements of global structure. The comparison can be roughly stated as follows:

$$\left\{\begin{matrix}\text{Kähler}\\ \text{rich detail}\end{matrix}\right\} \quad \text{versus} \quad \left\{\begin{matrix}\text{symplectic}\\ \text{flabby, global}\end{matrix}\right\}.$$

In this article I will try to give an idea of symplectic geometry by comparing it with Kähler geometry. I will do this in three areas:

- Embeddings of round balls
- Structure of 4-manifolds
- Properties of automorphisms

Basic Notions

Let M^{2n} be a smooth *closed* manifold, that is, a compact smooth manifold without boundary. A symplectic structure ω on M is a closed ($d\omega = 0$), nondegenerate ($\omega^n = \omega \wedge \cdots \wedge \omega \neq 0$) smooth 2-form. The nondegeneracy condition is equivalent to the fact that ω induces an isomorphism

$$\begin{array}{ccc} T_xM & \xrightarrow{\cong} & T_x^*M \\ X & \mapsto & \iota_X\omega = \omega(X,\cdot) \\ \text{vector fields} & & \text{1-forms.} \end{array}$$

Basic Example. The form $\omega_0 = dx_1 \wedge dy_1 + \cdots + dx_n \wedge dy_n$ on Euclidean space $\mathbf{R}^{2n}$. In this case, the above isomorphism is given explicitly by the formulae

$$\begin{array}{ccc} X = \frac{\partial}{\partial x_j} & \mapsto & \iota_X\omega_0 = dy_j \\ \frac{\partial}{\partial y_j} & \mapsto & -dx_j. \end{array}$$

Thus, if we identify both the tangent space $T_x\mathbf{R}^{2n}$ and the cotangent space $T_x^*\mathbf{R}^{2n}$ with $\mathbf{R}^{2n}$ in the usual way, viz:

$$\frac{\partial}{\partial x_j} \equiv e_{2j-1} \equiv dx_j, \quad \frac{\partial}{\partial y_j} \equiv e_{2j} \equiv dy_j,$$

this isomorphism is a rotation through a quarter turn.

Every symplectic structure ω determines a volume form $\omega^n/n!$, that is, a nonvanishing top-di-

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mensional form that integrates to give a volume. In two dimensions, of course, ω is simply an area form. In higher dimensions it was suspected long ago that a symplectic structure is much richer than a volume form, but there was no hard evidence of this until the early 1980s, with Eliashberg's work on symplectic rigidity, the Conley–Zehnder proof of the Arnold conjecture for the torus, and Gromov's proof of the nonsqueezing theorem. We will discuss some of this below. For a much more detailed treatment of these questions and many further references the reader can consult [MS].

Here is the first main theorem on symplectic structures.

Theorem 1 [Darboux]. Every symplectic form is locally diffeomorphic to the above form ω_0.

Thus locally all symplectic forms are the same. In other words, all symplectic invariants are global in nature. It has turned out that, apart from obvious invariants such as the de Rham cohomology class $[\omega] \in H^2(M, \mathbf{R})$ of the symplectic form, it is hard to get one's hands on these global invariants, which is why symplectic geometry has taken so long to be developed. Another important fact that goes along with the local uniqueness of symplectic structures (one cannot exactly call it a consequence) is that a symplectic structure has a rich group of automorphisms. We discuss this further below.

Symplectic structures have two main aspects: the geometric and the dynamic. We start with the geometric, the connection with Riemannian and Kähler geometry.

The Geometric Aspect

There is a contractible family of Riemannian metrics on M associated to ω which are constructed via ω-compatible almost complex structures J. Here J is an automorphism

$$J : TM \to TM, \qquad J^2 = -\mathrm{Id}$$

that turns TM into a complex vector bundle. The compatibility conditions are:

$$\omega(x, y) = \omega(Jx, Jy),$$
$$\text{and } \omega(x, Jx) > 0 \quad \text{for all } x \neq 0.$$

They imply that the bilinear form

$$g_J : \quad g_J(x, y) = \omega(x, Jy)$$

is a Riemannian metric. For each ω the set of such J is nonempty and contractible.

Examples

• The standard almost complex structure J_0 on $\mathbf{R}^{2n}$ given by

$$J_0\left(\frac{\partial}{\partial x_j}\right) = \frac{\partial}{\partial y_j}, \quad J_0\left(\frac{\partial}{\partial y_j}\right) = -\frac{\partial}{\partial x_j}$$

is compatible with ω_0.

• The almost complex structure J induced by the complex structure on a Kähler manifold.

There is an important difference between Kähler manifolds and symplectic manifolds. A Kähler manifold M has a fixed complex structure built into its points; M is made from pieces of complex Euclidean space $\mathbf{C}^n$ that are patched by holomorphic maps. One adds a metric g to this complex manifold and then defines the symplectic form ω_J by setting

$$\omega_J(x, y) = g(Jx, y).$$

(For this to work, g must be compatible with J in a rather strong sense: J has to be parallel with respect to the Levi-Civita connection in order for ω_J to be closed. Not all complex manifolds can be given a Kähler structure.)

On the other hand, a symplectic manifold *first* has the form ω, and *then* there is a family of J imposed at the tangent space level (not on the points). Note that the only intrinsic measurements that one can make on a symplectic manifold are 2-dimensional; i.e., if S is a little piece of 2-dimensional surface, then one can measure

$$\int_S \omega = \mathrm{area}_\omega\, S.$$

It was the great insight of Gromov to realize that in symplectic geometry the correct replacement for geodesics are *J-holomorphic curves.* These are maps $u : (\Sigma, j) \to (M, J)$ of a Riemann surface Σ into M that satisfy the generalized Cauchy–Riemann equation:

$$du \circ j = J \circ du.$$

(Here j is the complex structure on the Riemann surface.) In fact, the image $u(\Sigma)$ is a minimal surface in M when it is given the metric g_J, so the analogy with geodesics is not far-fetched. There is a very nice theory of these curves—one application is mentioned below—and they occur as an essential ingredient in many symplectic constructions, for example, in Floer theory.

In his 1998 Gibbs lecture Witten discussed two "deformations" of classical physics, one to quantum theory and the other to string theory. I would like to propose that in some sense the passage from Riemannian (or Kähler) to symplectic geometry is analogous to these deformations. Symplectic geometry was of course first explored because of the fact that the classical equations of motion can be put in Hamiltonian form and that symplectic properties can be exploited to solve these equations in certain important cases. Therefore, because symplectic structures are built into the classical theory, they are very important in the new deformed theories. In "classical" symplectic geometry very little was understood about global topological

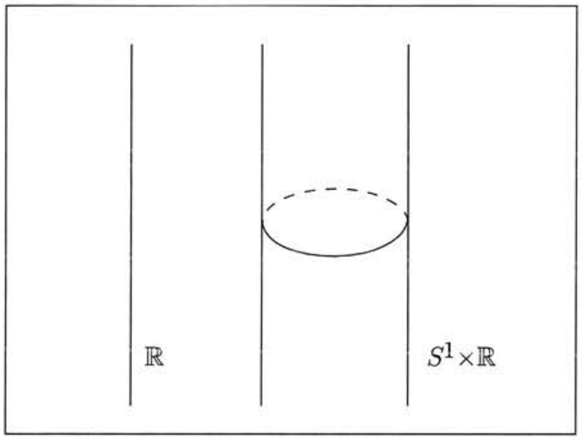

Figure 1. The classical time line is the real line R. This is complexified in string theory to $S^1 \times \mathbf{R}$.

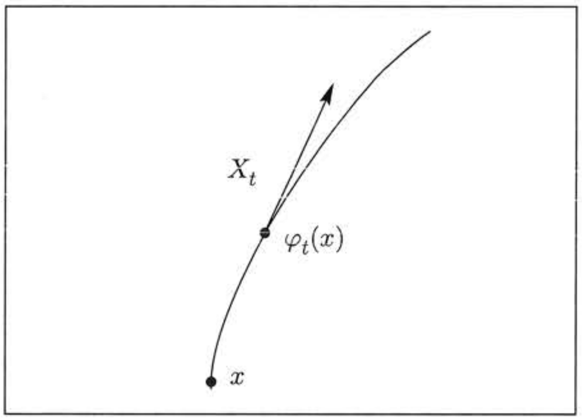

Figure 2. The path ϕ_t has flow lines $\{\phi_t(x)\}_{t\in[0,1]}$ tangent to the vector field X_t at $\phi_t(x)$. It is Hamiltonian if $\iota(X_t)\omega = dH_t$ for all t.

properties of symplectomorphisms. Now, in both of Witten's deformations, new structures are being found that relate in some way to the new global symplectic geometry that is concurrently being developed.

I shall not say anything here about the problem of quantization (though recently Fedosov and Kontsevich have achieved great success with this question), but now briefly discuss the interconnection with string theory. Witten pointed out that one basic consequence of replacing the points that make up the configuration spaces of classical physics by strings (which in the closed case are just circles) is that the time line of a point—usually identified with the real line **R**—is replaced by the time line of a string, which is a cylinder $S^1 \times \mathbf{R}$; see Figure 1. This cylinder can be identified with the quotient $\mathbf{C}/\mathbf{Z}$ of the complex plane **C** by a translation and so has a natural complex structure. Thus the passage to string theory involves replacing **R** by **C** (or $\mathbf{C}/\mathbf{Z}$), and so going from a geometry in which 1-dimensional objects such as geodesics are of paramount importance to one in which 2-dimensional objects such as J-holomorphic curves are the crucial elements. It is no accident that some of the new ideas that have come into mathematics from physics (such as quantum cohomology and mirror symmetry) involve J-holomorphic curves in an essential way.

The Dynamic Aspect

As mentioned above, the nondegeneracy of the symplectic form ω is equivalent to the condition that there is a bijective correspondence

$$\begin{array}{ccc} T_xM & \xrightarrow{\cong} & T_x^*M \\ X & \mapsto & \iota_X\omega = \omega(X,\cdot) \\ \text{vector fields} & & \text{1-forms.} \end{array}$$

The next important point is that the closedness of ω implies that the *symplectic* vector fields correspond precisely to the *closed* 1-forms. A vector field X is said to be *symplectic* if its flow ϕ_t^X consists of symplectomorphisms, that is, if

$$(\phi_t^X)^*\omega = \omega, \quad \text{for all } t.$$

Because

$$\frac{d}{dt}(\phi_t^X)^*\omega = (\phi_t^X)^*(\mathcal{L}_X\omega),$$

X is symplectic if and only if $\mathcal{L}_X\omega = 0$ where $\mathcal{L}_X$ denotes the Lie derivative. The calculation

$$\mathcal{L}_X\omega = \iota_X d\omega + d(\iota_X\omega) = d(\iota_X\omega)$$

shows that X is symplectic exactly when the corresponding 1-form $\alpha = \iota_X\omega$ is closed. Since every manifold supports many closed 1-forms, the group $\mathrm{Symp}(M,\omega)$ of all symplectomorphisms is infinite-dimensional. It has a normal subgroup $\mathrm{Ham}(M,\omega)$ that corresponds to the exact 1-forms $\alpha = dH$. By definition, $\phi \in \mathrm{Ham}(M,\omega)$ if it is the endpoint of a path $\phi_t, t \in [0,1]$, starting at the identity $\phi_0 = \mathrm{id}$ that is tangent to a family of vector fields X_t for which $\iota(X_t)\omega$ is exact for all t; see Figure 2. In this case there is a time-dependent function $H_t : M \to \mathbf{R}$ (called the *generating Hamiltonian*) such that $\iota(X_t)\omega = dH_t$ for all t.

When the first Betti number $b_1 = \dim H^1(M,\mathbf{R})$ of M vanishes, $\mathrm{Ham}(M,\omega)$ is simply the identity component $\mathrm{Symp}_0(M,\omega)$ of the symplectomorphism group. In general, there is a short exact sequence

$$0 \to \mathrm{Ham}(M,\omega) \to \mathrm{Symp}_0(M,\omega) \to H^1(M,\mathbf{R})/\Gamma_\omega \to 0,$$

where the flux group Γ_ω is a subgroup of $H^1(M,\mathbf{R})$.

Example. In the case of the torus T^2 with a symplectic form $dx \wedge dy$ of total area 1, the group Γ_ω is $H^1(M,\mathbf{Z})$. The family of rotations $R_t : (x,y) \mapsto (x+t, y)$ of the torus T^2 consists of symplectomorphisms that are not Hamiltonian. Its image under the homomorphism to $H^1(M,\mathbf{R})/\Gamma_\omega$ is the family of 1-forms $t[dy]$.

It has recently been shown [LMP 1997] that Γ_ω has rank at most b_1. One interesting question here is whether the flux group Γ_ω is always discrete. This is equivalent to asking whether the group $\mathrm{Ham}(M, \omega)$ is closed in the C^1-topology, that is, in the topology of uniform convergence of the first derivative. The group is discrete if

- the symplectic class $[\omega] \in H^2(M, \mathbf{R})$ is rational or
- if the map $\wedge[\omega]^{n-1} : H^1(M, \mathbf{R}) \to H^{2n-1}(M, \mathbf{R})$ is an isomorphism.

Because of the hard Lefschetz theorem, this last case includes all Kähler manifolds.

The group $\mathrm{Symp}(M, \omega)$ is a large and interesting group that contains a great deal of information. For example, Banyaga has shown that its structure as an abstract group uniquely determines the symplectic manifold (M, ω). In other words, if the groups $\mathrm{Symp}(M, \omega)$ and $\mathrm{Symp}(N, \sigma)$ are isomorphic as discrete groups, then there is a diffeomorphism $\phi : M \to N$ such that $\phi^*\sigma = \omega$. We will describe some other results on the group of symplectomorphisms later. Meanwhile, here is a recent result that shows that $\mathrm{Symp}(M, \omega)$ is significantly different from the group of all diffeomorphisms.

Proposition 2 [Seidel]. The natural map $\pi_0(\mathrm{Symp}(M, \omega)) \to \pi_0(\mathrm{Diff}(M))$ is not injective in many cases.

For example, the natural map is not injective if M is a $K3$ surface. To prove this, Seidel constructs a symplectic Dehn twist τ near a Lagrangian 2-sphere whose square is diffeotopic to the identity but not symplectically isotopic to the identity. There are other examples where the map $\pi_k(\mathrm{Symp}(M, \omega)) \to \pi_k(\mathrm{Diff}(M))$ is not onto (for example, when $M = S^2 \times S^2$).

Symplectic Embeddings of Balls

Gromov's Nonsqueezing Theorem

Consider a ball $B^{2n}(r)$ of radius r and a cylinder $Z(\lambda) = B^2(\lambda) \times \mathbf{R}^{2n-2}$ of radius λ in standard Euclidean space $(\mathbf{R}^{2n}, \omega)$. Here it is important that the the two coordinates (x_1, y_1) that span the disc $B^2(\lambda)$ are "symplectic", that is, $\omega_0(\frac{\partial}{\partial x_1}, \frac{\partial}{\partial y_1}) \neq 0$. The question is: when is there a symplectic embedding ϕ of the ball into the cylinder? Its answer is provided by Gromov's celebrated nonsqueezing theorem; see Figure 3.

Theorem 3 [Gromov]. There is a symplectic embedding of the ball of radius r into the cylinder of radius λ if and only if $r \leq \lambda$.

The idea of the proof is very roughly the following. For each ω_0-compatible almost complex structure J the cylinder has a slicing by J-holomorphic discs of area $\pi\lambda^2$. If the ball is embedded in the cylinder, this slicing will induce a slicing of the ball; but if J is suitably compatible with

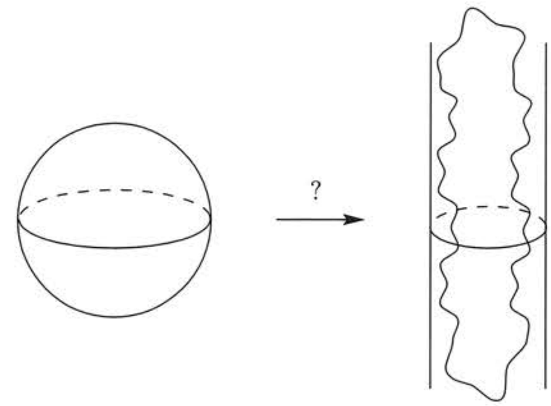

Figure 3. Trying to squeeze a ball into a thin cylinder.

the embedding, this slicing of the ball has to have some slices of ω_0-area $\geq \pi r^2$. Hence we must have $r \leq \lambda$.

This theorem underlies *all* of symplectic topology. As the following result shows, the nonsqueezing property characterizes symplectomorphisms. Darboux's theorem implies that if we want to find a criterion that characterizes general symplectomorphisms, it suffices to do this for symplectomorphisms of standard Euclidean space $(\mathbf{R}^{2n}, \omega_0)$. Define a *symplectic ball (or cylinder)* of radius r in $(\mathbf{R}^{2n}, \omega_0)$ to be the image of the standard ball (or cylinder) of radius r by a symplectic embedding. We will say that a local diffeomorphism ϕ has the nonsqueezing property if there is no symplectic ball B whose image $\phi(B)$ is contained in a symplectic cylinder with radius strictly less than that of B.

Theorem 4 [Eliashberg, Ekeland-Hofer]. If ϕ is a local diffeomorphism of $\mathbf{R}^{2n}$ such that both ϕ and its inverse ϕ^{-1} have the nonsqueezing property, then ϕ is either symplectic or antisymplectic, that is,

$$\phi^*(\omega_0) = \pm\omega_0.$$

Since the nonsqueezing condition involves only the images $\phi(B)$ of balls B, it is easy to see that it is satisfied by any uniform limit of symplectomorphisms. Hence we find:

Corollary 5 [Symplectic rigidity]. The group $\mathrm{Symp}(M, \omega)$ is closed in the group $\mathrm{Diff}(M)$ in the topology of uniform convergence on compact sets.

This is what I meant by saying in the first paragraph that symplectic geometry is intrinsically topological in nature. Not much is yet understood about symplectic geometry at this level.

Symplectic Packing

Suppose we want to embed k disjoint equal balls symplectically into a compact symplectic mani-

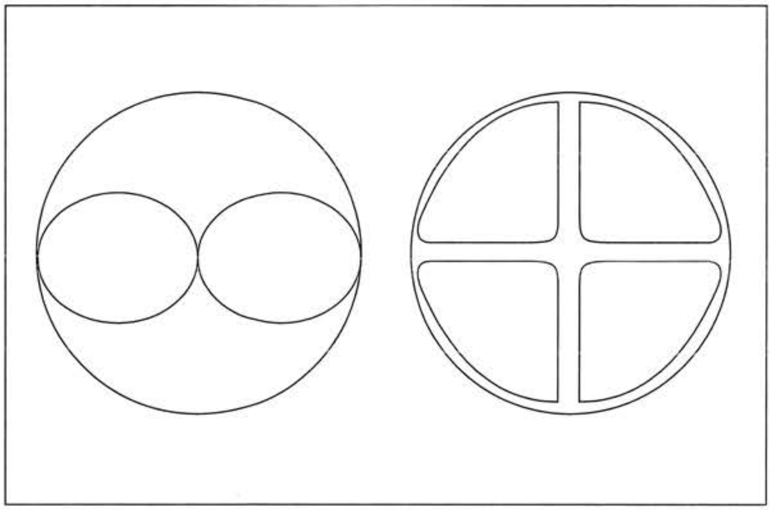

Figure 4. A 4-dimensional ball has a full packing by 4 balls, but not by 2.

fold (M, ω). What restrictions are there? One way to approach this problem is to define

$$\nu_k(M, m) = \sup \frac{\text{Vol}\,(k \text{ disj. equal balls in } M)}{\text{Vol}\,(M, \frac{\omega}{n!})}.$$

We say that (M, ω) has a *full packing* if $\nu_k(M, \omega) = 1$; otherwise, there are *packing obstructions.* See Figure 4.

One example that has been fully worked out is the case when M is the complex projective plane $\mathbf{C}P^2$ with the standard Fubini–Study metric. (Equivalently one could take M to be the unit ball $B^{2n}(1)$ in $\mathbf{R}^{2n}$.) In this case, results of Gromov, McDuff-Polterovich, and Biran show that $\nu_k(M, \omega)$ is as follows:

k	=	1	2	3	4	5	6	7	8	≥9
$\nu_k(M, \omega)$	=	1	$\frac{1}{2}$	$\frac{3}{4}$	1	$\frac{20}{25}$	$\frac{24}{25}$	$\frac{63}{64}$	$\frac{288}{289}$	1

The result that $\nu_k(\mathbf{C}P^2) = 1$ for all $k \geq 9$ is due to Biran [B].

Biran has also shown that for *every* symplectic 4-manifold there is an integer N such that

$$\nu_k(M, \omega) = 1 \quad \text{for} \quad k \geq N.$$

He proves this by showing that for all $\varepsilon > 0$ there is a subset V_ε of M such that $M - V_\varepsilon$ can be identified with a disc bundle over a Riemann surface with a standard symplectic form. Then he shows how to fill this disc bundle with balls. The existence of this disc bundle uses the deep work of Donaldson mentioned below, as well as an "inflation" technique of Lalonde-McDuff that allows one to change the symplectic form so that its volume is concentrated near the submanifold.

Thus symplectic packing is basically flabby: with enough balls one can maneuver them into shapes that fill the whole space. It is not known whether the analogous problem in the Kähler category is similarly flabby. Here one considers embeddings that are suitably compatible with both the holomorphic and the symplectic structure on M so that there is a corresponding Kähler form on the blow-up.[1] It is not hard to show that the above calculations for $\nu_k(\mathbf{C}P^2)$ apply also to Kähler embeddings if $k \leq 9$. Also, one can show that the Kähler equivalent $\nu_k^{\mathrm{K}}(\mathbf{C}P^2)$ of $\nu_k(\mathbf{C}P^2)$ takes the value 1 whenever $k = d^2$. However, it is unknown if $\nu_k^{\mathrm{K}}(\mathbf{C}P^2) = 1$ for all $k > 9$. This question is related to difficult conjectures about Seshadri constants and about the structure of holomorphic curves on a generic blow-up of $\mathbf{C}P^2$. Biran has recently obtained some interesting lower bounds for the numbers $\nu_k^{\mathrm{K}}(\mathbf{C}P^2)$ that involve continued fraction expansions. However, it is as yet unknown whether the appearance of these numbers is an artifact of his construction methods or whether they reflect something intrinsic to the problem.

Symplectic 4-Manifolds

In this section we discuss some recent results on the existence of symplectic and Kähler structures on closed and connected 4-manifolds. This question is still not fully understood. The topological properties common to all manifolds with a particular geometric structure can be thought of as a large-scale global expression of this structure. Thus Donaldson's theorem that every symplectic 4-manifold has a blow-up that supports a generalized symplectic fibration is an illustration of how important fibered structures are in symplectic geometry. Fibered structures also arise when one is trying to construct the most economical embeddings of balls.

We begin with some general remarks that contrast symplectic with Kähler 4-manifolds.

•It has been known for a long time that there are non-Kähler symplectic manifolds. The first example was known to Kodaira and later rediscovered by Thurston. Here M is the nilmanifold obtained by quotienting out $\mathbf{R}^4$ by the discrete group Γ that is generated by unit translations in the first three directions together with the map

$$(x, y, s, t) \mapsto (x, x + y, s, t + 1).$$

The symplectic form $dx \wedge dy + ds \wedge dt$ descends to a form ω on M. Note that M can also be considered as made from the manifold $T^2 \times S^1 \times [0, 1]$ by identifying the point $(x, y, s, 0)$ with $(x, x + y, s, 1)$. Therefore the projection

[1] *One way of stating the conditions is as follows: one considers embeddings of a Kähler ball $(B^{2n}(r), J_0, \omega')$ into M that are simultaneously symplectic and holomorphic, where J_0 is the usual complex structure on the unit ball and ω' is a Kähler form that integrates to πr^2 over every flat J_0-holomorphic 2-disc through the origin and that restricts on the boundary to a form that is pulled back from complex projective space via the Hopf map $S^{2n-1} \to \mathbf{C}P^{n-1}$.*

$(x, y, s, t) \mapsto (s, t)$ induces a map from M onto the torus T^2 whose fiber is also a torus. The monodromy (or attaching map) of this fibration has the formula $(x, y) \mapsto (x + y, y)$. This is an area-preserving and hence symplectic map but is not holomorphic. Therefore M has no obvious Kähler structure. In fact, it is easy to see that the first cohomology group $H^1(M, \mathbf{R})$ has dimension 3. This implies that M has no Kähler structure at all because of the well-known fact that the odd Betti numbers $\dim H^{2k+1}(M, \mathbf{R})$ of every Kähler manifold must be even. Indeed, $\dim H^{2k+1}$ can be written as a sum $\sum_{p+q=2k+1} \dim H^{p,q}$, which is even when $p + q$ is odd since $\dim H^{p,q} = \dim H^{q,p}$.

- Gompf showed in 1994 that for any finitely presented group G there is a closed symplectic 4-manifold (M^4, ω) with fundamental group G. On the other hand, there are restrictions on $\pi_1(M)$ if M is Kähler. For example, the remarks above imply that if M has dimension 4, we need the rank of $H_1(M) = G/[G, G]$ to be even. (There are other more subtle restrictions as well, which are at present not very well understood.)

- Gompf–Mrowka (1993) also constructed simply connected but non-Kähler symplectic 4-manifolds using Donaldson theory. Nevertheless, some results seem to imply that symplectic 4-manifolds are very similar to Kähler ones.

- Taubes's structure theorem (1995–96) for the Seiberg-Witten invariants of symplectic 4-manifolds shows that some important features of the Kähler case persist in the symplectic case. Using this result, Szabo and then Fintushel–Stern constructed simply connected nonsymplectic 4-manifolds with nonzero Seiberg–Witten invariants. It follows that the class of symplectic 4-manifolds is strictly larger than the class of 4-manifolds with Kähler structure and strictly smaller than the class of 4-manifolds with nonzero Seiberg-Witten invariants. It is still not understood exactly what the class of symplectic 4-manifolds is. However, as the next result shows, symplectic 4-manifolds can be considered as a kind of flabby deformation of Kähler surfaces.

- It has been known for a long time that algebraic manifolds have blowups that support Lefschetz fibrations. Since the complex structure on every Kähler surface can be slightly deformed to be algebraic, it follows that every smooth 4-manifold that has a Kähler structure also supports a Lefschetz fibration.

Donaldson has recently (1997) shown that every symplectic 4-manifold has a blowup that has the structure of a symplectic Lefschetz fibration. Philosophically this is akin to showing that every 3-manifold has a Heegaard splitting: in other words, it is a general structure theorem that as yet does not make clear all topological properties of these manifolds. In view of the importance of this result we will spend some time explaining it.

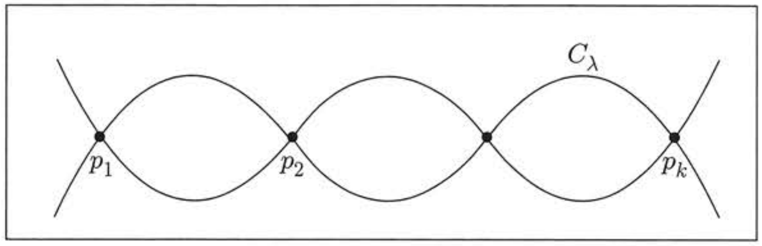

Figure 5. The pencil of subvarieties C_λ. The axis A of the pencil intersects the surface M in the points $p_1, \ldots, p_k$.

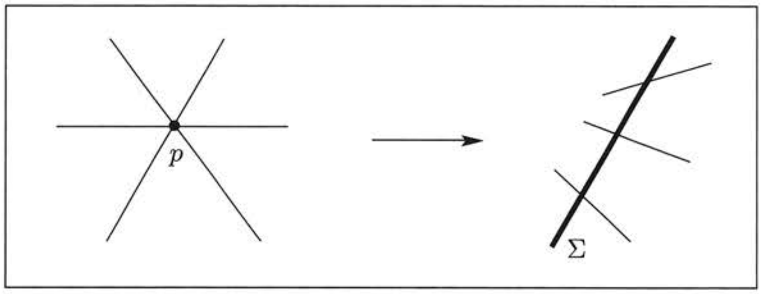

Figure 6. When the point p is blown up to the exceptional divisor Σ, the lines through p become disjoint.

Lefschetz Fibrations

Let $M \subset \mathbf{C}P^N$ be an algebraic surface. Cut M by a pencil P_λ, $\lambda \in \mathbf{C}P^1$, of hyperplanes with axis $A = \mathbf{C}P^{N-2}$. (Here P_λ is just the set of all hyperplanes through A.) This gives a family of subvarieties $C_\lambda = M \cap P_\lambda$ that all go through the set $M \cap A$; see Figure 5.

Since M has complex dimension 2 (and so real dimension 4), the set $M \cap A$ is a finite collection of points—presuming that A is generic—and the C_λ are complex curves that are nonsingular for all but a finite number of λ. Moreover, for generic A, the points in $M \cap A$ will be nonsingular on all the curves C_λ so that one can make the C_λ disjoint by blowing up these points; see Figure 6.

In this way one gets a family $\tilde{C}_\lambda$ of disjoint curves on the blown-up manifold $\widetilde{M}$, and the map

$$\begin{array}{rccc} \tilde{f}: & \tilde{M} & \to & \mathbf{C}P^1 \\ & x \in \tilde{C}_\lambda & \mapsto & \lambda \end{array}$$

is a singular holomorphic fibration; see Figure 7.

Example. Let $C_i = \{y_i\}$ for $i = 0, 1$ be two generic conics in $\mathbf{C}P^2$. For $\lambda = [\lambda_0 : \lambda_1] \in \mathbf{C}P^1$ define

$$C_\lambda = \{\lambda_0 y_0 + \lambda_1 y_1 = 0\}.$$

This gives a family of conics, all of them nondegenerate except for three pairs of lines.

Theorem 6 [Donaldson, 1997]. Every symplectic 4-manifold M has a blowup $\widetilde{M}$ for which there is a smooth map $f : \widetilde{M} \to \mathbf{C}P^1$ such that the following holds.

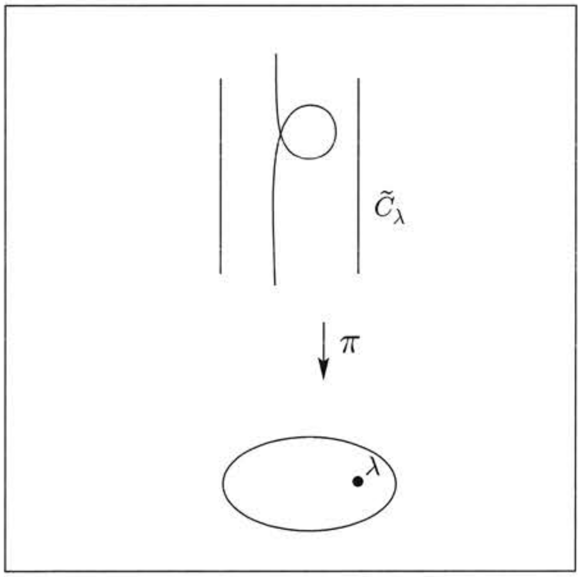

Figure 7. A Lefschetz fibration.

- All but finitely many fibers of f are symplectically embedded submanifolds.
- The remaining fibers are symplectically immersed with just one double point. Moreover, a neighborhood of each of these singular fibers has a compatible complex structure.

Thus one can think of f as a complex Morse function, with singularities modelled on the most generic singularities in the holomorphic case. In particular, the monodromy around each singular fiber is given by a Dehn twist. In the complex case the singularities must satisfy subtle global compatibility conditions that are not fully understood. However, there are no such conditions in the symplectic case. If $f : M \to \mathbf{C}P^1$ is a singular fibration as above such that the fibers support a smooth family of cohomologous symplectic forms that are compatible with the local structure near the singular fibers, then there is a compatible symplectic form Ω on M provided only that there is a cohomology class $a \in H^2(M)$ that restricts on the fibers to the class of the symplectic form.

To prove this theorem, Donaldson develops an "almost holomorphic" analysis that allows him to mimic the proof for algebraic manifolds. Very recently, he completed the generalization of this argument to higher dimensions, showing that every closed symplectic manifold has a suitable blowup that supports a symplectic Lefschetz fibration; see also Auroux [Au].

Groups of Automorphisms

We come to the last of the areas in which I am contrasting symplectic with Kähler geometry. The group $\mathrm{Symp}_0(M, \omega)$ of all symplectomorphisms of M that are symplectically isotopic to the identity was introduced earlier. I will write $\mathrm{Iso}_0(M, J, \omega)$ (or simply $\mathrm{Iso}_0(M)$) for the identity component of the group of isometries of the (closed) Kähler manifold (M, J, ω) when this is provided with the corresponding metric g_J. It is well known that this is a compact Lie group (often trivial). Further, because the symplectic form ω on a Kähler manifold is harmonic with respect to the Kähler metric and because a harmonic form is unique in its cohomology class by Hodge theory, the form ω is preserved by all isometries that fix its cohomology class $[\omega]$. Hence all elements of $\mathrm{Iso}_0(M)$ preserve ω and therefore also preserve the complex structure J.

Some 4-Dimensional Examples

First of all, let me describe some cases in which these two groups are closely related. Note that they can never be equal, since $\mathrm{Symp}_0(M, \omega)$ is infinite-dimensional.

- If the complex projective plane $\mathbf{C}P^2$ is given its standard structure, $\mathrm{Iso}_0(\mathbf{C}P^2)$ is the projective unitary group PU(3), while $\mathrm{Symp}_0(\mathbf{C}P^2, \omega)$ deformation retracts to PU(3).
- Let ω^λ be the symplectic form $(1+\lambda)\sigma_0 \oplus \sigma_1$ on $S^2 \times S^2$, where $\lambda \geq 0$ and where the σ_i are area forms on S^2 of area 1, and let J_{split} be the product almost complex structure. Then $\mathrm{Iso}_0(S^2 \times S^2, J_{split}, \omega^\lambda)$ is the product $SO(3) \times SO(3)$ for all λ. On the other hand, Gromov (1985) proved that $\mathrm{Symp}_0(S^2 \times S^2, \omega^\lambda)$ deformation retracts to $SO(3) \times SO(3)$ if and only if $\lambda = 0$. Moreover, it has been shown by Abreu (1997) and Abreu-McDuff that $\mathrm{Symp}_0(S^2 \times S^2, \omega^\lambda)$ does not have the homotopy type of a compact Lie group when $\lambda > 0$. In fact, when $k-1 < \lambda \leq k$, this group incorporates the isometry groups of the $k+1$ different complex structures $J_0 = J_{split}, J_1, \ldots, J_k$ on $S^2 \times S^2$ that are compatible with the Kähler form ω^λ. Similar results are true for the blowup of $\mathbf{C}P^2$ at one point. However, nothing similar is known about most other manifolds, even one as simple as T^4.

It is obviously unreasonable to expect that the symplectomorphism group would be homotopy equivalent to the group of Kähler isometries in general. However, the next part of the discussion aims to show that some features of the Kähler case do persist in the general case.

The Group of Hamiltonian Symplectomorphisms

Let us write $\mathrm{HIso}(M)$ for the intersection of the isometry group $\mathrm{Iso}(M)$ with the group $\mathrm{Ham}(M, \omega)$ of Hamiltonian symplectomorphisms. The Lie algebra of $\mathrm{HIso}(M)$ may then be identified with a finite-dimensional space of smooth functions H on M, normalized by the condition that the mean value $\int_M H\omega^n$ is zero. (As always, we assume that M is closed, that is, compact and without boundary.) Moreover, the exponential map is just the time one map of the corresponding flow:

$$\exp : H \mapsto \phi^H = \phi_1^H.$$

Since the exponential map is surjective when the group is compact, it follows that every element ϕ of HIso(M) is the time one map ϕ^H of a Hamiltonian function $H : M \to \mathbf{R}$. Now, every critical point of H gives rise to a fixed point of ϕ^H, since the generating vector field X_H of the flow ϕ_t^H satisfies the equation $\iota_{X_H}\omega = dH$ and so vanishes at such critical points. It follows that for every $\phi \in$ HIso(M) the number of its fixed points is at least as great as the number of critical points of a generating Hamiltonian H. Thus

$$\#\mathrm{Fix}\phi \geq \#\mathrm{Crit}H \geq \sum_i \dim H^i(M, \mathbf{R}),$$
$$\text{for all } \phi \in \mathrm{HIso}(M).$$

Arnold's famous conjecture is that the above statement remains true for every Hamiltonian symplectomorphism whose fixed points are all nondegenerate.[2] This was finally proved in 1996 for all symplectic manifolds by the combined efforts of many mathematicians, among them Floer, Hofer-Salamon, Fukaya-Ono, and Liu-Tian. Thus:

Theorem 7 [Arnold's conjecture]. If (M, ω) is any compact symplectic manifold and $\phi \in$ Ham(M) has no degenerate fixed points, then

$$\#\mathrm{Fix}\phi \geq \sum_i \dim H^i(M, \mathbf{R}).$$

Note that it is essential here that ϕ be Hamiltonian. For example, the rotation $(x, y) \mapsto (x + t, y)$ of the torus T^2 is a non-Hamiltonian symplectomorphism with no fixed points.

Hamiltonian Loops

Our final result concerns a curious and recently discovered property of Hamiltonian loops. First observe that any loop $\{\phi_t\} \in$ Diff(M) generates a homomorphism

$$\partial_\phi : H_*(M) \to H_{*+1}(M)$$

that takes a k-cycle Z in M to the $(k+1)$-cycle $S^1 \times Z \to M$ swept out by the action

$$S^1 \times M \to M : \quad (t, x) \mapsto \phi_t(x).$$

[2] *A fixed point x of ϕ is said to be nondegenerate if the graph of ϕ in $M \times M$ meets the diagonal transversally at (x, x). In the Kähler case discussed above there is no need for this hypothesis, since the fact that ϕ is an isometry implies that H is a Morse-Bott function. In particular, if it has degenerate critical points, then there are infinitely many of them. We restrict here to the nondegenerate case for the sake of simplicity: there is a corresponding conjecture in the general case that has not yet been proved for all manifolds. There are also conjectural homotopy-theoretic lower bounds for #Fixϕ that have also not yet been established.*

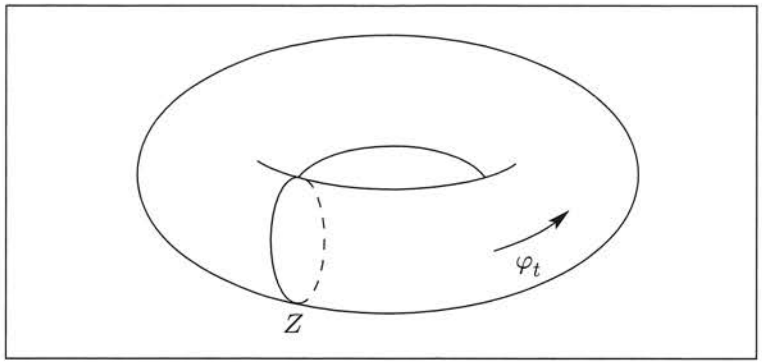

Figure 8. The cycle $\partial_\phi(Z)$.

See Figure 8. Clearly, the map ∂_ϕ depends only on the homology class of the loop $\{\phi_t\}$ in the space of continuous self-maps of M.

This map ∂_ϕ can be expressed geometrically in terms of symplectic fibrations. Given a loop ϕ_t of symplectomorphisms of M, one can construct a fibration $P_\phi \to S^2$ with fiber M by thinking of ϕ_t as a clutching function, viz:

$$\begin{array}{ccc} P_\phi & = & M \times D^+ \cup_{\phi_t} M \times D^- \\ \downarrow & & \downarrow \\ S^2 & = & D^+ \cup D^-. \end{array}$$

It is not hard to show that the loop ϕ_t is isotopic to a Hamiltonian loop exactly when there is a symplectic form Ω on P_ϕ that restricts to the form ω on each fiber M. Further, the map $\partial_\phi : H_k(M) \to H_{k+1}(M)$ is precisely the boundary map in the Wang exact sequence for the fibration $P_\phi \to S^2$.

Recent work of Lalonde-McDuff-Polterovich [LMP], which builds on ideas of Seidel, has shown that the map ∂_ϕ vanishes identically on rational homology when ϕ is a Hamiltonian loop. Thus we have the following result.

Proposition 8 [LMP]. If (P_ϕ, Ω) is a symplectic manifold that fibers over S^2 with symplectic fiber (M, ω), then there is a vector space isomorphism

$$H^*(P_\phi, \mathbf{Q}) \cong H^*(M, \mathbf{Q}) \otimes H^*(S^2, \mathbf{Q}).$$

This result generalizes in the Kähler case. Let us say that a fibration $M \to P \to B$ with the property that $H^*(P_\phi, \mathbf{Q})$ is additively isomorphic to $H^*(M, \mathbf{Q}) \otimes H^*(S^2, \mathbf{Q})$ is *cohomologically split.* Then Deligne showed that every holomorphic submersion from a Kähler manifold P to a base manifold B is cohomologically split. It is not yet known whether a similar result holds in the symplectic case, although there is a good notion of Hamiltonian fibration that generalizes the idea of a holomorphic submersion. (This is explained in the new edition of [MS] as well as in forthcoming work by [LMP].) The fact that at least some of these results on fibrations carry over to the symplectic case is yet another indication both of the naturality of fibered structures in symplectic geometry and of the special nature of Hamiltonian symplectomorphisms.

Acknowledgments

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Where Mathematics Meets the Internet

Walter Willinger and Vern Paxson

Introduction

The Internet has experienced a fascinating evolution in the recent past, especially since the early days of the Web, a fact well documented not only in the trade journals but also in the popular press. Unprecedented in its growth, unparalleled in its heterogeneity, and unpredictable or even chaotic in the behavior of its traffic, "the Internet is its own revolution," as Anthony-Michael Rutkowski, former executive director of the Internet Society, likes to put it. At the same time, folklore has it that mathematics lies at the heart of Internet operation. After all, the argument goes, mathematics is the language of computers, and the Internet is currently connecting tens of millions of them and still doubling every year [Lo98]. Yet the Internet is a new world, one where engineering reality wins over tradition-conscious mathematics and requires "paradigm shifts" that favor a combination of mathematical "beauty" and high potential for contributing to pragmatic Internet engineering. In this article we take a look at how the Internet differs in fundamental ways from the conventional voice networks, how the (r)evolution of the Internet is impacting the world of mathematics in the small as well as in the large—both on *how* mathematics is done and, for understanding the network itself, on *what sort of* mathematics is done—and why this, in turn, makes Internet engineering a gold mine for new, exciting, and challenging research opportunities in the mathematical sciences.[1]

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Teletraffic Theory and Internet Engineering

The term "teletraffic theory" originally encompassed all mathematics applicable to the design, control, and management of the public switched telephone networks (PSTN): statistical inference, mathematical modeling, optimization, queueing and performance analysis. Later its practitioners would extend this to include data networks such as the Internet too. Internet engineering, an activity that includes the design, management, control, and operations of the global Internet, would thus become part of teletraffic theory, relying on the mathematical sciences for new insights into and a basic understanding of modern data communications. However, from its early days the Internet emphasized engineering and experimentation and was less concerned with mathematics and theory. In fact, some in the Internet community are quick to point out that today's Internet "works" because it ignored mathematics—in particular, teletraffic theory—and herein lies an interesting tale.

Mathematics and POTS

For someone living in an industrialized country, what is the likelihood of not getting a dial tone when trying to make a phone call?[2] Now, what about not being able to connect to a popular Web server over the Internet?

The answers to these questions range from once in a month or year in the first case to once in an hour or day in the second case. Indeed, traditional

[1] *Note that this article is not intended to provide a comprehensive bibliographical guide to the latest developments and advances in this area; for such a guide the interested reader may want to consult, for example, the recent survey paper [WTE96].*

[2] *Here we mean a voice call. We address the interesting case of dialing up to an Internet Service Provider below.*

teletraffic theory—as applied to POTS (plain old telephone service)—has arguably been one of the most successful applications of mathematical techniques in industry. It has led to first-rate telephone networks whose quality of service we fully rely on and take for granted. It has enabled enormous efficiencies in the deployment and day-to-day operations of telecommunications networks and has resulted in near-universal telephony throughout the industrialized world. Among the main reasons for this tremendous success of teletraffic theory and practice in traditional telephony are the *highly static* nature of conventional PSTNs and a well-defined and ever-present notion of *limited variability*, a trademark of homogeneous systems where one can talk about "typical" users and "generic" behavior and where averages describe system performance adequately. Another important reason has been the special appeal of the most widely used models to the engineering community, mainly because of their simplicity, physical interpretation, and practical relevance: they required only a few inputs that could be readily estimated in practice.

The static nature of traditional PSTNs contributed to the popular belief in the existence of "universal laws" governing voice networks, the most significant of which is the presumed *Poisson* nature of call arrivals at links in the network where traffic is heavily aggregated, such as at interoffice trunk groups. This law states that call arrivals are mutually independent and that the call interarrival times are all exponentially distributed with one and the same parameter λ.

Equivalently, if $X = (X_k : k \geq 1)$ denotes the number of call arrivals in successive, nonoverlapping time intervals of length $\Delta t > 0$, then X is the increment process of a Poisson process with parameter λ if and only if the random variables X_k are independent and identically distributed with

$$(1) \qquad P[X_k = n] = e^{-\lambda \Delta t} \frac{(\lambda \Delta t)^n}{n!}, \qquad n \geq 0.$$

Traffic models such as the Poisson process, whose full dynamics can be described with one or just a few parameters, are termed *parsimonious*, a highly desirable property for reasons we develop later.

The Poisson law has remained valid for modeling purposes for at least fifty years. So has a related invariant of POTS traffic that specifies that call "holding times" (durations) follow more or less an exponential distribution. Three other important teletraffic laws are: growth rates are highly predictable, allowing for fine-tuned short- and long-term capacity planning; network controls and operations are fully centralized, so one can envision taking advantage of information about the network's global state; and offered services are strictly regulated and monitored.

On the other hand, the static PSTN environment has resulted in a steady decline of the perceived importance of continued measurements and has emphasized instead the need for analytical techniques. While teletraffic theory was originally based on empirical studies and on traffic measurements that were collected laboriously from the public telephone networks,[3] soon the belief in the Poisson process and the exponential distribution as "universal laws" for POTS overcame the curiosity associated with collecting and analyzing more data. Moreover, new mathematical results provided a sound physical basis for the observed Poisson nature of call arrivals on trunk groups. As an example, the Palm-Khintchine theorem states that the superposition of many independent and properly normalized renewal processes—each one describing the call arrivals on a single phone line—forms a Poisson process. The resulting traffic models were, in general, mathematically tractable and could be used to predict accurately many performance measures of interest. Queueing theory was born. A faith in "true" traffic models took over, the need for further traffic measurements was glossed over, and the main focus shifted to turning queueing theory into a full-fledged mathematical discipline.

Ironically, the complacency engendered by this mathematical elegance and (particularly) success has recently been rocked by changes in the "static" world of telephony. Fifty-year-old patterns of telephone use, the bedrock of the teletraffic modeling success story, now have been greatly undermined by two major new uses of the telephone network. These changes began with the advent of faxes in the 1980s and have continued and become more drastic with the popularity of the Web.

The key change is that telephone calls used for fax transmission and Internet access have statistical characteristics dramatically different from a typical voice call. They tend to be significantly longer and much more variable in their duration than a voice call, and their numbers have recently increased dramatically, especially in terms of Internet access calls. Both types of calls are now playing havoc with the existing PSTN engineering infrastructure designed to deal with voice calls only. In some places, call "blocking" has increased to unacceptable levels, especially during late evening hours (popular with Web surfers), and ad hoc engineering methods have become necessary to prevent temporarily Internet access calls from saturating access to the public telephone network. Clearly, theory no longer meets reality, and as a result capacity planning becomes dicey and inexact. Concentrated, industry-wide efforts for off-loading Internet traffic from the PSTN are under way.

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[3] *Pioneering work by Erlang, Palm, Wilkinson, and others over half a century ago.*

Goodbye Poisson

One might expect that the voice network modeling success story would enjoy another triumph when applied to data networks, and indeed this has been attempted. But in fact much of the voice traffic modeling has proven nothing short of disastrous when applied to data networks, for the simple but profound reason that *the rules all change* when it is computers and not humans doing the talking.

Voice traffic has the property that it is relatively homogeneous and predictable and, from a signaling perspective, spans long time scales. Consequently, many concurrent voice connections can be easily "multiplexed" to share a common (expensive) wire or "link" by allocating a fixed amount of the link's capacity to each connection. When a new call request arrives, it is easy to determine whether a given link has sufficient capacity to carry the additional load. As a result, voice networks have been engineered in a *circuit-switching* fashion. That is, the "routers" internal to the network, which are responsible for forwarding traffic from one link to the next so that it ultimately reaches its destination, keep track of each currently active connection and when new traffic arrives, look up its corresponding connection to determine where to forward the traffic. The principal abstraction is known as providing "virtual circuits", because the network behaves as if it provides a direct circuit from the traffic source all the way to its destination.

In contrast to voice traffic, data traffic is much more variable, with individual connections ranging from extremely short to extremely long and from extremely low-rate to extremely high-rate. These properties have led to a design for data networks in which each individual data "packet" or "datagram" transmitted over the network is forwarded through the network independently of previous packets that may have been transmitted by the same connection. Each packet is self-contained, and the routers need only inspect the "header" of the packet to determine its destination and forward it through the network. Consequently, the routers do *not* keep track of each currently active connection.

This shift away from circuit-switching toward *packet-switching* has profound implications. On the one hand, it results in highly efficient networks. Any time capacity is available in the network, newly arriving packets can benefit from it. Each packet in the network competes with all the others—if there happens to be little competing traffic along a particular path, then a connection using it can enjoy the entire "bandwidth" of the path and transfer its data very quickly. If many connections compete along the same path, then each will receive a (perhaps unfair) portion of the available bandwidth. In addition, packet-switching buys enormous *robustness*: it enables networks to route transparently around router or link failures without perturbing active connections. Routers have no problem accepting the rerouted traffic because, as far as they can tell, it is not in any way "new" traffic—they have no notion of "current" traffic and hence no problem accepting traffic they did not know existed until that very moment—a situation very different from a circuit-switched network, in which the routers cannot easily accept rerouted traffic because they have no knowledge of the corresponding virtual circuit.

However, links can become overloaded because packets arrive for transmission along them at rates exceeding the capacity of the link. Such packets will be "buffered", awaiting transmission along the link, but if the excess rate is sustained—a condition termed "congestion"—then ultimately the buffers in the routers will fill up, and some packets must be discarded or dropped. To ensure that sources behave properly in the presence of congestion in the network, the protocols used for transmitting data in the Internet include *end-to-end congestion control* mechanisms that decrease automatically the rate at which data are transmitted when congestion is detected. An important consequence of the use of congestion control is that traffic in the network is shaped by the conditions each connection has encountered in its past. Thus, Internet traffic includes a basic mechanism that introduces significant, complicated correlations across time as well as complex interactions among the active connections.

A damaging legacy of the telephony influence on data network research was a virtually complete absence in the 1970s and 1980s of attempts to validate crucial modeling assumptions against actual data network traffic measurements. Yet, just a few measurement studies suffice to discover that data traffic is highly variable or very *bursty*. That is, it does not come at a steady rate, but instead in starts and fits with lulls in between. The term "bursty" has a readily understood intuitive meaning, but it turns out that nailing down its precise, mathematical meaning has profound implications for developing mathematical models of network traffic. The natural approach for getting a handle on burstiness is to define it in terms of a *time scale* over which activities and lulls occur. For telephony, this time scale is related to the rate λ of the Poisson process (1) that describes the dynamics of call arrivals. For example, if $\lambda = 100/\text{sec}$, then the time scale of burstiness is around 10 msec, and periods of sustained greater-than-average activity or sustained lower-than-average lulls over much smaller or larger time scales occur with rapidly vanishing probability.

However, practitioners have long observed that traffic bursts in data networks do indeed occur on many different time scales and that such multiscale burstiness simply does not fit the world of tradi-

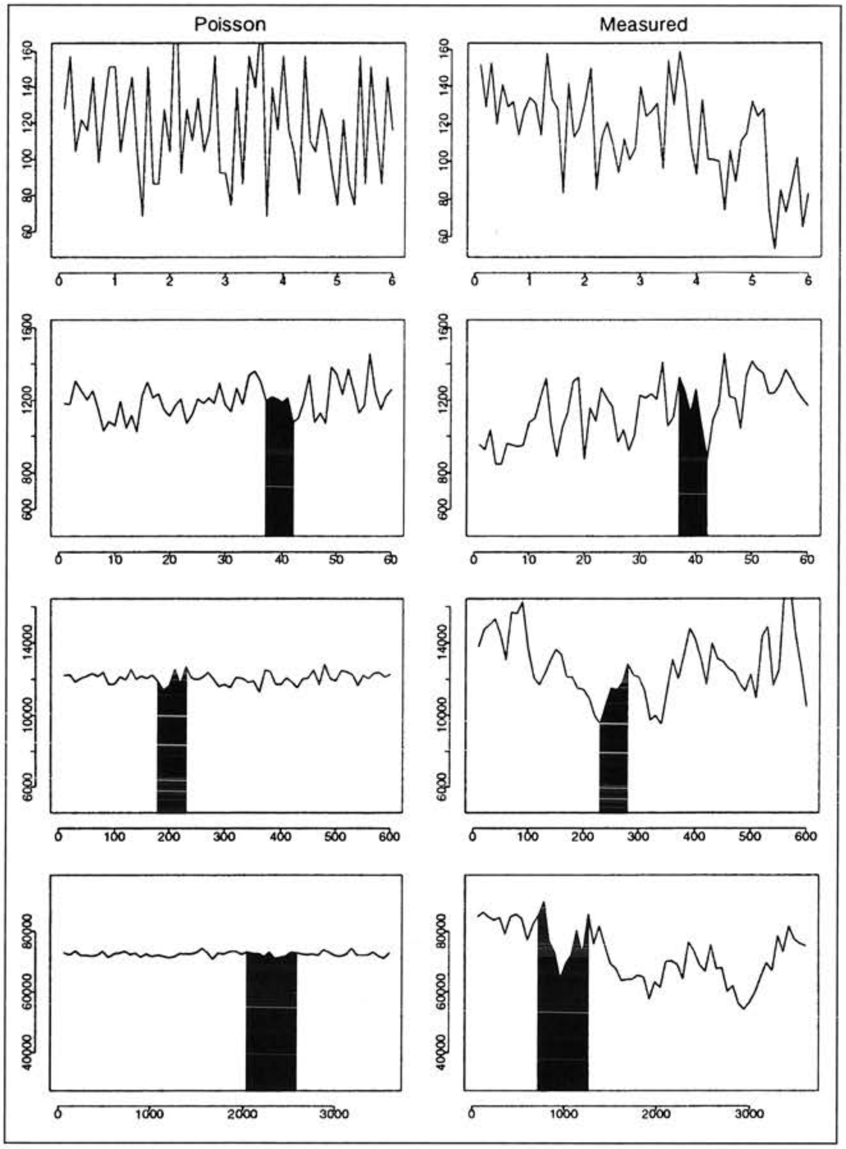

Figure 1. Synthesized traffic from a Poisson model vs. Internet traffic to which its mean and variance were fitted, viewed over three orders of magnitude.

tional Poisson-based traffic modeling. The Poisson framework does not even provide a vocabulary for discussing burstiness of this sort.[4] Figure 1 is a visual demonstration of the failure of Poisson modeling to capture the burstiness present in actual network traffic. The plots were generated based on an hour-long trace of Internet traffic collected off a network link connecting a large corporation to the Internet.[5] From this trace we synthesized another, hour-long series of packet arrivals created by fitting a simple Poisson-based model to the mean and variance of the measured sample. More elaborate modeling could be done, but the end effect (see below) would be the same.

We then observe visually the burstiness of the original trace and the synthetic trace as we vary the time scale of observation. The top row shows a randomly selected subset of each trace on a time scale of 100 msec; that is, each point in the plots reflects the number of packets observed during a 100 msec interval, for a total of 6 sec. The second row shows a time scale a factor of ten larger: now, each point reflects the number of packets per 1 sec, spanning 60 sec total. The black regions illustrate from where the plots in the row above were made. A key point is that we not only have increased the scale of the X-axis by a factor of 10, but we have done the same to the Y-axis. With the third row we have again increased the scale in both X and Y by a factor of ten and in the final row by another factor of six, such that here the plots span the entire hour of the traces.

The difference between the Poisson model and the measured traffic is obvious and striking: as the time scale increases, the Poisson traffic "smooths out", becoming quite tame, while the measured traffic shows no such predilection. This difference is absolutely crucial from an engineering perspective: traffic that behaves as shown in the left column can be easily engineered for. Above a certain time scale there are no surprises—everything boils down to knowing the long-term arrival rate—no need for big buffers in routers or switches, no reasons for being conservative in choosing safe operating points for engineering backbone trunks, and why even think of user-perceived quality of service as being a relevant issue? In stark contrast, measured traffic like that shown in the right column is *wild*, remains so even on quite coarse time scales, and plays havoc with conventional traffic engineering: routers require big buffers to accommodate the traffic fluctuations across many time scales; in the absence of any effective controls, safe operating points have to be set conservatively because the traffic can saturate the link at any time and over any time scale and adequate overall network performance can no longer be taken as a guarantee of happy individual users.

The edifice of Poisson modeling repeatedly told Internet network engineers to expect the behavior shown on the left—but what they really observe is the rollercoaster ride on the right! The Internet engineering community has thus come to consider teletraffic theory as irrelevant (and actually detrimental) to the development of the Internet. More specifically, it has criticized the Poisson-based ap-

[4] *Indeed, we find researchers falling back on metaphors to try to characterize their observations: "traffic 'spikes' (which cause actual losses) ride on longer-term 'ripples', that in turn ride on still longer-term 'swells'." [FL91]*

[5] *The measurements were gathered by J. Mogul in 1995 and are available from the Internet Traffic Archive,* `http://www.acm.org/sigcomm/ITA/`.

proach on grounds that the models: (i) have little in common with network engineers' practical experience observing their networks; (ii) are theoretical constructs based on assumptions lacking validation against measured data, especially when extended with additional parameters for describing burstiness; (iii) are too complex to aid in developing intuition or a physical understanding of actual network traffic dynamics ("black boxes"); and (iv) require inputs (parameter estimates) that, in practice, cannot be specified, collected, or estimated.

Hello Fractals

Many networking experts argue that the only way to gain an in-depth understanding of data network traffic is—simply put—doing away with teletraffic tradition and starting from scratch. Interestingly, mathematics, which has been largely responsible for the success story of teletraffic theory for the voice network, has recently provided strong ammunition in support of the networking experts' arguments. However, as voice traffic turns out to differ drastically from data traffic, so too do the underlying mathematical ideas and concepts. The relevant mathematics for POTS is one of *limited variability* in both time—traffic processes are either independent or have temporal correlations that decay exponentially fast—and in space; i.e., the distributions of traffic-related quantities have exponentially decaying tails. But for data networks, the mathematics is one of *high or extreme variability.* Statistically, temporal high variability in traffic processes is captured by *long-range dependence*, i.e., autocorrelations that exhibit a power-law decay. On the other hand, extreme forms of spatial variability can be described parsimoniously using *heavy-tailed distributions* with infinite variance, i.e., probability distributions F with the property that for large x-values,

$$1 - F(x) \approx \kappa_1 x^{-\beta}, \tag{2}$$

where κ_1 is a positive finite constant that does not depend on x and where the tail index β is in the interval $(0, 2)$. This property is, for example, satisfied by the well-known family of "Pareto distributions", originally introduced for modeling the distribution of income within a population.

It turns out that power-law behavior in time or space of some of their statistical descriptors often cause the corresponding traffic processes to exhibit *fractal* characteristics. In the present context, we say that a traffic process has fractal characteristics if there exists a relationship between certain quantities Q of the underlying process and the resolution τ, of the general form

$$Q(\tau) \approx \kappa_2 \tau^{f(D)}, \tag{3}$$

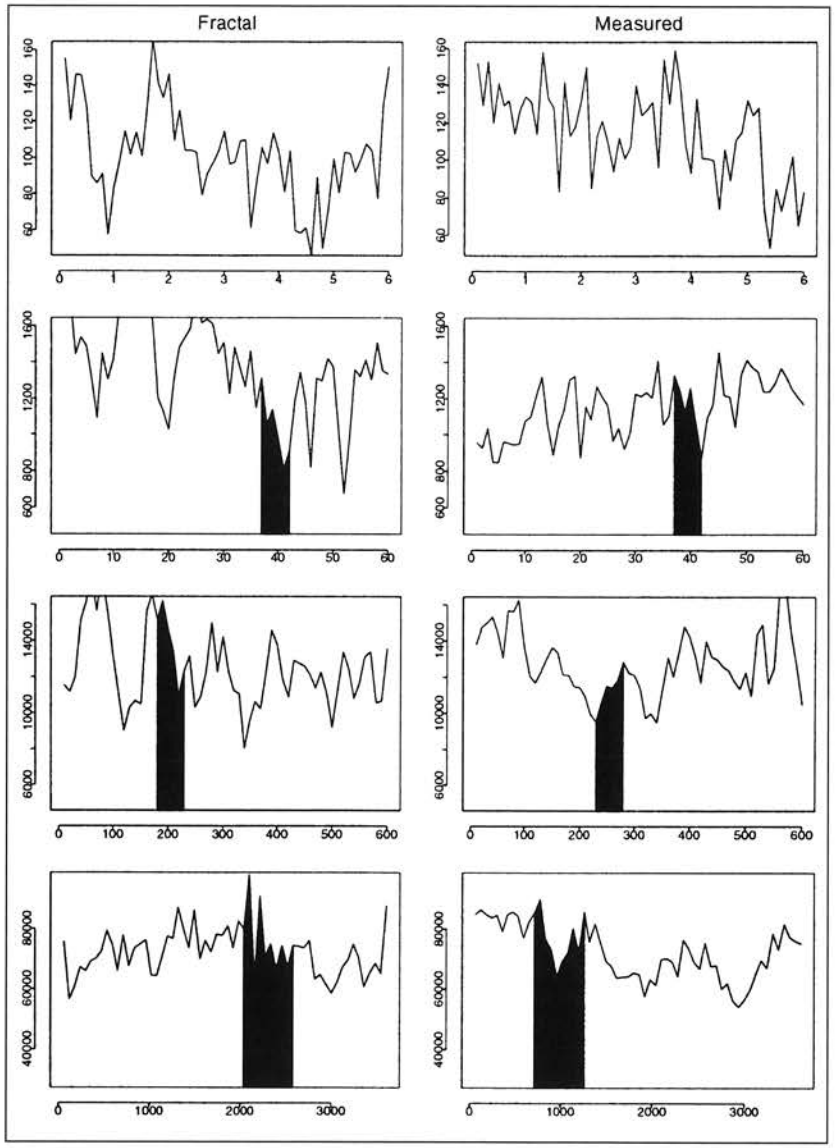

Figure 2. Synthesized traffic from a simple fractal model vs. Internet traffic to which its mean, variance, and Hurst parameter (H) were fitted, viewed over three orders of magnitude.

where κ_2 is a positive finite constant that does not depend on τ. Here τ denotes a resolution in time or space at which Q is evaluated, and (3) specifies how Q must vary as a function of the resolution τ; $f(\cdot)$ is a simple, often linear, function of D, and D is a fractal dimension. To declare fractality, the above relationship is supposed to hold for a range of different τ-values, with a value of D that is less than the embedded dimension.

Fractal concepts have been nonexistent in teletraffic theory. Yet a look at Figure 1 (right side) shows fractal-like behavior over a wide range of time scales, from hundreds of milliseconds to seconds to tens of seconds and beyond. In fact, Figure 2 shows the same sort of plot as in Figure 1, except now instead of using a Poisson-based model, we use a very simple mathematical model called *fractional Gaussian noise* that is strictly fractal in a sense to be made precise shortly.

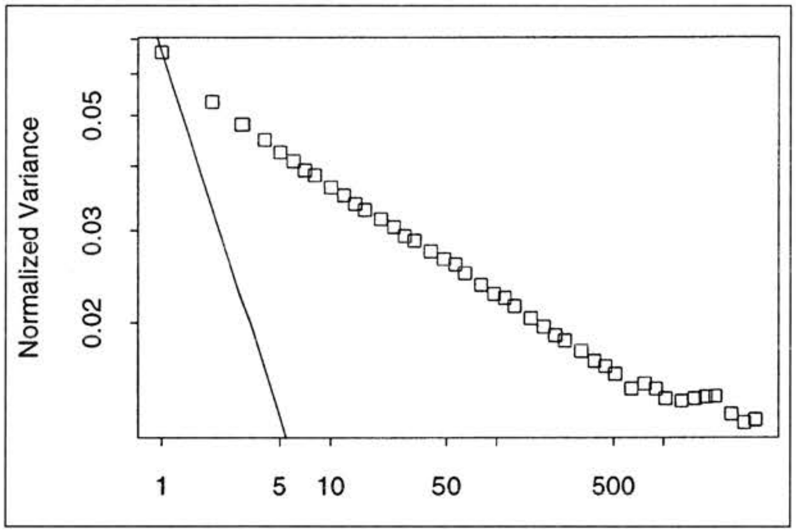

Figure 3. Variance-time plot for measured Internet traffic. The steep downward line to the left corresponds to the variance-time plot expected for Poisson traffic.

For now, a covariance-stationary Gaussian process $X = (X_k : k \geq 1)$ is called a fractional Gaussian noise with *Hurst* parameter $H \in [0.5, 1)$ if the autocorrelation between X_n and X_{n+k}, $k \geq 0$, is given by $\mathbf{cor}(X_n, X_{n+k}) = \frac{1}{2}(|k+1|^{2H} - 2|k|^{2H} + |k-1|^{2H})$. Along with fitting the model to the measured traffic's mean and variance, it requires one extra parameter, the Hurst parameter H, which quantifies the strength of the fractal scaling. Visually, the synthesized traffic using the fractal model is in the right ballpark, and we can achieve this using only one additional parameter! This last comment is a crucial property of the fractal modeling approach: it preserves *parsimony*, meaning that the model is sufficiently simple that we have some hope of applying it across a wide range of conditions without requiring too many guesses as to how to set its parameters.

In view of the general skepticism that exists in the different circles in the mathematical community concerning the need, usefulness, and appropriateness[6] of fractals, what can we say about fractal-like scaling in measured data network traffic? To examine this question, we call a discrete-time, covariance-stationary, zero-mean stochastic process $X = (X_k : k \geq 1)$ *exactly self-similar* or *fractal* with scaling parameter $H \in [0.5, 1)$ if, for all levels of aggregation or "resolution," $m \geq 1$,

$$X^{(m)} = m^{H-1} X,$$

where the equality is understood in the sense of finite-dimensional distributions and where the aggregated processes $X^{(m)}$ are defined by:

$$X^{(m)}(k) = m^{-1}(X_{(m-1)k+1} + \cdots + X_{km}), \qquad k \geq 1.$$

For example, the fractional Gaussian noise process introduced earlier is exactly self-similar with scaling parameter equal to the Hurst parameter. It is easy to check that for an exactly self-similar process with scaling parameter H, the functional relationship given by

$$\mathbf{Var} X^{(m)} = \kappa_1 m^{2H-2}$$

holds and fits the form of (3). The resulting linear log-log representation of $\mathbf{Var} X^{(m)}$ vs. m is called the *variance-time plot*. An illustration of it based on the Internet traffic trace used for Figures 1 and 2 is shown in Figure 3. Clearly, the observed scaling range spans three decades, indicating compelling evidence of fractal-like scaling. In other traces from different networks, scaling ranges spanning three to five decades are common.

When assessing the validity of describing a process using a self-similar model, one must be very careful not to mistake actual nonstationarities (e.g., connection arrival rate varying with time) for highly variable but stationary fractal behavior. The two can appear very similar, both to the eye and to a number of statistical tests. However, this concern can be addressed by making good use of the very large size of network traffic traces. For example, we can extract numerous five-minute portions of a trace, analyze them for possible fractal behavior, and then compare the results to those for neighboring five-minute portions, and also to encompassing ten-minute portions, to see if the analyses yield consistent results, which then support arguing that the data are well modeled as stationary. Ordinarily, this process might encounter problems as we run out of data points and the subsamples become too small for compelling analysis. But for network traffic, we have "data to burn". In turn, this motivates the development of novel statistical techniques that exploit fully the impressive sample sizes and replace traditional concepts that have been fine-tuned over the years to work to perfection when the sample size is small. As shown above, these new methodologies have little in common with traditional inference techniques such as assessing goodness-of-fit or hypothesis testing, but instead demonstrate how the concept of "borrowing strength from large data sets", coined by J. Tukey, applies in practice and can result in compelling evidence for, in this case, the fractal nature of Internet traffic.

Why Getting to Know the Internet Is Painfully Hard

Although the finding of the fractal nature of Internet traffic can be viewed as a promising start toward solid characterizations of Internet traffic, the truth is that it has barely made a dent, because there are a number of often underappreciated fea-

[6]*See, for example, the recent survey by Avnir et al. [ABLM98] that reports, for all the* Physical Review *journals from 1990 to 1996, a scaling range of experimentally declared fractality that averages a mere 1.3 decades (orders of magnitude, base 10).*

tures that make it immensely difficult to characterize and understand the Internet in any sound fashion. Each property reflects a form of *change*—the fact that virtually nothing about the network is "typical" in any sense. There is change over time, between sites, and in the basic assumptions about how the network is used [Pa94].

The Changing Internet

The first, basic element of change concerning the Internet is that of *growth*. Simply put, the network grows exponentially, has done so for well over a decade, and shows no signs of slowing down. Figure 4 illustrates one growth statistic: the volume of traffic in bytes per day flowing through the USENET bulletin board system. The data start in 1984 and continue to 1994. The measurements fit beautifully a straight line, reflecting *sustained exponential growth* of about 80% per year for over a decade (note log-linear scale). Clearly, Internet growth is nothing new—it in no way began with the Web—and current statistics are consistent with the growth continuing completely unabated.

Another respect in which the Internet exhibits striking change concerns characteristics of its traffic as measured at different sites and moments in time. For example, a 1991 sample of Internet traffic at a research laboratory found that about 67% of the data bytes going into or out of the site were from use of the Internet's standard file transfer protocol, FTP. Yet, at the same point in time, a sample of a university's traffic found that only 18% of the data bytes were from FTP. For another university the figure was 50%. Clearly, if researchers studied just one of these sites, regardless of how carefully, they would have come to a conclusion completely incorrect for some other Internet sites!

The same problem also occurs over modest amounts of time. An October 1992 sample of file transfer (FTP) traffic at a research laboratory found that the median data transfer size was 4,500 bytes. This median was computed over more than 60,000 transfers—presumably a highly robust statistic. Yet five months later, the same statistic computed over more than 80,000 transfers yielded 2,100 bytes, less than half the earlier value! In March 1998 the same median, now computed over 450,000 transfers, was 10,900 bytes. Thus, regardless of how diligently one studied any one of these three points in time, conclusions about this "highly robust" statistic were grievously inaccurate for the other points in time!

Another basic source of problematic Internet change concerns the extremely rapid advent of new applications. In October 1992 the aforementioned research lab participated in a total of forty-five WWW connections over the entire month. But in the months that followed, the Web exploded, and

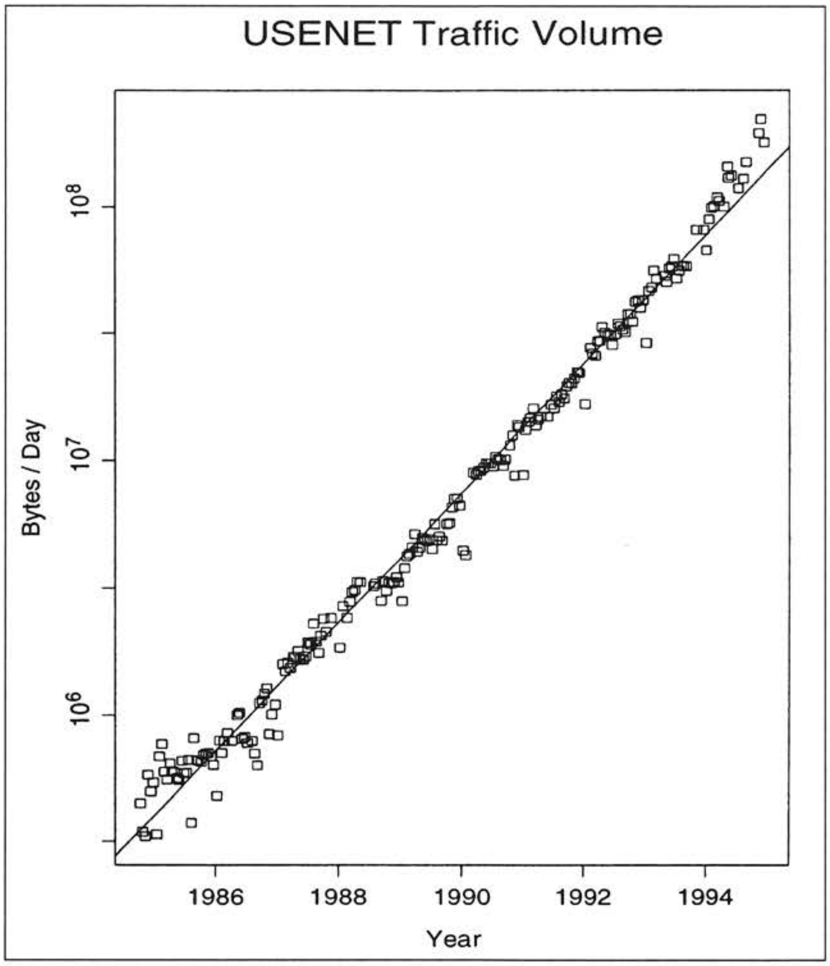

Figure 4. Bytes per day sent through the Internet's USENET bulletin board system. Data courtesy of R. Adams.

that same site's Web traffic began to *double every six weeks* and continued doing so for *two entire years*. Today the site participates in more than half a million WWW connections each day. From the perspective of Internet researchers, the Web came from out of nowhere. No one, not even its staunchest proponents, had predicted such rapid success in their wildest dreams. Worse, its traffic has properties that until then were not common in the Internet. Carefully considered extrapolations regarding future traffic became obsolete virtually overnight![7]

Toward Scientific Inference

Clearly, if one's goal is to understand and predict Internet behavior in any sound fashion, then the difficulties outlined in the previous section must be sobering; they demonstrate that there are enormous hurdles to overcome in terms of how rapidly the network changes and the great diversity embodied within it. One approach for dealing with the pace at which the Internet changes, as well as with

[7] *We note that this phenomenon is not unique to the Web. Other applications have also exploded. The Web*—so far—*is the only one that has continued to explode for more than a few years.*

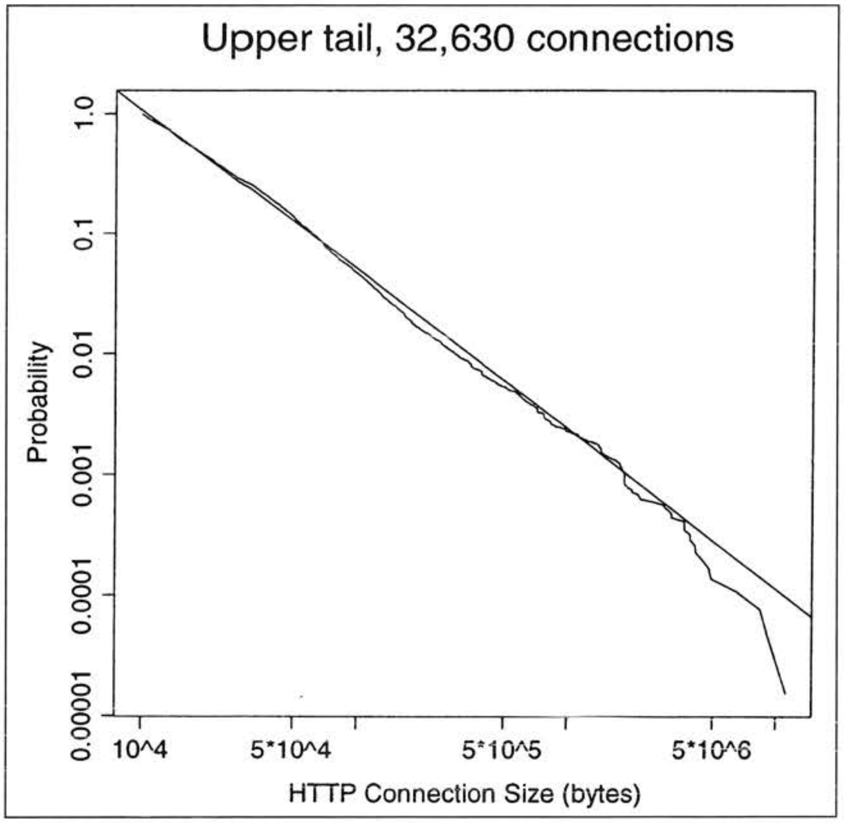

Figure 5. (Conditional) log-log complementary distribution plot of WWW connection sizes, given that the connection size is at least 10,000 bytes.

its extreme heterogeneity, is to base findings about the Internet on careful examinations of a wide range of Internet measurements, taken at different points in time, at different points in the network, and under a variety of different networking conditions. However, this approach has its own drawbacks: not only does it mean diligent and immensely time-consuming "digging around" in data, but statistical inference as it is currently taught and practiced has little to offer when faced with the task of drawing statistically sound conclusions from a large number of *large* data sets. Conventional statistical inference emphasizes the analysis of *single* data sets that are typically small, works to near perfection when it comes to the testing of "true models" using small samples, and has developed over the years an arsenal of techniques and tools that help an analyst "squeeze a data set dry" [Ch95].

What Internet traffic researchers instead require are inference methods that can fruitfully span a large collection of high-volume data sets. They need tools for searching for lawlike relationships across different data sets that generalize to a wide range of different conditions. These approaches define what is generally called *scientific inference*. They have a long history in the physical sciences but have been all but ignored in the social sciences and in the traditional statistics literature. To study Internet traffic, we want scientific inference for what J. Tukey calls "broadening the basis", which means trying to uncover *traffic invariants*, i.e., features in traffic that are insensitive to the constantly changing conditions that networks experience. Such an approach emphasizes building intuition and physical understanding over traditional black-box descriptions or conventional data fitting. At the same time, scientific inference provides the proper framework for Internet traffic researchers who are desperate for *parsimonious* models of Internet traffic: any model with an immodest number of parameters is doomed to impracticality, because knowledgeable researchers know there is no hope of assigning meaningful values to all of the parameters. Put another way: parsimony in the context of Internet traffic is achievable only if the search for traffic invariants turns out to be successful.

Is There Hope? Is There Math?

Unfortunately, there exist no scientific inference recipes for the identification of traffic invariants in an abundance of high-quality, high-volume data sets of Internet traffic measurements. One can, of course, still try to find invariants by diligent manual analysis and hard or unconventional thinking. Any successfully identified invariant becomes worth its weight in gold, as it offers hope that some sort of coherent and parsimonious model of the network might actually prove attainable. In the following we outline briefly what we consider to be some of the successfully identified invariants to date.

First, while Poisson models have been decisively rejected as a basis for characterizing the arrivals of individual data packets in the Internet, there is solid evidence that these models do apply for the much more modest domain of characterizing the "arrivals" of humans to the Internet. That is, the times at which people begin using the Internet for a specific task do indeed conform to a memoryless process with an arrival rate that can be deemed constant over time intervals of many minutes to perhaps an hour. This invariant is based on data sets of Internet-related measurements that contain information about the start times of, for example, TELNET and FTP connections [PF95] or WWW sessions [FGWK98], collected over a number of years and at numerous locations.

Another, much more intriguing invariant is that when considering the sizes (in number of bytes or packets) or durations (measured in seconds) of a set of network sessions or connections, one almost always finds that the empirical distribution exhibits the heavy-tailed property (2), with $\beta < 2$ and sometimes even $\beta \approx 1$. These cases indicate extreme variability: $\beta < 2$ means that the traffic process at hand is well modeled as exhibiting *infinite variance*, and in the case $\beta \leq 1$ as having an *infinite mean.*

Figure 5 illustrates that these heavy tails are very well grounded in measured data. The data for this plot came from a day's WWW traffic at a large research laboratory. The day was chosen arbitrarily from (literally) hundreds of days' worth of recorded traffic. We now look at the size of each WWW connection. All in all, there were 226,000 connections. If we restrict ourselves to those connections transferring at least 10,000 bytes (the upper 14% tail) and plot their complementary distribution function (2) against the corresponding size, both on a log-log scale, then we get the plot shown in Figure 5. A straight line on such a plot corresponds to tail behavior that agrees with that of a Pareto distribution, and its slope gives $-\beta$. It is strikingly clear that the more than 32,000 points plotted in Figure 5 do indeed fall on a line and that, with $\beta \approx 1.3$, the data are indeed consistent with *infinite variance.*

Note that the heavy-tail property is for the distribution of an *aggregate* property of a traffic source, such as how much total data it will send. It says nothing about *how* the source will in fact send the data when dividing them into a series of packets for transmission across the network. Consequently, one might well wonder to what use we can possibly put the finding of the infinite variance property at the session or connection level as a traffic invariant. The surprising answer is that there are new mathematical results that relate the presence of connection sizes or durations with infinite variance directly with the finding of fractal scaling in aggregate network traffic at the packet level! Thus, the compelling presence of the infinite variance property in data set after data set of connection-level Internet measurements has also become the bedrock of the shift away from Poisson-based modeling of data traffic over to fractal-based modeling. That it is an invariant therefore explains why fractal scaling is an invariant. In addition, it turned out to be the basis for a very simple physical explanation of the empirically observed fractal nature of aggregate network traffic (i.e., total number of packets or bytes per time unit). As such, heavy tails aided immensely in demystifying fractal traffic modeling.

Even more striking is that in fact the progression of results proceeded oppositely to what we outlined above. It was not the case that researchers observed the heavy-tailed or infinite variance property of individual connections and then went from there to postulate fractal traffic models. Instead, based on an extensive analysis of numerous traces collected from different local area networks during a four-year period and by applying the principles of "broadening the basis" and "borrowing strength from large data sets," some researchers first made the—at the time, nearly crazed—leap to postulate fractal traffic models [LTWW94]. Furthermore, while at that time the researchers could not directly answer the natural question of "Why fractal?" they did speculate as to possible mechanisms—speculation that basically told the network research community "go look for heavy tails." Once the researchers knew what to look for, they started finding them everywhere! For example, heavy tails can be found in: CPU time consumed by different processes, sizes of files in a file system, Web item sizes, inter-keystroke times when a person types, sizes of FTP bursts, and sizes and durations of bursts or idle periods of individual Ethernet connections.

These examples serve to illustrate that some of the hard-won progress to date toward getting to know the dynamics of Internet traffic has come from close collaborations between mathematicians and networking researchers. On the one hand, mathematicians feel generally overwhelmed by all the details related to the architecture of modern-day data networks, the underlying protocol hierarchies, and the different network technologies. Nevertheless, many of these apparently minor details need to be understood to ensure that the mathematics research does not become detached from the networking application. On the other hand, networking researchers are generally less interested in the fine details of a mathematical proof or definition but want to be convinced at an intuitive level and/or through empirical arguments. When left on their own, Internet experiments and instrumentation and the resulting measurements and prototypes are impressive engineering achievements, and the theoretical results in fractal geometry represent intriguing and beautiful mathematics. However, the prospect is that in combination they will contribute to a significantly improved understanding of the Internet.

Should Mathematicians Care?

The original finding of fractal scaling phenomena in Internet traffic was greeted with skepticism by many mathematicians. They considered it as yet another example of a "fad" that comes and goes, with ultimately nothing to show for it, similar to what had happened in other areas in the natural or social sciences such as hydrology, economics, or biophysics, where the fractal "craze" proved to be short lived and had absolutely no impact beyond some philosophical discussions about the general purpose of modeling.

What these mathematicians missed was that the application of fractal analysis to networking was fundamentally different from these other applications. In addition to Internet engineering reality being the driving force, the available data sets are unique and outstanding, not only with regard to volume and quality, but, more importantly, with respect to the amount of information that is contained in every observation (i.e., data packet). This information provides detailed knowledge about the different layers in the hierarchical structure of modern-day networks, about how the different protocols that operate on those layers interact with one another, and indirectly about interactions between the different connections that share a given link. The richness of the data has a profound impact on how the data sets are analyzed, interpreted, and modeled. It is difficult to think of any other area in the sciences where the available data provide such detailed information about so many different facets of behavior.

The switch from Poisson to fractal thinking in network traffic research has had a major impact on our understanding of actual network traffic, to the point where we now know why aggregate Internet traffic exhibits fractal scaling behavior over time scales from a few hundreds of milliseconds onwards. A measure of the success of this shift in thinking is that the corresponding mathematical arguments are at the same time rigorous and simple, are in full agreement with the networking researchers' intuition, and can be explained readily to a nonnetworking expert. An equally important part of this new understanding is the realization that we do not yet have a similarly clear picture of the dynamics of Internet traffic over fine time scales, from hundreds of milliseconds downwards, where the end-to-end congestion control mechanisms determine the flow of packets at the different layers in the networking hierarchy. However, recently reported empirical findings suggest that measured Internet traffic over those small time scales exhibits pronounced local irregularities that are consistent with *multifractal* scaling behavior and can be analyzed effectively using wavelet-based techniques. While wavelets can be expected to advance significantly the multifractal analysis of Internet traffic, the networking application is equally likely to influence the development of new wavelet-based techniques: ways to exploit fully the properties and rich structure of the available data sets.

Finally, we mention developments of a different nature that again beg for mathematical attention and hold promise for interesting mathematical problems. Several networking research projects are now working on *systematic* Internet measurements: sets of potentially thousands of "probe platforms" deployed throughout the network that engage in both independent and orchestrated measurement of network paths in attempts to characterize the network's behavior and to locate trouble spots. Such a networkwide view of Internet traffic dynamics includes both temporal and spatial dimensions, as well as a dimension defined by the different layers in the networking hierarchy. Clearly, the interesting problems here are those of interactions, correlations, and heterogeneities in time, space, and across the different networking layers. In addition, when the ultimate goal is to enable the tens of millions of Internet users to determine what performance they can obtain from the network, irrespective of where they are and when they want this information, and how to improve the engineering of the network to meet their myriad needs, then the analysis problems acquire a central element of *scale*, extending well beyond what has previously been attempted. While the sheer scale may appear daunting, we still have the significant advantage of superb data sets with which to work. The problems then acquire a character of tantalizing challenge, and solving them moves beyond mere interesting mathematics into the regime of answering questions that will help determine just how effective this monstrous emerging global infrastructure actually proves.

Acknowledgments

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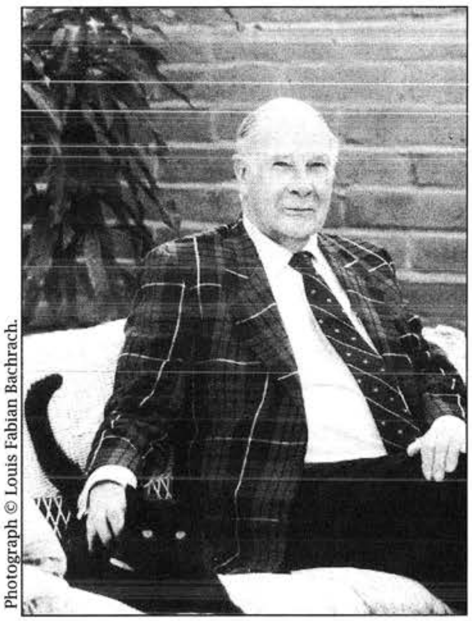
Richard Wesley Hamming (1915–1998)

Samuel P. Morgan



Photograph © Louis Fabian Bachrach.

Richard W. Hamming

Richard Wesley Hamming, mathematician, pioneer computer scientist, and professor, died of a heart attack on January 7, 1998, in Monterey, California, at the age of eighty-two. His research career began at Bell Laboratories in the 1940s, in the early days of electronic computers, and included the invention of the Hamming error-correcting codes. In the 1970s he shifted to teaching, and at his death he was Distinguished Professor Emeritus of computer science at the Naval Postgraduate School. He is survived by his wife, Wanda, a niece, and a nephew.

Dick Hamming, as he was known to friends, was born in Chicago on February 11, 1915. He received a B.S. in mathematics from the University of Chicago in 1937, an M.A. from the University of Nebraska in 1939, and a Ph.D. in mathematics from the University of Illinois in 1942. His doctoral thesis, written under the supervision of W. J. Trjitzinsky, was entitled "Some Problems in the Boundary Value Theory of Linear Differential Equations".

After brief teaching positions at the University of Illinois and the University of Louisville, Dick was recruited in 1945 to work at Los Alamos to run the IBM machines that were doing calculations for the Manhattan Project. Wanda followed him to Los Alamos, where she was hired to use a desk calculator, working eventually for Enrico Fermi and Edward Teller. Although Dick jokingly described his position at Los Alamos as "computer janitor", the work gave him a vision of the role that numerical computation was destined to play in the scientific and technological world of the future. He saw that experiments were going to be possible with computers that were not possible in the laboratory, and he stayed at Los Alamos for six months after most of the other scientists had left "to figure out," as he told *IEEE Spectrum* in 1993, "what had happened there, and why it had happened that way."

Dick arrived at Bell Laboratories in 1946 and joined a group of applied mathematicians that included the communication theorist Claude Shannon and the statistician John Tukey. The group regarded itself as chartered to "do unconventional things in unconventional ways and still get valuable results." Dick was hired to do elasticity theory, but the presence of computers required him to spend more and more time on them, and his career became centered on bringing large-scale scientific computation into Bell Labs. Much of his research between 1946 and 1960 dealt with error-correcting codes and predictor-corrector methods for numerical integration. At this time he also developed an interest in digital filters that continued throughout his career. He was from time to time promoted to head a department of re-

Samuel P. Morgan retired in July 1998 as a Distinguished Member of Technical Staff at Bell Laboratories. His e-mail address remains spm@research.bell-labs.com.

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searchers, but since he explicitly did not want management responsibilities, these assignments always came to an end. My contacts with Dick were during the years 1947–76 while we were colleagues, first in the Mathematics and Statistics Research Center and then in the Computing Science Research Center at Bell Labs.

After 1960 Dick became increasingly interested in teaching and writing. Between 1960 and 1976, while retaining his base at Bell Labs, he held visiting or adjunct professorships at Stanford University, the City College of New York, the University of California at Irvine, and Princeton University. In 1976 he retired from Bell Labs to become an adjunct professor (later senior lecturer) of computer science at the Naval Postgraduate School. He became Distinguished Professor Emeritus in 1997 and taught his last class in December 1997.

Among Dick's professional honors were the Turing Award (1968) of the Association for Computing Machinery (ACM), the Emanuel R. Piore Award (1979) of the Institute of Electrical and Electronics Engineers (IEEE), and the Harold Pender Award of the University of Pennsylvania (1981). In 1988 the IEEE Richard W. Hamming Medal, "For exceptional contributions to information sciences and systems," was named after him, and he was the first recipient. In 1996 in Munich he received the prestigious $130,000 Eduard Rhein Award for Achievement in Technology for his work on error-correcting codes. He was president of the ACM (1958–60), a member of the National Academy of Engineering, and a Fellow of IEEE.

Dick wrote nine books, some of which went through multiple editions (see sidebar, page 1015). He published some seventy-five technical articles and held three patents.

Error-correcting Codes

Dick is most famous for inventing the Hamming error-correcting codes [1] and for the concept of Hamming distance, which is central to coding theory. Data in digital systems are typically stored, transmitted, and processed in binary form as blocks of bits. If a single bit is in error, the message is garbled or the computation spoiled. In large-scale computers or telephone switching systems, an enormous number of computations must be performed without a single error in the end result. Dick set himself the task of making the computer itself detect and correct isolated errors so that the computation could proceed in a way that would be more efficient than simply doing everything three times and accepting the majority result.

His approach was based on a generalization of parity checking. A simple parity check works as follows. Suppose we have a block of n bits and add an $(n+1)$st bit so that the whole message has an even number of 1's in it. This is called an even parity check. At the receiving end, if there are not an even number of 1's in the message, then there must be an odd number of errors in the message. If bit errors occur independently and if the message is short and the bit error rate is small, then the message most probably contains a single error, but we do not know which bit is incorrect.

Position							Decimal
1	2	3	4	5	6	7	Value
0	**0**	0	**0**	0	0	0	0
1	**1**	0	**1**	0	0	1	1
0	**1**	0	**1**	0	1	0	2
1	**0**	0	**0**	0	1	1	3
1	**0**	0	**1**	1	0	0	4
0	**1**	0	**0**	1	0	1	5
1	**1**	0	**0**	1	1	0	6
0	**0**	0	**1**	1	1	1	7
1	**1**	1	**0**	0	0	0	8
0	**0**	1	**1**	0	0	1	9
1	**0**	1	**1**	0	1	0	10
0	**1**	1	**0**	0	1	1	11
0	**1**	1	**1**	1	0	0	12
1	**0**	1	**0**	1	0	1	13
0	**0**	1	**0**	1	1	0	14
1	**1**	1	**1**	1	1	1	15

Table 1. Hamming code with $r = 3$.

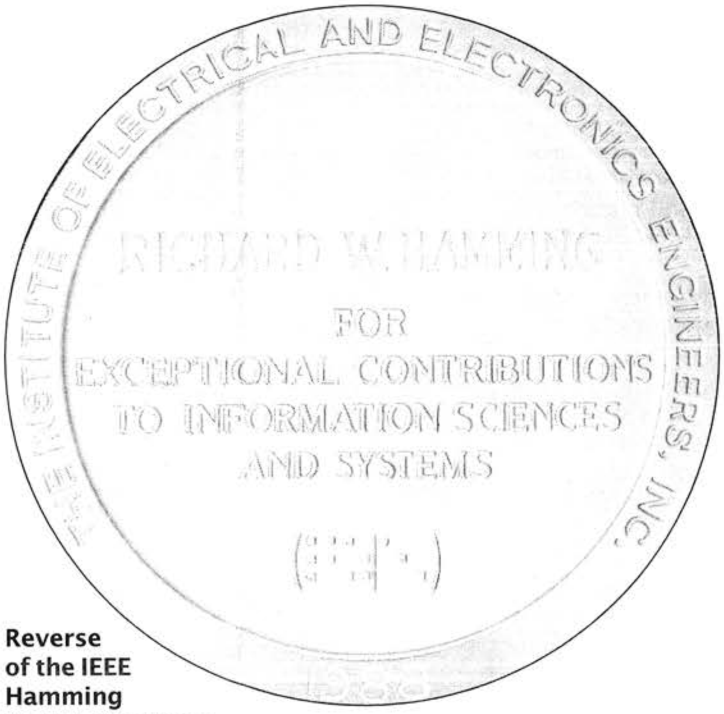
The Hamming codes use multiple parity checks to locate and correct single-bit errors. Each check is now a sum only over bits in selected positions. In the simplest case, message words of length $2^r - r - 1$ bits, where r is any integer, are to be sent together with r check bits, so that each code word (message bits plus check bits) contains $2^r - 1$ bits. The positions of the code word are numbered from left to right. The first check bit is in position 1 and is a parity check over the positions that have a 1 as the least significant bit of their binary representations (that is, positions 1, 3, 5, 7, ...). The second check bit is in position 2 and is a parity check over the positions that have a 1 as the second least significant bit of their binary representations (that is, positions 2, 3, 6, 7, ...). The third check bit is in position 4 and checks the positions that have a 1 as the third least significant bit (positions 4, 5, 6, 7, 12, ...), and so on. If no parity checks fail, the code word is assumed to be correct. If one bit of the code word is in error, the error is at the location whose binary representation equals the pattern of the failed parity checks.

Table 1 shows the Hamming code for $r = 3$. The check bits, in boldface, are in positions 1, 2, and 4 of each code word. Their values may be computed from the remaining (message) bits, which represent the numbers 1 through 15 in binary.

The photograph (next page) shows the reverse of the IEEE Hamming medal, which carries the parity check matrix

$$\mathbf{H} = \begin{pmatrix} 1 & 1 & 1 & 0 & 1 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 1 & 0 & 0 & 1 \end{pmatrix}$$

for the Hamming code of Table 1. **H** is used as follows, with a permuted version of Table 1 in which the positions are renumbered in the order 7 6 5 3 4 2 1 to bring the check bits to the end of



Reverse of the IEEE Hamming Medal, showing a parity check matrix for a Hamming error-correcting code.

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the code word. Let **r** be a binary column vector of length 7 representing any received word, not necessarily a code word. Using Boolean arithmetic, calculate

$$\mathbf{s} = \mathbf{Hr},$$

where **s** is a binary column vector of length 3. If $\mathbf{s} = 0$, then **r** is a code word. Otherwise, **s** will coincide with one of the 7 columns of **H**. If **s** coincides with the ith column of **H**, then the ith bit of **r** is in error and must be reversed in order to recover the correct code word.

Error-correcting codes can be interpreted geometrically. Define the *Hamming distance* between two code words as the number of positions in which the code words differ. The minimum Hamming distance between code words in Table 1 is 3. Since a single-bit error moves a received word a distance 1 from the correct word, single-bit errors can be unambiguously corrected by changing the received word to the nearest code word. Furthermore, Hamming codes are *perfect*, in the sense that every received word is at a distance at most 1 from a code word. It is easy to verify that the number of code words times the number of words that are at a distance no greater than 1 from a code word is equal to the total number of possible words. This means that every pattern of check failures actually occurs for some single-bit error in the transmitted word. More recent codes, which undertake to correct more than a single error, are rarely perfect; that is, some patterns of bit errors can occur that do not lead to unambiguous decoding.

Dick observed that a code having a minimum Hamming distance $2t + 1$, where t is any integer, can correct t errors; and if the minimum distance is $2t + 2$, the code can correct t errors and detect, but not correct, $t + 1$ errors. The codes described above are single error correcting, and by adding an additional parity bit to each word they become double error detecting. These codes solved a large part of the maintenance problem for telephone company switching equipment, and "Hamming bits" went into computer memories in the late 1950s, for example, in the IBM 7030 Stretch supercomputer.

We can indicate briefly how the Hamming codes are related to some families of multiple-error-correcting codes that are in current use. In general, a linear error-correcting code may be characterized by the number triple $[n, k, d]$, where n is the number of symbols in the code words, k is the number of symbols in the message words, and d is the minimum distance. Thus, the code of Table 1 is a $[7, 4, 3]$ code.

In algebraic coding theory, message words and code words are represented by polynomials with coefficients over a Galois field $GF[q]$ of order q, where q is a power of a prime. The polynomial $c(X)$ representing a code word is obtained by multiplying the message polynomial $m(X)$ by a fixed generator polynomial $g(X)$. Two related families of codes, both invented about 1960, permit the correction of an arbitrary number of errors by the use of appropriate redundancy.

Bose-Chaudhuri-Hocquenghem (BCH) codes can be (although they need not be) constructed over the field $GF(2)$. A binary BCH code with code word length $2^r - 1$ and minimum distance at least $2t + 1$, so that it will correct t errors, can always be constructed with at most rt check digits. That is, the code will have performance at least as good as

$$[2^r - 1,\ 2^r - 1 - rt,\ 2t + 1].$$

When $t = 1$, this BCH code is equivalent to a Hamming single-error-correcting code, up to a permutation.

Reed-Solomon (RS) codes are constructed over a field $GF(q)$, where q is a prime power and $q > 2$. Reed-Solomon codes are maximum distance separable codes; that is, the code constructed over $GF(q)$ with minimum distance d is described by the triple

$$[q - 1,\ q - d,\ d].$$

For example, NASA uses a $[255, 223, 33]$ RS code over $GF(2^8)$ for deep-space communication. In another widely used application, a $[32, 28, 5]$ code and a $[28, 24, 5]$ code are used in an interleaved scheme to correct burst errors of length up to 4000 bits on compact discs [2].

In a sense, Dick's 1950 paper set off the current avalanche of coding theory and applications, although he left it to others to ride the avalanche.

Numerical Analysis

Much of Dick's early work was in numerical analysis. One of his contributions to this field was the Hamming predictor-corrector (PC) set for ordinary differential equations.

Numerical integration of an ordinary differential equation, say, $y' = f(x, y)$, consists of finding approximate values of y at a set of equispaced values of x. Milne's method was a once-popular approach. Briefly, Milne predicts the next value of y using the predictor

$$\bar{y}_{n+1} = y_{n-3} + \frac{4h}{3}[2y'_n - y'_{n-1} + 2y'_{n-2}],$$

where h is the step size or spacing between values of x. Milne then corrects the value of y using the corrector

$$y_{n+1} = y_{n-1} + \frac{h}{3}[\bar{y}'_{n+1} + 4y'_n + y'_{n-1}].$$

For any PC method the starting values of y have to be found by some other method, such as Runge-Kutta.

Unfortunately, Milne's method is unstable; that is, errors due to roundoff noise are amplified as the solution progresses. The problem may not be serious if one is trying to follow a growing solution, such as the solution $\exp(\lambda x)$ of $y' = \lambda y$ when $\lambda > 0$. However, if one attempts to track a decreasing solution, such as $\exp(\lambda x)$ when $\lambda < 0$, the roundoff noise eventually swamps the desired solution.

Dick made a general study [3] of PC methods using Milne's predictor together with correctors of the form

$$y_{n+1} = ay_n + by_{n-1} + cy_{n-2} + h[d\bar{y}'_{n+1} + ey'_n + fy'_{n-1}],$$

where $a, b, \dots, f$ are arbitrary constants. On the basis of various criteria, he proposed the corrector

$$y_{n+1} = \frac{1}{8}[9y_n - y_{n-2}] + \frac{3h}{8}[\bar{y}'_{n+1} + 2y'_n + y'_{n-1}].$$

The Hamming corrector is stable—that is, roundoff errors are damped out—for equations like $y' = \lambda y$ when λ is negative so long as h satisfies $-2.6 < h\lambda < 0$.

The Hamming PC set held the field for a number of years. Recently the Adams-Bashforth set, which uses an extra value of the derivative and has a slightly larger stability region, has found favor [4, 5]. However, the nature of the problem to be solved often plays a role in choosing a numerical integration method.

Hamming Maxims

The purpose of computing is insight, not numbers.

It is better to do the right problem the wrong way than to do the wrong problem the right way.

Let's not raise the falutin' index [an injunction against the use of pretentious, "high-falutin'" terminology].

If you don't work on important problems, it's not likely you'll do important work.

If the prediction that an airplane can stay up depends on the difference between Riemann and Lebesgue integration, I don't want to fly in it.

Hamming's Books

Numerical Methods for Scientists and Engineers, McGraw-Hill, 1962; 2nd ed. 1973; Dover reprint 1985; translated into Russian.

Calculus and the Computer Revolution, Houghton-Mifflin, 1968.

Introduction to Applied Numerical Analysis, McGraw-Hill, 1971.

Computers and Society, McGraw-Hill, 1972.

Digital Filters, Prentice-Hall, 1977; 2nd ed. 1983; 3rd ed. 1989; translated into several European languages.

Coding and Information Theory, Prentice-Hall, 1980; 2nd ed. 1986.

Methods of Mathematics Applied to Calculus, Probability and Statistics, Prentice-Hall, 1985.

The Art of Probability for Scientists and Engineers, Addison-Wesley, 1991.

The Art of Doing Science and Engineering: Learning to Learn, Gordon and Breach, 1997.

Dick's greatest influence on numerical analysis was probably through his two books on the subject [4, 6]. The books were organized for the nonspecialist user, with general methods subsuming special cases, and always with an eye toward what works in practice. They were unique in their focus on the whole context in which the numerical analyst should function. Dick insisted that the user of numerical methods should consider both the source of the problem and the use to which the results were going to be put. He enjoyed working with physicists, chemists, and engineers and was remarkably adept at dealing with "walk-in" problems. His clientele extended over a large part of Bell Labs.

Finally, Dick's books were full of unobtrusive good ideas. For example, he suggested a technique for estimating the level of systematic inaccuracy in a computed "black box" function. He observed that taking higher-order differences of a set of function values tends eventually to produce quantities with a telltale pattern of alternating signs, at which point the size of the remaining numbers re-

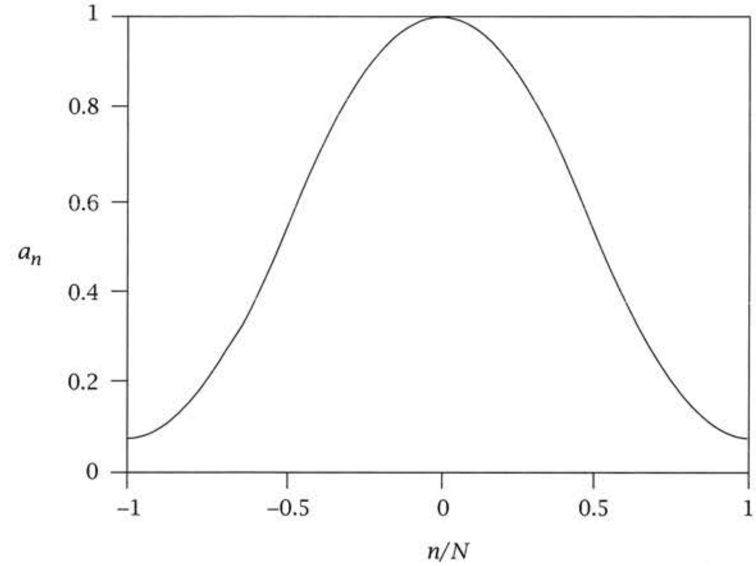

Figure 1. Hamming window weight coefficients.

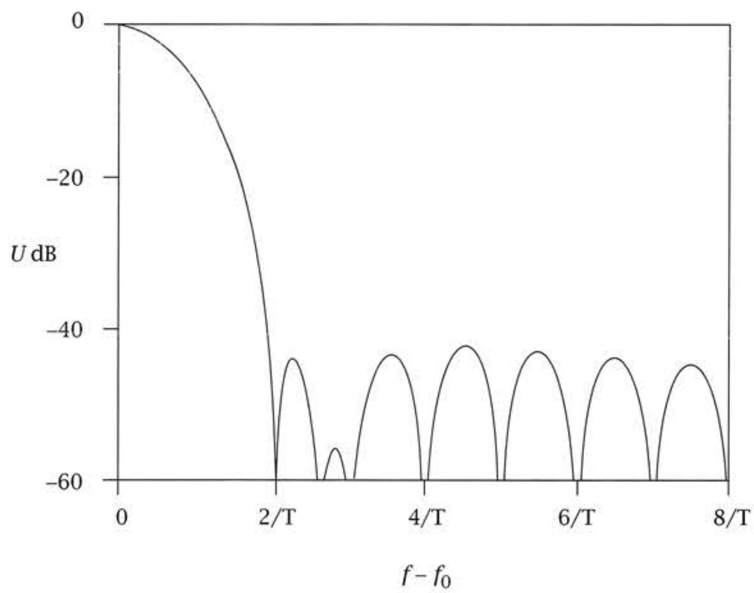

Figure 2. Hamming window frequency transform.

flects the absolute error in the computation. This observation is routinely used in scientific computing to estimate accuracy when only function values are available.

Digital Filters

Dick's contributions to digital filters began during his first years at Bell Labs and were initially stimulated by his association with Ralph Blackman and John Tukey [7]. In this field he is credited with the invention of the *Hamming window*, which may be explained as follows.

In mathematical terms, a digital filter is realized by a linear combination of equispaced samples of a function of time, taken over an interval T. For example, if the input function is $u(t)$ and there are $2N + 1$ samples, the output of the filter at a particular time is

$$\sum_{n=-N}^{N} c_n u(t + nT/2N),$$

where the c_n are the filter weights.

The properties of a digital filter are defined in terms of its effect on the harmonic time function $u(t) = \exp(2\pi i f t)$. Usually the filter is designed to pass a particular frequency, say f_0, and to discriminate against nearby frequencies. In order to make the center frequency f_0 explicit, it is convenient to introduce phases into the weight coefficients by writing

$$c_n = a_n \exp(-n\pi i f_0 T/N).$$

Then we are interested in the function

$$U(f) = \sum_{n=-N}^{N} a_n \exp[n\pi i(f - f_0)T/N],$$

which is the response to $\exp(2\pi i f t)$ and is called the *frequency transform*. The coefficients a_n are called the *filter window*.

The frequency transform $U(f)$ typically has a principal maximum, or main lobe, at f_0 and subsidiary maxima, or side lobes, at other frequencies. In some applications it is desirable to keep the magnitudes of the side lobes as low as possible with respect to the main lobe.

Dick found a set of filter coefficients [7, 8] that are particularly effective in suppressing side lobes. The coefficients of the Hamming window are given by

$$a_n = 0.54 + 0.46 \cos n\pi/N$$

for $-N \le n \le N$. The Hamming window, which has also been called a raised cosine on a pedestal, is shown in Figure 1.

The series for $U(f)$ can be summed explicitly for a Hamming window with any value of N. However, the limiting value for large N is particularly simple. Up to normalization it is

$$U(f) = \frac{0.54 \sin[\pi(f - f_0)T]}{[\pi(f - f_0)T]} + \frac{0.46[\pi(f - f_0)T] \sin[\pi(f - f_0)T]}{\pi^2 - [\pi(f - f_0)T]^2}.$$

The quantity $20 \log_{10} |U(f)/U(f_0)|$, that is, the normalized value of the frequency transform in decibels, is plotted in Figure 2. The transform is symmetric about $f = f_0$, and the lobe widths are inversely proportional to the width T of the time window. The highest side lobe is 42.68 dB below the main lobe.

For comparison, a uniform window, in which all the coefficients a_n are equal, corresponds to the transform

$$U(f) = \frac{\sin[\pi(f - f_0)T]}{[\pi(f - f_0)T]},$$

whose highest side lobe is only 13.27 dB below the main lobe.

Window design involves various tradeoffs: for example, between the width of the main lobe, the height of the largest side lobe, and the rate of rolloff of the distant side lobes. Different window functions have been designed to meet different requirements, but the Hamming window is perhaps the most widely used because of its simplicity and effectiveness.

Dick's long interest in digital filters led him to write a succinct monograph [8] that is now in its third edition. Much of the literature on digital filter design appears in electrical engineering journals and makes heavy use of the terminology of that field. Dick's book aims to make the mathematical ideas that underlie the analysis and design of filters available to a broad audience. A hallmark of Dick's writing is his attempt to avoid jargon. His book on digital filters is a classic example of this writing. The book is filled with his unique insights, which make it a valuable reference for practitioners of the digital filter design art.

Dick came into the world of computing just as it was emerging from the era of desk calculators and entering the era of electronic computers. He saw, much sooner and more clearly than most of his colleagues, how the daily work of almost everybody at Bell Labs would come to depend on computers. In the early 1960s he predicted that half the budget of Bell Labs would eventually go to computing; his estimate, which proved to be low, was much higher than anyone else's. He made it his business to educate the organization for the change.

As a numerical mathematician he undertook to teach scientists and engineers how to use computers to solve their problems in a hands-on way. His best-known maxim, "The purpose of computing is insight, not numbers," anticipated that the user would watch the computation as it proceeded and might use the ongoing results to gain additional insight into the original problem.

Dick's approach to numerical mathematics was highly effective in its day. Today's world of software libraries is superficially quite different. Nowadays most users of numerical mathematics depend on software packages that are written by specialists and may be highly sophisticated. However, in the modern world of canned software, faster computers, and bigger and more complex problems Dick's maxims for and warnings to users are more important than ever before.

Dick was concerned that the user would not understand the algorithms and/or would use them incorrectly. The main concern today is communicating the physical problem to the software package correctly. Dick noted that "a good theoretician can account for almost any result that is produced, right or wrong," which makes it important to be able to tell if we have a sensible answer. Customers of computing software need to be skeptical of the results produced. The worry here is not that the software tools will incorrectly solve the problem as posed. The real worry is that the problem as posed may not be the problem the user wants solved. Because of the difficulty of monitoring what goes on inside a large software package and of interpreting diagnostics that may come from different parts of the package, it is important to lay out in advance some checkable conditions that the solution must satisfy (for example, conservation laws for systems of partial differential equations). There is still no substitute for Dick's emphasis on common-sense thinking.

Dick Hamming made seminal contributions to computer science in its early days, and as a person he was never dull. He had strong opinions, and he liked to express them. His voice comes through in his books in a way that few technical authors achieve. He liked to give people advice, especially young people, whom he would educate and entertain with his often-repeated lecture "You and Your Research". He enjoyed the speaker's platform, and on occasion he enjoyed, as he jokingly said, "hamming" with a small *h*. One might agree or disagree with a Hamming pronouncement (I agreed with him much of the time), but no one who ever met him or heard him is likely to forget him.

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Book Review

Polyhedra

Reviewed by Bill Casselman

Polyhedra
Peter R. Cromwell
Cambridge University Press, 1997
460 pages
Hardcover $44.95 (£30.00 U.K.)
ISBN 0-521-55432-2

This is an unusual book, one hard to classify, but certainly valuable and a labor of love. It is a book on what might be called the classical theory of polyhedra, as opposed to the modern theory of polytopes. It is concerned mostly with three-dimensional geometry and indeed mostly the geometry of previous centuries, although it does discuss recent and nonnegligible contributions to the main topic. It is probably not quite suitable as a text for an undergraduate geometry course, but it would prove invaluable as a reference book in such a course. The cost of the book is not excessive if the book is priced by size (!), but a paperback version would perhaps be more affordable for an undergraduate.

This is not a book on the history of geometry, but it includes many historical digressions in a somewhat informal but entertaining style. As a proper geometry book ought to, it contains many useful geometrical illustrations and some extremely impressive, even beautiful, figures excerpted from classical works of mathematics. The quality of the author's illustrations in the book might be slightly better, but the sheer quantity of figures is overwhelming, and the linkage between illustrations and discussion in the text is on the whole extremely good. It is perhaps unfortunate that almost the first illustration accompanying a proof, that of the incommensurability of the side and diagonal of a regular pentagon, is poorly conceived.

The major virtue of the book is that the author has managed to find many interesting paths in mathematics not often traveled. One pleasant feature is that many, if not most, arguments in the book seem to have been taken from original sources, but with useful and enlightening modifications.

The topics covered in Chapter 1 include a few brief remarks on early geometry among the Egyptians and Babylonians and a short discussion of the Greek discovery of irrationality. There is not much originality in these sections, which make up perhaps the weakest part of the book. It then discusses the volume of prisms, including some less well-known material from a classic Chinese work with some illuminating accompanying figures. It then discusses Hilbert's third problem, the one that originated with Hilbert's theory of equidecomposability and led to Dehn's discovery of the scissors equivalence classes of three-dimensional polyhedra.

Chapter 2 is on more or less regular polyhedra. The author describes the explicit construction of the five Platonic solids, dealing nicely with the different possible notions of regularity. (He takes up this account again later on in the first part of Chapter 6.)

Chapter 3 is an interesting tour of the history of geometry from the Hellenistic era through the

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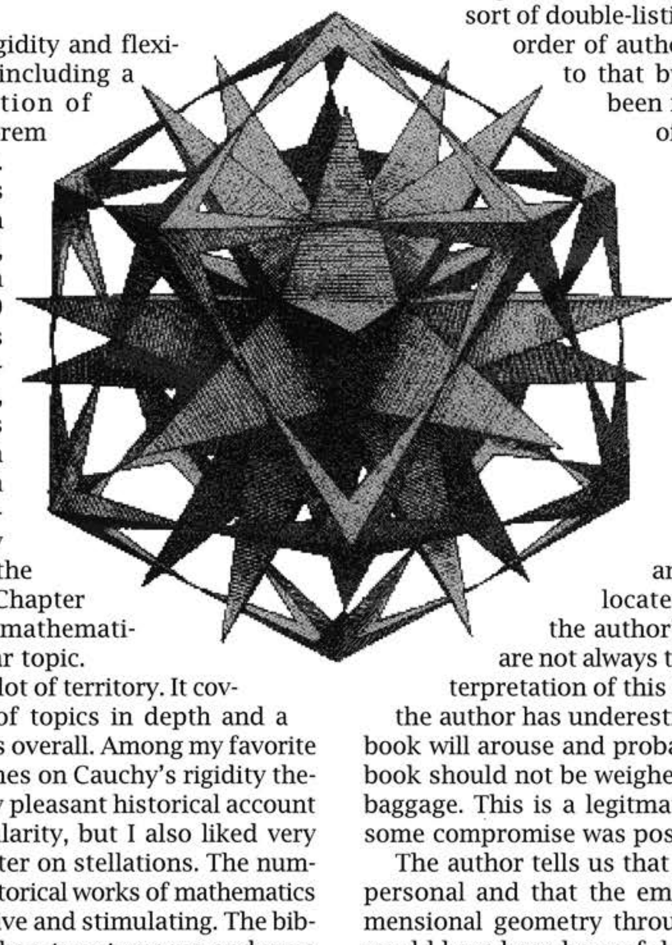
Renaissance. Again, this is not so much a history as a sequence of historically based digressions, but these digressions are often fascinating.

Chapter 4 is on relatively obscure but nonetheless intriguing geometrical work of Kepler.

Chapter 5 is about Euler's formula for what we call the Euler characteristic of polyhedra. It includes discussion of contributions of Descartes, Legendre, Cauchy, Möbius, and Poinsot, as well as less well-known mathematicians such as L'Huilier and Hessel.



Chapter 6 is on rigidity and flexibility of polyhedra, including a fairly clear exposition of Cauchy's rigidity theorem for convex polyhedra.

Chapter 7 includes a very clear discussion of stellated polyhedra, and Chapter 8 is on symmetry. Chapters 9 and 10 are on various combinatorial questions about polyhedra, including various ways to color them and a very useful discussion of the role of computers in the proof by Appel and Haken on the four-color theorem. Chapter 10 will be for most mathematicians the least familiar topic.

This book covers a lot of territory. It covers a small number of topics in depth and a huge number of topics overall. Among my favorite discussions are the ones on Cauchy's rigidity theorem, including a very pleasant historical account of the notion of regularity, but I also liked very much the whole chapter on stellations. The number of little- known historical works of mathematics referred to is impressive and stimulating. The bibliography fills more than twenty pages and runs from items by Plutarch, Alberti, Dürer, Pacioli, Vasari, Descartes, Bonnet, and dozens of authors whose names I had never seen before, through Ernst Haeckel, Joseph Needham, Otto Neugebauer, and J. V. Field, and onto the more usual fare of Heath, Coxeter, Hilbert, Grünbaum, and Senechal. The history told in the book is rarely deep, but the breadth of topics covered more than makes up for that minor flaw. It seems likely that the author has actually examined most of the items, both well known and obscure, that he refers to.

I have a few minor complaints. The reference list is huge, and it is likely that most, if not all, of the items in the list are referred to in some way or another sooner or later. The author gives the sources for quotations, but no precise references for topics covered—no footnotes or numbered references, for example—and the task of tracking down particular topics among the references will often be daunting. My own ideal in this regard, in a book not unlike this one in many ways, is Neugebauer's *The Exact Sciences in Antiquity*, where at the end of each chapter references are threaded together beautifully. In *Polyhedra*, however, one is left on one's own. Better organization of the references would have been especially valuable considering the magnitude of the reference list. Even some sort of double-listing, one in alphabetical order of author's names in addition to that by chapter would have been nice. Another problem of a similar nature is that there are several figures extracted from old, even rare, editions of classical works. These are often extremely intriguing figures which one might like to see, so to speak, in the flesh. But in order to find them one would have to know the exact source—in which edition, for example, the figures were located and perhaps where the author's copy was found. We are not always told these things. My interpretation of this sort of problem is that the author has underestimated the interest his book will arouse and probably feels also that the book should not be weighed down with scholarly baggage. This is a legitmate concern, but surely some compromise was possible.

The author tells us that his choice of topics is personal and that the emphasis is on three-dimensional geometry throughout, but even so it would have been be useful to have some mention of a larger context for some topics. He discusses symmetries of three-dimensional polyhedra, for example, but there is no explicit mention of Coxeter groups (generated by reflections) despite the special role they play even in three dimensions. The proof of the existence of the regular polyhedra is essentially the classical proof, which seems to modern mathematicians a bit disjointed. In the section on Cauchy's enumeration of star polyhedra (Chapter 7) the author comes close to the proof of existence, appealing directly to symmetry that was apparently first discovered by Tits (explained in the one great book by Bourbaki), but doesn't quite get to it. Of course, this may be one place where the author feels the topic is so well covered elsewhere that it is not necessary to cover it here. Also missing is a discussion of the relationship between Poinsot's regular polyhedra and Riemann surfaces of higher genus, discovered by Du Val and Threlfall, which many find the most intriguing properties of these unusual geometrical objects.

The discussion of Cauchy's rigidity theorem is useful and original, and Cromwell's treatment of the famous lacuna in Cauchy's proof I found to be especially interesting, but it is still difficult to follow if one wants a complete proof, and most readers will want to look elsewhere for additional light. (My own favorite discussion is the one in Heinz Hopf's Springer Lecture Notes.) Perhaps because it is so well known, his discussion of the area formula for spherical triangles is brief, accompanied by no pictures. (Cromwell seems not to be aware of Thomas Harriot's unpublished but well-known proof from the year 1603.)

The figures Cromwell includes from historical documents are fine, but his own graphical work is occasionally lacking in panache. Even in the age of computers, drawing complicated figures in three dimensions is not easy, and in view of the sheer quantity of figures he does include this should not be counted a major sin. It is tempting to contemplate the nature of technological progress by contrasting the extraordinary detail in the figures reproduced from a sixteenth-century work by Wenzeln Jamnitzer with the rather spare illustrations made by the author himself. The revolution in mathematical typography brought about by TeX has not yet been extended to mathematical graphics. On the other hand, there is an insert of several color photographs of very fine quality.

There are a fair number of spelling and typographical errors in the book. An errata list (including a few replacement pages in PostScript) and other interesting things can be found at the author's Web page:

`http://www.liv.ac.uk/~spmr02/book/`.

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Note: Image on page 979 reprinted from *Perspectiva corporum regularium* by W. Jamnitzer (Graves 148.f.13), permission of University College London Library.

Kiyosi Itô Receives Kyoto Prize

KIYOSI ITÔ is to receive the 1998 Kyoto Prize in the category of Basic Sciences. The prize, which carries a cash award of 50 million Japanese yen (approximately $350,000), is presented by the Inamori Foundation and is Japan's highest private award for lifetime achievement.

The Research of Kiyosi Itô

Kiyosi Itô has made great contributions to the advancement of mathematical sciences, physics, engineering, biology, and economics through his research in stochastic analysis. He is primarily known for his invention of stochastic differential equations, which enable us to describe random motions—similar to Brownian motion—and random phenomena in nature and society. Solving a stochastic differential equation leads to the construction of a probability measure in the path space.

The notion of Brownian particles, which grew out of observation of the motion of pollen grains in water, was first studied by physicists A. Einstein, J. Perrin, and others at the beginning of the twentieth century. In 1923 N. Wiener laid the mathematical foundation for stochastic analysis by constructing a probability measure on the path space which describes Brownian motion.

In the subsequent establishment and development of modern probability theory, the initiation of Itô's theory of stochastic differential equations in 1942 brought about drastic changes in stochastic analysis. He reconstructed stochastic analysis as analysis based on the notion of stochastic integrals. This theory continues to play a key role in the foundation of stochastic analysis. Coincidentally, during that same year R. Feynman, the winner of the 1965 Nobel Prize in Physics, submitted his doctoral dissertation on physics based on path integrals.


Photograph courtesy of Inamori Foundation.

Kiyosi Itô

Since the early 1950s the theory of stochastic differential equations has been gaining new perspectives through interactions with various branches of mathematics, including partial differential equations, potential theory, harmonic integrals, differential geometry, and harmonic analysis, as well as theoretical physics. Thanks to the efforts of P. Malliavin, S. Watanabe, and others, we now have a mathematically well-established calculus on path spaces. Attempts have been made to develop asymptotic analysis and differential geometry on path spaces as well.

Itô's initial motivation for developing stochastic differential equations was purely mathematical. However, this theory wound up reaching far beyond the confines of mathematics and has been playing a crucial role in various applications in physics, biology, economics, and engineering. Itô's theory of stochastic differential equations, now known as the "Itô calculus", is one of the indispensable tools in analyzing random phenomena. It may not be an exaggeration to say that the research on filtering done by R. Kalman, the 1985 Kyoto Prize laureate in Advanced Technology, could not have developed to its current stage without stochastic differential equations. In the mathematical finance research of F. Black and M. Scholes, who received the 1997 Nobel Prize in Economics, the Itô calculus played a role analogous to that played by ordinary calculus in classical mechanics. Stochastic differential equations and "Itô's formula" for stochastic integrals are indispensable tools nowadays, even in the real world of finance. Virtually no textbook on mathematical finance fails to have a chapter on the Itô calculus. Itô has made significant contributions to many other topics as well, such as one-dimensional generalized diffusion processes and multiple Wiener expansions.

Itô's work in stochastic analysis, along with the central role he has played in its subsequent development, typify the twentieth-century mathematical sciences—having mathematical depth and strong interaction with a wide range of areas.

Biographical Sketch

Kiyosi Itô was born on September 7, 1915, in Hokusei-cho, Mie Prefecture, Japan. He graduated from the Imperial University of Tokyo in 1938. He served in the Statistics Bureau of the Cabinet Secretariat of Japan from 1939 until 1943, when he became an assistant professor in the Faculty of Science at Nagoya Imperial University. In 1945 he received his D.Sc. from the Imperial University of Tokyo. He became a professor at Kyoto University in 1952 and professor emeritus in 1979. He held concurrent positions at the Institute for Advanced Study (1954–75), Aarhus University (1966–69), Cornell University (1969–75), and Gakushuin University (1979–85). He served as director of the Research Institute for Mathematical Sciences at Kyoto University from 1976 to 1979.

Itô has received some of Japan's highest honors, including the Asahi Prize (1978), the Imperial Prize and the Japan Academy Prize (1978), and the Fujiwara Prize (1987). He also received Israel's Wolf Foundation Prize in 1987. He is an associate foreign member of the Académie des Sciences of France, a member of the Japan Academy, and a foreign member of the U.S. National Academy of Sciences. He has received honorary degrees from the Swiss Federal Institute of Technology in Zurich and the University of Warwick.

About the Prize

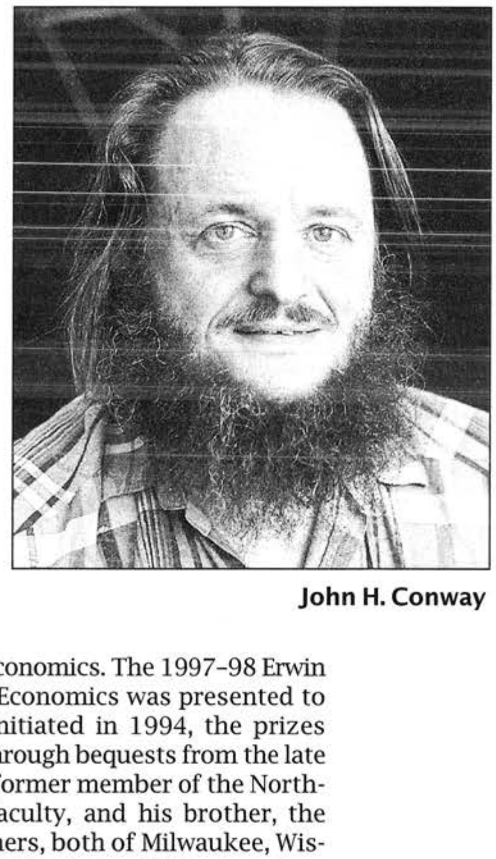
The Kyoto Prizes are presented annually by the nonprofit Inamori Foundation to recognize individuals and groups worldwide who have made significant contributions to the betterment of humanity. The foundation was established in 1984 through a personal endowment of $200 million from Kazuo Inamori, the founder and chairman emeritus of the Kyocera Corporation, the world's top producer of technical ceramics, and DDI Corporation, one of Japan's leading telecommunications providers.

Two other Kyoto Prizes are to be presented this year: biologist Kurt Wüthrich is to receive the Advanced Technology prize and media artist Nam June Paik is to receive the prize for Creative Arts and Moral Sciences. Each laureate will receive a diploma, a Kyoto Prize medal of 20 karat gold, and a cash gift of 50 million yen. The prizes will be presented during awards ceremonies to be held November 9–12 in Kyoto.

Among previous recipients of the Kyoto Prize are several who have worked in the mathematical sciences: Rudolf E. Kalman (1985), Claude E. Shannon (1985), John McCarthy (1988), I. M. Gelfand (1989), André Weil (1994), and Donald E. Knuth (1996).

—from Inamori Foundation news release

John H. Conway Receives Nemmers Prize



Photograph by Robert P. Matthews, courtesy of Princeton University.

John H. Conway

JOHN H. CONWAY, von Neumann Professor of Mathematics at Princeton University, has been awarded the 1997-98 Frederic Esser Nemmers Prize in Mathematics from Northwestern University.

The Nemmers Prize in Mathematics is awarded to scholars who display "outstanding achievement in their discipline as demonstrated by major contributions to new knowledge or the development of significant new modes of analysis." The prize carries a $100,000 stipend and is presented every other year to a scholar who displays work of lasting significance in mathematics.

In connection with the receipt of the award, Conway will spend a period of residence at Northwestern, during which he will present a public lecture and interact with students and members of the faculty.

Conway, one of the preeminent theorists in the study of finite groups and one of the world's foremost knot theorists, is the author of more than 10 books and more than 130 journal articles on a wide variety of mathematical subjects. He has also done important work in number theory, game theory, coding theory, tiling, and the creation of new number systems. The system of "Surreal Numbers", which he invented, is the subject of a popular book by computer scientist Donald Knuth.

Conway is also widely known as the inventor of the "Game of Life", a computer simulation of simple cellular "life", governed by simple rules which give rise to amazingly complex behavior. It was popularized by Martin Gardner's columns in *Scientific American* in the early 1970s and has had a large number of devotees ever since. Conway may well have the distinction of having more books, articles, and Web pages devoted to his creations than any other living mathematician.

Conway was educated at Cambridge University and served as a professor of mathematics there prior to joining Princeton in 1986. He is a Fellow of the Royal Society and received the Pólya Prize of the London Mathematical Society.

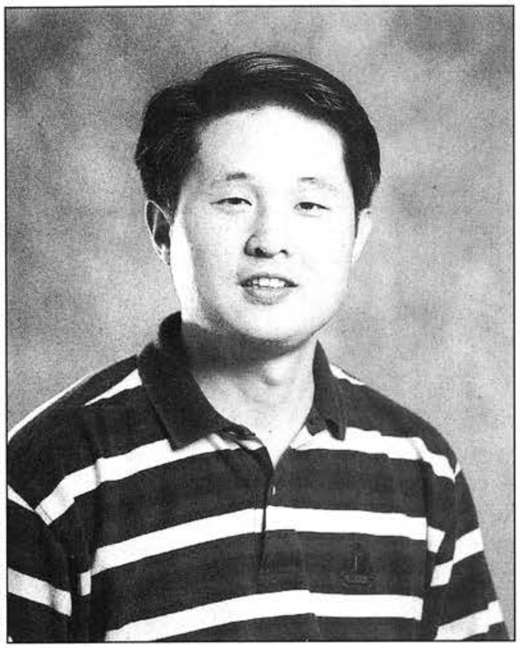
Northwestern University awards Nemmers Prizes in mathematics and in economics. The 1997-98 Erwin E. Nemmers Prize in Economics was presented to Robert J. Aumann. Initiated in 1994, the prizes were made possible through bequests from the late Erwin E. Nemmers, a former member of the Northwestern University faculty, and his brother, the late Frederic E. Nemmers, both of Milwaukee, Wisconsin. The 1998 selection committees were composed of faculty members from the University of California at Berkeley, Harvard University, Massachusetts Institute of Technology, Yale University, and Northwestern.

Previous recipients of the Frederic Esser Nemmers Prize in Mathematics are Yuri I. Manin (1994) and Joseph B. Keller (1996).

Consistent with the terms of the Nemmers' bequests, past recipients of the Nobel Prize and current or former full-time members of the Northwestern University faculty are ineligible for a Nemmers Prize.

—from Northwestern University news release

1997 Fulkerson Prize



Photograph by Michael Moore. © 1998 Microsoft Corp.

Jeong Han Kim

The D. Ray Fulkerson Prize in Discrete Mathematics was awarded on August 25, 1997, at the opening session of the XVIth International Symposium on Mathematical Programming in Lausanne, Switzerland. The prize of $1,500 is jointly sponsored by the AMS and the Mathematical Programming Society.

The prize committee for the 1997 prize consisted of Ronald Graham, AT&T Research; Ravi Kannan, Yale University; and Éva Tardos (chair), Cornell University. To be eligible, papers had to be published in a recognized journal during the six calendar years preceding the year of the Symposium. The term "discrete mathematics" is intended to include graph theory, networks, mathematical programming, applied combinatorics, and related subjects. While research in these areas is usually not far removed from practical applications, the judging of papers is based on their mathematical quality and significance.

The 1997 Fulkerson prize was awarded to JEONG HAN KIM of Microsoft Research for the paper "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 Ramsey number $R(s,t)$ is the minimum n such that every red-blue coloring of the edges of the complete graph K_n includes either a red complete graph on s nodes or a blue complete graph on t nodes. The Ramsey number was introduced by Erdős and Szekeres in a paper in 1935. The 1947 paper by Erdős on the symmetric Ramsey number $R(t,t)$ is generally viewed as the start of the probabilistic method in combinatorics. Since then developments in bounds on the Ramsey number have been intertwined with developments of the probabilistic method.

After the symmetric case, the Ramsey number $R(3,t)$ is the most studied. Erdős and Szekeres proved that $R(3,t)$ is $O(t^2)$. This upper bound was improved by Graver and Yackel in 1968 to $O(t^2 \frac{\log\log t}{\log t})$, and then in 1990 by Ajtai, Komlós, and Szemerédi to $O(\frac{t^2}{\log t})$. The best-known lower bound for $R(3,t)$ was $\Omega(\frac{t^2}{\log^2 t})$, proved in a 1961 paper by Erdős.

Jeong Han Kim's paper solves this sixty-year-old problem by improving the Erdős lower bound to match the upper bound of Ajtai, Komlós, and Szemerédi. The paper is a veritable cornucopia of modern techniques in the probabilistic method; it uses martingales in a sophisticated way to obtain strong large deviation bounds.

Kim received his Ph.D. in 1993 from Rutgers University, where his advisor was Jeff Kahn. He worked at AT&T Research for four years before joining the Theory Group at Microsoft Research in 1997.

Past recipients of the Fulkerson Prize are: Richard M. Karp, Kenneth Appel, Wolfgang Haken, and Paul D. Seymour (1979); D. B. Judin, A. S. Nemirovskii, L. G. Khachiyan, G. P. Egorychev, D. I. Falikman, M. Grötschel, L. Lovasz, and A. Schrijver (1982); Jozsef Beck, H. W. Lenstra Jr., and Eugene M. Luks (1985); Éva Tardos and Narendra Karmarkar (1988); Martin Dyer, Alan Frieze, Ravi Kannan, Alfred Lehman, and Nikolai E. Mnev (1991); and Lou Billera, Gil Kalai, Neil Robertson, Paul D. Seymour, and Robin Thomas (1994).

—Éva Tardos, for the prize committee

Testimony on Behalf of the Joint Policy Board for Mathematics

The Joint Policy Board for Mathematics regularly arranges for representatives of the AMS, the Mathematical Association of America, and the Society for Industrial and Applied Mathematics to testify before Congress on issues of importance to the mathematical sciences community. What follows is the text of testimony presented by AMS President Arthur Jaffe to the House subcommittee concerned with the budget of the National Science Foundation.

Testimony on the FY 1999 National Science Foundation Budget Request

Subcommittee on Veterans' Affairs, Housing and Urban Development, and Independent Agencies
Committee on Appropriations
United States House of Representatives

April 21, 1998

Good morning, Mr. Chairman and Members of the Subcommittee. I am Arthur Jaffe, president of the American Mathematical Society, chairman of the Joint Policy Board for Mathematics, and Landon T. Clay Professor of Mathematics and Theoretical Science at Harvard University. I speak today on behalf of the Joint Policy Board for Mathematics (JPBM), which is a collaboration of three professional societies: the American Mathematical Society, the Mathematical Association of America, and the Society for Industrial and Applied Mathematics. These organizations have a combined membership of over 57,000 mathematical scientists and educators, whose interests span research on mathematics, both disciplinary and interdisciplinary; applications of mathematics to science, engineering, industry, and business; and mathematics education at all levels.

Thank you for this opportunity to comment on appropriations under the subcommittee's jurisdiction. Let me start, Mr. Chairman, by thanking the subcommittee for the strong support it has shown for the National Science Foundation over the years. We hope for your continued support in FY 1999. The Joint Policy Board for Mathematics wholeheartedly endorses full funding of the FY 1999 budget request for the National Science Foundation, providing a critical 10 percent increase.

We believe that what mathematics, science, and engineering represent is a top priority for investment in the future of our country. However, the NSF budget has seen no real growth since FY 1995 and was part of the almost threefold decline in R&D funding as an overall percent of GDP over the past thirty years. Thus we have been shortchanging the most promising investment in our country's future. Moreover, given the extraordinary importance of the NSF's mission, we believe the need for a full appropriation transcends any particular approach to budgeting.

The importance of the NSF's support for basic research and education has been expressed by a bipartisan group of members both in the House and in the Senate. This budget request is consistent with the authorization bill passed by the House, with the authorization bill moving through Senate committee, and with the Senate's budget resolution, which assumes full funding in FY 1999. The Coalition for National Science Funding (CNSF), a coalition of more than fifty scientific organizations, has endorsed the budget request, and I have attached the CNSF statement to my testimony. Furthermore, an ad hoc coalition of over one hundred presidents of scientific organizations (including the three JPBM presidents) issued a "unified statement" calling for a renewal of science funding over the next decade. These societies have over 3 million members: mathematicians, scientists, and engineers from across the country. I have attached the statement to this testimony.

I believe it is widely understood that:

1. We enjoy unparalleled prosperity today. Much of this is driven by technology growing out of the investment in basic scientific research that we have made over the past thirty years.
2. Tomorrow's new technologies will evolve from today's basic research.
3. Our strength as a world power tomorrow relies on our ability to educate our population in mathematics and science.
4. The NSF bears a prominent share of the responsibility for basic research, and it also contributes to education.

NSF and Mathematics Research—the Enabling Discipline

We are especially supportive of the NSF's proposed budget of $114.1 million for the Division of Mathematical Sciences (DMS), as the Foundation has identified and documented a special need for strong growth in this area. For thirty years we have been in the midst of a golden age of mathematics research. Although American mathematics is the envy of the rest of the world, our leadership is in jeopardy. A panel appointed by the NSF documents this view in a March 1998 study entitled "Report of the Senior Assessment Panel for the International Assessment of U.S. Mathematical Sciences." This study illustrates the inadequate support of twentieth-century mathematics, alongside its increasing role as the enabling discipline for all fields of science and engineering. In FY 1999 the NSF will emphasize a number of interdisciplinary research areas, including furthering the fruitful mathematical ties into physics and opening new dialogues between research mathematicians and their colleagues performing research in biology and medicine. However, interdisciplinary advances rest on disciplinary strength and progress; the nurturing of fundamental disciplines suffers today, and thus progress for tomorrow is threatened.

The interdependence of different scientific disciplines recurs as a theme throughout scientific history; its relevance increases with the growing complexity of modern research. For example, modern medical imaging would be impossible without two hundred years of mathematical development leading to the present-day breakthroughs in applications of wavelets. Life is hard to imagine without the programmable digital computer, an invention that arose from the abstract and seemingly impractical discipline of mathematical logic but whose use depends on the wealth of new algorithms resulting from current research in mathematics. Mathematical research on probability theory contributed to the 1997 Nobel Prize in economics, and the widespread use of this mathematical model has had a profound impact on today's financial markets and on risk analysis. The mathematics behind it arose without any conception that it would ultimately be relevant to economics or business.

A mathematician at UC Berkeley recently developed numerical algorithms and extremely fast computer codes to simulate the manufacture of computer chips. The new methods greatly enhance the ability to model and predict some aspects of semiconductor manufacturing, and the associated mathematical approach has been adopted by leading semiconductor companies. The ultimate goal of these and other such algorithms, models, and simulations is to influence semiconductor manufacturing and design in the same way that computer simulations revolutionized aircraft design.

Today's revolution in communication and encryption is a wonderful mixture of themes. It combines the quite recent realization of the applicability of the most abstract parts of mathematics along with the most powerful computational tools and algorithms made possible by engineers, physicists, computer scientists, and applied mathematicians. As explained at a recent congressional briefing on mathematics, encryption involves large-scale computation and also rests on concrete applications of number theory and algebraic geometry, two central fields of mathematics that forty years ago were believed to have no possible practical applicability. Paradoxically, modern mathematics is both devising new encryption schemes on the one hand and devising new mathematical and computational tools on the other to break apparently secure codes. News comes in surprising ways, and this past week we learned that digital cellular phone encryption, which was believed to be secure, has been broken.

Symmetry in nature plays a central role in the formulation of physical laws. Recently two new kinds of symmetry of these laws have been conjectured in physics; they are given the names mirror symmetry (because this can be thought of like a reflection in a mirror) and duality symmetry (because they are similar to known relations between electric and magnetic forces). The assumption of these conjecture symmetries leads to enormous conceptual as well as computational insights that have been studied extensively over the past five years. This year a justification of mirror symmetry has been found in certain special cases, promising to open new directions in our formulation and understanding of the laws of nature, their reflection as mathematical truths, and their forming the basis of new areas of knowledge.

NSF and Mathematics Education

The NSF also provides most of the federal funding that enables the mathematical community to work toward the improvement of mathematics education at all levels. It is impossible to separate science education from scientific research. The NSF Division of Undergraduate Education (DUE) sponsors programs that link students to the work of research mathematicians and scientists. For example, the Research Experiences for Undergraduates (REUs) have played an important role in exciting undergraduate mathematicians and scientists by making available summer participation in research and thereby fostering the early transition from unharnessed potential to energized creativity.

In a complementary fashion, I underscore the important role of the NSF graduate fellowships. These awards have in the past been central in focusing the talent pool that has resulted in the visionary world leadership of our universities. They play an absolutely crucial role in the vexing problem of providing incentive for young potential research mathematicians, scientists, and engineers to continue in their fields, and they provide concrete recognition of their accomplishments as they progress toward becoming the next generation of first-class American researchers. Likewise the postdoctoral fellowship programs extend the training of mathematicians and scientists at the crucial time when they are making the delicate transition from initial scientific discovery to world scientific leadership. It is through this continued encouragement and development that we instill insight and that we focus our next generation of Fields Medal winners and Nobel Prize laureates, as well as the many other researchers whose contributions provide the depth to make our country great. It is from today's pool of talented mathematicians, scientists, and engineers that the next generation of leaders will emerge whose ideas will hatch the basic discoveries to drive our economy and world competitiveness, and hence our national security.

While U.S. graduate education shines, our schools do not. The results of the Third International Mathematics and Science Study show that U.S. students drop from approximately average in fourth grade to the very bottom by twelfth grade. This is the case not only in averages but even when measuring the top 10 percent of student performance. We must do more to ensure that our school students are learning challenging mathematics, and a strong federal role is essential for our success. We urge the subcommittee to provide the full budget request for the proposed joint mathematics educational initiatives of the NSF, to be undertaken in cooperation with the Department of Education. We hope that both agencies, drawing on their respective strengths, will produce results that raise the content and international performance of U.S. students in mathematics.

Conclusion

Mr. Chairman, there are many other projects I could describe to demonstrate the extraordinary impact NSF programs have on mathematics science, engineering, and education. I don't have time today; however, I would like to invite you, the members of the subcommittee, and your staffs to attend the Fourth Annual CNSF Exhibition and Reception on May 20, at which you can see first-hand a small sample of NSF-funded research projects in all fields and you can talk with some of the mathematicians and scientists whose ideas produced these advances.

Let me emphasize that support for research and education in mathematics, the basic sciences, and engineering ranks among the most productive investments Congress can make in the future of our country. Yet the United States spends less as a percentage of GDP on civilian research than our major international competitors. Working with less than 5 percent of the total federal R&D budget, the NSF assumes major responsibility for many critical components of science and technology and works diligently toward the achievement of excellence in science, mathematics, and engineering education. Moreover, the NSF pursues partnerships and encourages the participation of other federal agencies, of the states, and of industry in its activities, thereby leveraging its comparatively small budget. I again urge you to provide a 10 percent increase in FY 1999 appropriations for the National Science Foundation.

Author Note: I am grateful to A. Odlyzko for drawing my attention to the fact that my assertion of a decline by a factor of three in R&D/GDP over thirty years is too large. According to figures published by the National Science Foundation in "National Patterns of R&D Resources: 1996", we have experienced a decline in federal R&D/GDP from 1.93% in 1964 to 0.89% in 1994, or by a factor of 2.2 over that thirty year period.

Mathematical Sciences in the FY 1999 Budget

Lisa A. Thompson

This article appears as Chapter 21 in "AAAS Report XXIII: Research and Development, FY 1999" published in April 1998. It is a report on the federal budget request submitted by the President to the Congress in February 1998 and does not reflect subsequent Congressional action.

Summary

- Federal support for the mathematical sciences would grow by 8.1%, from an estimated $180.8 million in FY 1998 to a proposed $195.4 million in FY 1999. Adjusted for inflation, the increase would amount to 6.0%.
- The National Science Foundation's Division of Mathematical Sciences would account for nearly all of this growth; it would spend $114.1 million in FY 1999, a proposed increase of 17.4% over the FY 1998 level.
- Combined support from the five mathematical sciences programs at the Department of Defense would decline by an estimated 6.1%, to $58.5 million, in FY 1999.
- The Department of Energy's support for the mathematical sciences would grow by 9.4% in FY 1999, potentially its first real funding increase in three years.

Introduction

The federal government maintains seven dedicated programs in the mathematical sciences at three agencies: the Departments of Defense (DOD) and Energy (DOE) and the National Science Foundation (NSF). These programs support research and related activities carried out primarily at academic institutions.

The NSF provides more than half of all federal support for the mathematical sciences and the only significant investment in fundamental research to expand the intellectual frontiers throughout the field and thus plays a key role in ensuring the vitality of the mathematical sciences and its availability as a resource for progress in science, technology, and industry.

The DOD maintains five mathematical sciences programs that together account for about a third of federal support for the field. These programs fund activities based on their potential to contribute to the missions of the DOD research agencies and the technology thrusts established at the highest levels of the department. Here the mathematical sciences are increasingly regarded as a problem-solving technology that can reduce costs in the development and deployment of hardware and software.

The Department of Energy also maintains a small dedicated program, and other federal agencies support research in the mathematical sciences—mostly applied mathematics and statistics—to enable progress in fields related to their missions. These agencies include the Department of Transportation, the Environmental Protection Agency, the National Aeronautics and Space Administration, the National Institutes of Health, and the National Institute of Standard and Technology. It is difficult to estimate the scope and extent of this research without detailed after-the-fact reporting from these agencies, because they do not have dedicated mathematical sciences programs. Much of this research is carried out in agency R&D centers, although they make some grants to university-based mathematical scientists.

FY 1999 Support for the Mathematical Sciences

In FY 1999 aggregate spending by the seven mathematical sciences programs would total $195.4 million, 8.1% above the estimated FY 1998 level of $180.8 million. This would amount to a 6.0% increase after adjusting for inflation.

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The $14.6 million projected increase would result from a $16.9 million increase in the NSF's support for the mathematical sciences, a $1.5 million increase in DOE's support, and a $3.8 million decrease in DOD's support.

This would be the first decline in recent years in overall DOD support for the mathematical sciences and the first time that none of the DOD mathematical sciences program budgets would see an increase. While the funding at several of the DOD programs has been stagnant at best, growth in other programs usually made up for any decreases.

These figures would thus accelerate a trend concerning relative proportions among agency support for the field: the proportion of support coming from the NSF has been growing and would top 60% under the FY 1999 plans.

FY 1999 Mathematical Sciences Program Budgets

The table at the end of this chapter shows the budgets of the seven federal mathematical sciences programs for FY 1997–99. These programs provide support for a variety of research and related activities, including individual and group awards, institutes and centers, equipment, and education and human resources development. Following is information on each program and its FY 1999 budget proposal. Note that the FY 1999 spending figures for the DOD programs are technically not proposals, as DOD does not project budget figures at that level of detail; rather, they are estimates obtained from the programs themselves.

National Science Foundation. The NSF Division of Mathematical Sciences (DMS), part of the Mathematical and Physical Sciences Directorate (MPS), invests in the development of mathematical and statistical ideas and techniques, supports their interaction with other scientific and engineering disciplines, and encourages their diffusion into the technology base. Its portfolio includes grants for individual investigators and small groups, research institutes and centers, computing equipment, postdoctoral fellowships, research conferences, and undergraduate programs such as curriculum development.

DMS would spend $114.1 million in FY 1999, a proposed increase of 17.4% over the FY 1998 level of $97.2 million. Part of the proposed increase is attributed to a "corrective action" to bring the DMS budget in line with those of the other MPS divisions. The spending proposal includes $79.1 million for research project support, a 12.7 percent increase, and $35.0 million for infrastructure support, a 29.6 percent increase.

DMS plans to use $6 million of the proposed $8.9 million increment for research project support to increase the average size and duration of its awards. With the remainder, emphasis would be placed on research that contributes to interagency, NSF-wide, and MPS-wide activities, especially the NSF's initiative in Knowledge and Distributed Intelligence (KDI) as well as MPS thrusts on the origins of the universe, the quantum realm, and molecular science.

The $8 million increment for infrastructure support would be divided among the Grants for Vertical Integration of Research and Education in the Mathematical Sciences program (VIGRE, $4.5 million), a contribution to a joint NSF-Department of Education initiative to improve K–8 mathematics education ($3.0 million) being coordinated by NSF's Education and Human Resources Directorate, and enhanced support for institutes ($0.5 million).

The table also includes an estimate of the portion of the FY 1999 budget request of the MPS Office of Multidisciplinary Activities (OMA) that might be used to support mathematical activities.

Air Force Office of Scientific Research (AFOSR). The Mathematics and Geosciences Directorate of AFOSR provides funds for research and related activities in the mathematical sciences in support of the Air Force mission. Research areas include optimization, signal processing, probability and statistics, computational mathematics, and dynamics and control. The best estimate for the mathematical program's FY 1999 budget is that it would remain the same as the FY 1998 estimate, $17.9 million.

Army Research Office (ARO). The ARO mathematical sciences program focuses on the mathematics of materials science, high performance computing, image and signal analysis, including automatic target recognition, mathematical and computational issues in intelligent systems, and other areas of interest to the Army. The program supports several centers and institutes that fall under the University Research Initiative (URI). The program's estimated FY 1999 spending would be $12.0 million, the same as in FY 1998.

Defense Advanced Research Projects Agency (DARPA). The Applied and Computational Mathematics Program at DARPA supports mathematical research to facilitate the development of technologies identified by the agency as important to meeting future military needs. The program funds university and industrial researchers to solve well-defined mathematical and computational problems and work with other DOD scientists to employ the resulting knowledge and tools in the development process. It also funds joint programs with the NSF to familiarize new researchers with the needs of DARPA.

Estimated funding for the program in FY 1999 would be $19.5 million, a $3 million cut from the estimated FY 1998 level of $22.5 million.

National Security Agency (NSA). The National Security Agency is the nation's largest employer of mathematical scientists. Its in-house research activities are highly classified. In 1984 NSA initiated a competitive grants program to support unclassified academic research in discrete mathematics, algebra, number theory, probability, statistics, and cryptology. The program was a response to a sharp decline in the number of Americans earning advanced degrees in the mathematical sciences.

Although that number has stabilized, U.S. citizens still earn less than half of the mathematical doctorates awarded by U.S. institutions. Yet the purchasing power of NSA's external grants program has been dropping steadily during the 1990s. Its budget will have declined by 50% in real terms between FY 1990 and FY 1998. Another decrease is projected for FY 1999.

NSA also provides funds for mathematical research through programs at predominantly minority institutions and supports some contracts for directed mathematical research; spending for these activities is not included in the table.

Office of Naval Research (ONR). The Mathematical, Computer, and Information Sciences Division, part of the ONR's Information, Surveillance, and Electronics Department, supports research in the mathematical areas of applied analysis, discrete mathematics, numerical analysis, operations research, and probability and statistics in support of the naval mission. In FY 1999 ONR's support for the mathematical sciences would drop by 9.1%, from $7.7 million in FY 1998 to $7.0 million. This would follow an even steeper drop between FY 1997, when the program spent $9.6 million, and FY 1998.

Department of Energy. The Office of Computational and Technology Research's Mathematical, Information, and Computational Sciences Division has two missions: to support a broad range of research in the mathematical, computational, and computer sciences necessary to underpin all the other sciences and to manage a network of state-of-the-art supercomputing facilities for DOE-supported researchers. Most of its funding is devoted to R&D in applied computer and computational science and technology carried out at the national laboratories.

It also invests in a small mathematical sciences program, providing support to the labs and to universities for basic research and related activities in analytical, numerical, and computational methods. The objective is to develop mathematical tools useful in solving complex scientific problems that hinder progress toward national energy and environmental goals. The program would be funded at $17.5 million in FY 1999, an increase of $1.5 million over the FY 1998 level. The increment would be used for a new research initiative on Predictability of Complex Phenomena, the results of which would be relevant for a number of problems of interest to DOE, including nuclear stockpile stewardship, environmental remediation, and global climate modeling.

Federal Support for the Mathematical Sciences
FY 1997–FY 1999 (in millions of dollars)

	FY 1997 Actual	FY 1998 Estimate	FY 1999 Request	Change Amount	FY 1998–99 Percent
National Science Foundation					
DMS	92.9	97.2	114.1	16.9	17.4%
Other MPS	5.3	5.3	5.3	0.0	0%
Total, NSF	98.2	102.5	119.4	16.9	16.5%
Department of Defense					
AFOSR	17.1	18.0	18.0	0.0	0%
ARO	13.0	12.0	12.0	0.0	0%
DARPA	18.5	22.5	19.5	−3.0	−13.3%
NSA	2.1	2.1	2.0	−0.1	−4.8%
ONR	9.6	7.7	7.0	−0.7	−9.1%
Total, DOD	60.3	62.3	58.5	−3.8	−6.1%
Department of Energy					
Univ. Support	5.0	5.0	5.0	0.0	0.0%
National Labs	11.0	11.0	12.5	1.5	13.6%
Total, DOE	16.0	16.0	17.5	1.5	9.4%
Total, all agencies	174.5	180.8	195.4	14.6	8.1%

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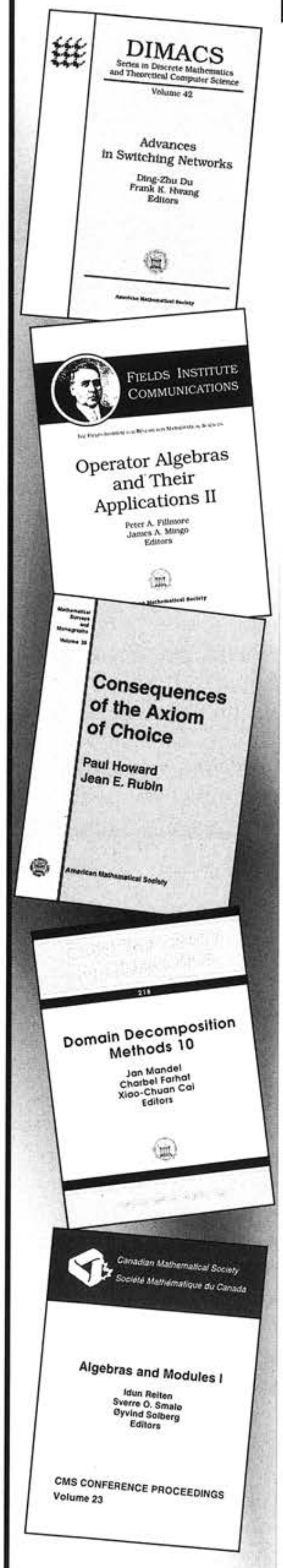

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Mathematics People

AMS-AAAS Fellows Chosen

This year the AMS is again participating in the Mass Media Science and Engineering Fellowship program of the American Association for the Advancement of Science (AAAS). This program places graduate students in internships in major media organizations for ten weeks during the summer. The purpose of the program is to improve public understanding and appreciation of science and technology and to sharpen the ability of the fellows to communicate complex technical issues to nonspecialists.

A mathematics graduate student holds a fellowship this summer through the sponsorship of the AMS. EDOUARD SERVAN-SCHREIBER, a graduate student at the University of California at Berkeley, is spending his fellowship at National Geographic Television.

In addition, SARA ROBINSON, also a graduate student at the University of California at Berkeley, holds the SIAM-AAAS Fellowship sponsored by the Society for Industrial and Applied Mathematics, which she is spending at the *Dallas Morning News*.

—Elaine Kehoe

Mathematicians Elected to American Academy of Arts and Sciences

Seven mathematicians have been elected to membership in the American Academy of Arts and Sciences in 1998. They are: ROY ADLER (IBM T. J. Watson Research Center), FAN CHUNG (University of Pennsylvania), WILLIAM FULTON (University of Chicago), PETER W. JONES (Yale University), CURTIS MCMULLEN (Harvard University), YUM-TONG SIU (Harvard University), and JOHN G. THOMPSON (University of Florida). MICHÈLE F. VERGNE (École Normale Supérieure, Paris, France) and MIGUEL VIRASORO (International Center for Theoretical Physics, Trieste, Italy) were elected as foreign honorary members.

The American Academy of Arts and Sciences was founded in 1780 to foster the development of knowledge as a means of promoting the public interest and social progress. The membership of the academy is elected and represents distinction and achievement in a range of intellectual disciplines: mathematical and physical sciences, biological sciences, social arts and sciences, and humanities and fine arts.

—AAAS Announcement

Aharonov and Berry Awarded Wolf Prize in Physics

The Wolf Foundation Prize in Physics for 1998 has been jointly awarded to YAKIR AHARONOV of Tel Aviv University and the University of South Carolina and MICHAEL V. BERRY of Bristol University, United Kingdom. The two were honored for their discovery of the quantum topological and geometrical phases, particularly the Aharonov-Bohm effect and the Berry phase, and their incorporation into many fields of physics. The work of Aharonov and Berry has stimulated research in such varied areas as nuclear, fluid, and molecular physics, string theory, cosmology, gravitational physics, solid state physics, the foundations of quantum mechanics, and recent attempts to develop quantum computing.

Yakir Aharonov was born in Israel in 1932 and received his Ph.D. from Bristol University in 1960. He has taught at Yeshiva University and has held a joint professorship at Tel Aviv University and the University of South Carolina since 1973. He held a Miller Research Professorship at the University of California at Berkeley in 1988–89. His numerous awards and honors include the Weizmann Prize in Physics and the Rothschild Prize in Physics, both awarded in 1984; the 1989 Israel National Prize in Physics; and the

Photos courtesy of the Wolf Foundation, Israel.

Yakir Aharonov Sir Michael Berry

1995 Hewlett-Packard Europhysics Prize. He is a fellow of the American Physical Society and a member of both the U.S. National Academy of Sciences and the Israel Academy of Sciences and Humanities.

Michael V. Berry was born in the United Kingdom in 1941 and received his Ph.D. from St. Andrews University in 1965. He has been associated with Bristol University since 1967, where he is currently a Royal Society Research Professor. Among his awards and honors are the 1990 Paul Dirac Medal and Prize of the United Kingdom Institute of Physics, the Hewlett-Packard Europhysics Prize for 1995, and the Kapitsa Medal of the Russian Academy of Sciences (1997). He was named a Knight Bachelor at the Queen's Birthday Honors in 1996. He is a fellow of the Royal Society of London; a member of the European Academy, the Royal Society of Sciences of Uppsala, and the Indian Academy of Sciences; and a foreign member of the U.S. National Academy of Sciences.

Professors Aharonov and Berry will share the $100,000 prize, which was presented on May 10, 1998, in Jerusalem by President Ezer Weizman of Israel. The Wolf Foundation was established by Ricardo Wolf, once Cuban ambassador to Israel, for the purpose of promoting science and art for the benefit of mankind.

—From a Wolf Foundation announcement

1998 USA Mathematical Olympiad Winners

The 27th USA Mathematical Olympiad (USAMO) exam was held on April 28, 1998, and consisted of six questions to be solved in six hours. A total of 179 students were selected to take the exam on the basis of their performances on the American High School and American Invitational Mathematics Examinations.

This year for the first time a female student, MELANIE WOOD of Park Tutor High School in Indianapolis, Indiana, won first-place honors. She shares first place with ALEXANDER B. SCHWARTZ of Radnor High School in Radnor, Pennsylvania. The other winners were: REID BARTON of Arlington, Massachusetts, who is home-schooled; GABRIEL CARROLL, Oakland Technical High School, Oakland, California; KEVIN D. LACKER, Sycamore High School, Cincinnati, Ohio; DAVID E. SPEYER, Choate Rosemary Hall, Wallingford, Connecticut; PAUL A. VALIANT, Milton Academy, Milton, Massachusetts; and DAVID T. VICKREY, Vermillion High School, Vermillion, South Dakota. Kevin Lacker was also a winner in last year's competition.

The Mathematical Olympiad Summer Program, which prepares the team for the International Mathematical Olympiad (IMO), includes as participants the top eight winners and twenty-two other high-ranking USAMO students. This program is sponsored by the Office of Naval Research and the Matilda Wilson Foundation, with support from the University of Nebraska-Lincoln, the site of the program.

The top six winners—Barton, Carroll, Lacker, Schwartz, Valiant, and Wood—represented the United States in the IMO, which was held July 15 and 16 in Taipei, Taiwan. Travel funds to the IMO are provided by the Army Research Office. The USAMO is run by American Mathematics Competitions.

—Mathematical Association of America

Fred Glover Receives von Neumann Prize

FRED W. GLOVER, U.S. West Chaired Professor in Systems Science at the University of Colorado, Boulder, has been awarded the 1998 John von Neumann Theory Prize, the highest prize given in the field of operations research and management science.

The $5,000 prize, awarded by the Institute for Operations Research and the Management Sciences, was given to Glover "for his fundamental contributions to integer programming, networks, and combinatorial optimization." His principal areas of research include applications of computers to the fields of optimization, decision support, industrial planning, financial analysis, systems design, multicriteria analysis, applied artificial intelligence, energy, natural resources planning, logistics, transportation, and large-scale allocation models. He developed the framework for the metaheuristic called Tabu Search, which has been instrumental in solving difficult problems in many areas, ranging from scheduling to financial planning to training neural networks.

Fred Glover was born on March 8, 1937, in Kansas City, Missouri. He graduated from the University of Missouri, Kansas City, in 1960 and received his Ph.D. from Carnegie-Mellon University in 1965. He has taught at the University of California, Berkeley; the University of Texas; and the University of Minnesota. He was professor of management sciences and information systems at the University of Colorado from 1970 to 1986 and has been U.S. West Chaired Professor there since 1986. He served as director of research at the Center for Applied Artificial Intelligence, of which he was a founding member, at Colorado between 1984 and 1990. He has received numerous academic honors and awards. He was honored by the North Atlantic Treaty Organization (NATO) Division of Scientific Affairs for research and lecture presentations at NATO Advanced Study Institutes on networks and logistics planning. He has also received the National Award for Research Excellence in Operations Research/Computer Science of the Operations Research Society of America, the Outstanding Achievement Award of the American Institute of Decision Sciences, the International Business Machines Award for Mathematical Programming Research, and the Energy Research Institute Award for research on alternative energy resources and uses.

—*Elaine Kehoe*

1998 d'Alembert Prize Awarded

Every two years the Société Mathématique de France presents the d'Alembert Prize. Established in 1984, the prize is intended to encourage mathematical works in the French language and the exposition of mathematics for the general public. The prize recognizes an article, book, radio or television broadcast, film, or other project that is designed to improve understanding of mathematics and its recent developments.

The 1998 d'Alembert Prize has been awarded to JEAN-PAUL DELAHAYE of l'Université des Sciences et Techniques de Lille for his most recent work, "Le fascinant nombre pi", published by Belin in the collection, *Bibliothèque pour la science.*

—*Société Mathématique de France*

Addition, National Academy of Sciences Elections

The June/July issue of the *Notices* carried an announcement about recent elections to membership in the National Academy of Sciences. One name was omitted from the list of new Academy members in the mathematical sciences: ANDREW YAO of Princeton University.

Visiting Mathematicians

(Supplementary List)

Mathematicians visiting other institutions internationally during the 1998–1999 academic years were listed in the June/July 1998 issue of the *Notices*, pp. 730–31, and the August 1998 issue of the *Notices,* p. 885. The following is an update (home country is listed in parentheses).

SANG-EON HAN (Korea), University of Rochester, Mathematics, 2/99–1/00.

GENNADI KASPAROV (Russia), Dartmouth College, Operator Algebras, KK-Theory, Noncommutative Geometry, Functional Analysis, Representation Theory, 9/98–6/99.

VLADIK KREINOVICH (U.S.A.), Chinese University of Hong Kong, Interval Mathematics, Mathematical Foundations of Knowledge, Representation and Intelligent Control, 12/98–1/99.

FATIMA SILVA LEITE (Portugal), Arizona State University, Geometric Control Theory, 3/98–7/99.

GUOQING LIU (People's Republic of China), University of Texas at El Paso, Interval Mathematics, 11/98–8/99.

NURIA MUTA (Spain), University of Texas at El Paso, Interval Mathematics, Geometry, 8/98–11/98.

PETRI OLA (Finland), University of Rochester, Partial Differential Equations, 9/98–12/98.

IULIANA OPREA (Romania), Arizona State University, Dynamical Systems, 8/98–5/99.

MICHAEL PLUMMER (U.S.A.), University of Odense, Denmark, Graph Theory, 9/98–11/98.

VASILY V. STRELA (Russia), Dartmouth College, Applied Analysis, 9/97–6/99.

STEVEN H. WEINTRAUB (U.S.A.), University of Göttingen, Germany, Differential Topology, Algebraic Geometry, 1/99–7/99.

JUERGEN WOLFF VON GUDENBERG (Germany), University of Southwestern Louisiana, Interval Mathematics, 11/98–12/98; University of Texas at El Paso, Interval Mathematics, 1/99–2/99.

JINDRICH ZAPLETAL (Czech Republic), Dartmouth College, Set Theory, 7/98–6/00.

Deaths

DAME MARY CARTWRIGHT, of Cambridge, England, died on April 3, 1998. Born on December 17, 1900, she was a member of the Society for 49 years.

H. L. CLAASEN, of Amsterdam, The Netherlands, died on May 25, 1998. Born on June 17, 1937, he was a member of the Society for 20 years.

ALBERT EDREI, professor emeritus, Syracuse University, died on April 29, 1998. Born on November 26, 1914, he was a member of the Society for 47 years.

JOHN WARREN FORMAN, retired from IBM, died on May 22, 1998. Born on November 25, 1918, he was a member of the Society for 48 years.

LEONID S. FRANK, of the University of Reims, France, died on December 29, 1997. Born on April 25, 1934, he was a member of the Society for 23 years.

ROBERT B. GARDNER, of the University of North Carolina, Chapel Hill, died on May 5, 1998. Born on February 27, 1939, he was a member of the Society for 37 years.

MARVIN L. VEST, professor emeritus, West Virginia University, died on December 28, 1997. Born on May 17, 1906, he was a member of the Society for 37 years.

CALOGERO VINTI, of the University of Perugia, Italy, died on August 25, 1997. Born on July 12, 1926, he was a member of the Society for 18 years.

Mathematics Opportunities

American Mathematical Society Centennial Fellowships

Invitation for Applications for Awards for 1999–2000
Deadline: December 1, 1998

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 1984–1996, the fellowship program was aimed at midcareer mathematicians. The changes adopted three 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 the candidate's research development.

The stipend for fellowships awarded for 1999–2000 is expected to be approximately $37,000, with an additional expense allowance of about $1,500. Acceptance of the fellowship cannot be postponed. Fellowship holders may use their 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 two to five fellowships a year for the past ten years. A list of previous fellowship winners can be found at `http://www.ams.org/ams/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 on 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, 1998**. Awards will be announced in February 1999 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 401-455-4103. 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

NSF Mathematical Sciences Postdoctoral Research Fellowships

The Mathematical Sciences Postdoctoral Research Fellowship program of the Division of Mathematical Sciences (DMS) of the National Science Foundation (NSF) awards fellowships each year for research in pure mathematics, applied mathematics and operations research, and statistics. The deadline for this year's applications is **October 16, 1998**. A full program announcement is forthcoming. More information can be found through the World Wide Web at `http://www.nsf.gov/mps/dms/dmsdead.htm` (the DMS Program Deadline page—look for October 16) or from the Infrastructure Program, Room 1025, Division of Mathematical Sciences, National Science Foundation, 4201 Wilson Boulevard, Arlington, VA 22230; telephone 703-306-1870; e-mail: `msprf@nsf.gov`.

—*DMS Announcement*

NSA Grant and Sabbatical Programs

The Mathematical Sciences Program of the National Security Agency (NSA) provides grants and sabbatical opportunities to support research by academic mathematical scientists.

The grant program offers funding in four categories: the Young Investigators' Grant; the Standard Grant; the Senior Investigators' Grant; and the Conferences, Workshops, and Special Situations Grant. The NSA makes grants to universities and nonprofit institutions to support self-directed research in the following areas of mathematics (including possible computational aspects): algebra, number theory, discrete mathematics, probability, and statistics. In addition, it supports research in the design and analysis of cryptographic algorithms. The deadline for submission of all grant proposals is **October 15, 1998**. Awards are generally made in November of the following year. The principal investigators to be supported by the grant must be U.S. citizens or permanent residents, and students and postdoctoral researchers to be supported must be U.S. citizens or permanent residents who intend to become citizens. Grant proposals must arrive at the NSA on the deadline date; allow at least ten days for mailing. Submit proposals to: NSA Mathematical Sciences Program, National Security Agency, ATTN: R51A, Ft. George G. Meade, MD 20755-6000.

The NSA also accepts proposals for small grants for conferences, workshops, and special academic endeavors. Proposals for these may be submitted at any time and will be reviewed as they are received at NSA. Allow at least eight months for review, negotiation, and processing.

The sabbatical provides support for academic mathematical scientists to visit the NSA for periods ranging from 9 to 24 months. The sabbaticals primarily involve cryptanalysis, but may also involve algebra, probability, statistics, number theory, and discrete mathematics. NSA provides visiting mathematicians with funds to supplement their university's stipends to at least equal their monthly salaries. A choice is offered between an allowance for moving expenses or a housing supplement. Applicants and their immediate family members must be U.S. citizens and must participate in a thorough, extensive screening process. Applicants must submit a U.S. Government application form (SF-171, available in campus placement offices), a curriculum vitae with a complete list of publications, and other relevant information to: Director, NSA Mathematical Sabbatical Program, ATTN: R51A, National Security Agency, Ft. George G. Meade, MD 20755-6000.

Further information may be obtained from the NSA's Web site: `http://www.nsa.gov:8080/programs/msp/`, or by calling 301-688-0400, sending e-mail to `msp@math13.math.umbc.edu`, or writing to Director, Mathematical Sciences Program, at the address given above.

—*National Security Agency*

Call for Nominations for AWM Hay Award

The Executive Committee of the Association for Women in Mathematics (AWM) has established the Louise Hay Award for Contributions to Mathematics Education, to be awarded annually to a woman at the Joint Prize Session at the Joint Mathematics Meetings every January. The purpose of this award is to recognize outstanding achievements in any area of mathematics education, to be interpreted in the broadest possible sense.

Louise Hay was widely recognized for her contributions to mathematical logic and for her strong leadership as head of the Department of Mathematics, Statistics, and Computer Science at the University of Illinois at Chicago. Her devotion to students and her lifelong commitment to nurturing the talent of young women and men secure her reputation as a consummate educator. The annual presentation of this award is intended to highlight the importance of mathematics education and to evoke the memory of all that Hay exemplified as a teacher, scholar, administrator, and human being.

The nomination document(s) should include: 1) a one- to three-page letter of nomination highlighting the exceptional contributions of the candidate to be recognized, 2) a curriculum vitae of the candidate not to exceed three pages, and 3) three letters supporting the nomination. It is strongly recommended that the letters represent a range of constituents affected by the nominee's work.

Send *five* complete copies of nomination material for this award to: The Hay Award Selection Committee, Association for Women in Mathematics, 4114 Computer & Space Sciences Building, University of Maryland, College Park, Maryland 20742-2461. For further information call the AWM at 301-405-7892 or send e-mail to awm@math.umd.edu.

Please note that nominations via e-mail or fax are not acceptable. The deadline for nominations to be received at the AWM office is **October 1, 1998.**

—AWM announcement

Call for Nominations for SIAM von Karman Prize

The Society for Industrial and Applied Mathematics (SIAM) will present the Theodore von Karman Prize at the 1999 SIAM Annual Meeting in Atlanta, Georgia, May 12-15. The award will be given for a notable application of mathematics to mechanics and/or the engineering sciences made during the five to ten years preceding the award. The award may be given either for a single notable achievement or for a collection of such achievements.

The award consists of a hand-calligraphed certificate and a $1,000 cash prize. Expenses for the winner to attend the annual meeting to receive the award will be borne by SIAM.

Further information about the award, including names of past winners, may be found at http://www.siam.org/prizes/vonkar.htm.

A letter of nomination, including a description of achievement(s) should be sent by **September 1, 1998,** preferably by e-mail to: von Karman Prize Selection Committee, c/o Allison Bogardo, SIAM, 3600 University City Science Center, Philadelphia, PA 19104-2688; e-mail: bogardo@siam.org; telephone: 215-382-9800; fax: 215-386-7999.

The selection committee consists of Jerrold E. Marsden (Caltech, chair), Philippe G. Ciarlet (Laboratoire d'Analyse Numérique, Paris), and Joseph B. Keller (Stanford University).

—SIAM

Reference

*The **Reference** section of the* Notices *is intended to provide the reader with frequently sought information in an easily accessible manner. New information is printed as it becomes available and is referenced after the first printing. As soon as information is updated or otherwise changed, it will be noted in this section.*

Upcoming Deadlines

September 1, 1998: Deadline for nominations for Theodore von Karman Prize; for details see "Mathematics Opportunities" in this issue.

September 15, 1998: Deadline for nominations for candidates for Sloan Research Fellowships in Mathematics. For information write Sloan Research Fellowships, Alfred P. Sloan Foundation, 630 Fifth Avenue-Suite 2550, New York, NY 10111. World Wide Web: `http://www.sloan.org/`.

September 15, 1998: Deadline for nominations for AWM Alice T. Schafer Mathematics Prize. For information—phone: 301-405-7892; e-mail: `awm@math.umd.edu`.

October 1, 1998: Deadline for nominations for the Louise Hay Award; for details see "Mathematics Opportunities" in this issue.

October 15, 1998: Deadline for submission of grant proposals to the National Security Agency. For further information, consult the NSA Web site at `http://www.nsa.gov:8080/programs/msp/grants.html`, call 301-688-0400, send e-mail to `msp@math13.math.umbc.edu`, or write to Director, Mathematical Sciences Program, Attn: R51A, National Security Agency, Fort George R. Meade, MD 20755-6000.

October 16, 1998: Deadline for applications for the NSF Mathematical Sciences Postdoctoral Research Fellowship Program. More information will be available at the NSF Web site: `http://www.nsf.gov/mps/dms/dmsdead` or from the Infrastructure Program, Room 1025, Division of Mathematical Sciences, National Science Foundation, 4201 Wilson Boulevard, Arlington, VA 22230, telephone 703-306-1870, e-mail: `msprf@nsf.gov`.

December 1, 1998: Deadline for applications for fellowship opportunities in Asia offered by the NSF. World Wide Web: `http://www. twics.com/~nsftokyo/home.html` or by e-mail: `JKPinfo@nsf.gov`.

Where to Find It

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

Backlog of Mathematics Research Journals

Journal (Print)	Number issues per Year	Approximate Number Pages per Year	1997 Median Time (in Months) from: Submission to Final Acceptance	Acceptance to Final Publication	Editor's Current Estimate of Median Time between Submission and Publication (in Months)	Observed Waiting Time in Latest Published Issue (in Months) Q1	M	Q3
Acta Inform.	12	1112	17	NR	12	10	10	11
Aequationes Math.	6	640	10	10	12	12	14	20
Algebras Groups Geom.	4	500	3	3	5	4	9	11
Algorithmica	3	1536	NR	NR	NR	14	15	24
Amer. J. Math.	6	1400	NR	10	14-16	14	18	19
Ann. Appl. Probab.	4	1300	NR	NR	NR	7	8	9
Ann. of Math.	6	1400	10	11	18	14	27	38
Ann. Probab.	4	2000	NR	NR	NR	10	10	13
Ann. Sci. École Norm. Sup.	6	900	9	9	14	7	8	18
Ann. Statist.	6	2700	9	6	15	8	9	11
Appl. Math. Lett.	6	800	4	4	8	7	9	12
Appl. Math. Optim.	3	720	NR	NR	NR	16	17*	18
Arch. Hist. Exact. Scis.	6	600	2	8	8	12	14	17
Arch. Math. Logic	8	544	8	12	15	19	22	26
Arch. Rational Mech. Anal.	20	2000	NR	14	12	20	21*	22
Bull. Austral. Math. Soc.	6	1000	9	7	6	10	11	11
Bull. London Math. Soc.	6	520	5	11	12-16	9	11	12
Bull. Soc. Math. France	4	600	4-5	6	NR	12	16	20
Calc. Var. Partial Diff. Equations	8	770	NR	10	NR	12	14	16
Canad. J. Math.	6	1344	11	8	12-18	11	16	20
Canad. Math. Bull.	4	512	NR	NR	NR	13	17	19
Circuits Systems Signal Proc.	6	800	NR	NR	NR	3	4	9
Comm. Algebra	12	4200	NA	NA	11	7	8	10
Comm. Math. Phys.	27	6642	4	7	10	11	13	21
Comm. Partial Diff. Equations	6	2100	NR	NR	NR	5	5	6
Comput. Math. Appl.	24	3200	4	4	8		NA	
Computing	8	768	NR	NR	NR	10	10	10
Constr. Approx.	1	560	NR	NR	NR	14	16	17
Discrete Comput. Geom.	8	1200	10	11	13	10	16	20
Duke Math. J.	15	3000	8	18	22	13	14	15
Graphs Combin.	4	382	6	10	18	14	16	16
Houston J. Math.	4	800	12	3	12	9	11	17
Illinois J. Math.	4	704	11	6	17	13	15	21
IMA J. Appl. Math.	6	624	6	12-13	12	9	10	14
IMA J. Math. Appl. Med. Biol.	4	400	14	9	15		NA	
IMA J. Math. Control Inform.	4	400	6	8	10	13	15	19

1997 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.

Journal (Print)	Number issues per Year	Approximate Number Pages per Year	1997 Median Time (in Months) from: Submission to Final Acceptance	Acceptance to Final Publication	Editor's Estimate of Waiting Time for Paper Submitted Currently to be Published (in Months)	Observed Waiting Time in Latest Published Issue (in Months) Q_1	M	Q_3
IMA J. Numer. Anal.	4	650	24	11	20	9	13	14
Indag. Math.	4	560	5	14	18	13	15**	15
Indiana Univ. Math. J.	4	1300	NR	NR	NR	7	9	15
Inst. Hautes Études Sci. Publ. Math.	2	400	6-8	3	6	31	34	41
Internat. J. Math. Math. Sci.	4	832	8-12	6	18	12	20	24
Invent. Math.	12	2740	NR	NR	17	10	11	15
Israel J. Math.	6	2300	6	12	17	21	25	30
J. Algebraic Geom.	4	800	6	6	9	12	18	22
J. Algorithms	8	1664	11	7	18	5	6	19
J. Amer. Math. Soc.	4	1000	7	4	11	5	5	6
J. Amer. Statist. Assoc.	4	1800	12	9	3	8	10	11
J. Appl. Math. Stochastic Anal.	4	450	7	7	14	6	9	12
J. Assoc. Comput. Mach.	6	1000	20	6	12	12	20	21
J. Austral. Math. Soc. Ser. A	6	840	NR	NR	NR	10	12	16
J. Austral. Math. Soc. Ser. B	4	576	8	19	22	16	19	21
J .Classification	2	320-384	18	6	9		***	
J. Complexity	4	500	9	6	15	11	18	27
J. Comput. System Sci.	6	1000	NR	NR	NR		NA	
J. Cryptology	1	288	NR	NR	NR	14	18	25
J. Differential Geom.	9	2000	NR	NR	NR	11	13	19
J. Engrg. Math.	8	800	NR	NR	NR	12	14	18
J. Geom. Anal.	4	720	NR	NR	NR	35	57	64
J. Integral Equations Appl.	4	550	7	10	15	11	12	16
J. London Math. Soc.	6	1248	NR	NR	NR	28	28	30
J. Math. Biol.	10	960	12	6	15	9	12	13
J. Math. Phys.	12	6752	3	4	7	4	4*	6
J. Operator Theory	4	800	9	9	12	9	11	18
J. Symbolic Logic	4	1408	8	18	24	19	23	26
Linear Algebra Appl.	18	6500	NR	NR	NR	6	7*	8
Manuscripta Math.	12	1632	12	2	10	6	6	7
Math. Ann.	12	2400	NR	NR	NR	11	13	14
Math. Biosci.	16	1200	16	6	12	4	5	5
Math. Comput. Modelling	24	3200	6	6	12	5	6	9
Math. Comp.	4	1700	10	11	21	15	16	19
Math. Control Signals Sys.	4	381	9	7	16	6	8	14
Math. Oper. Res.	4	1024	NR	NR	NR	10	12	14
Math. Programming Ser. A	13	1638	NR	NR	NR	17	23	24
Math. Social Sci.	6	600	9	12	12	4	7†	9
Math. Z.	12	2300	NR	5	NR	21	24	27
Mem. Amer. Math. Soc.	6	3200	13	15	28	17	22	36
Methods Appl. Anal.	4	460	7	7	12	9	10	11
Michigan Math. J.	3	618	7	9	16	8	10	12
Monatsh. Math.	8	704	8	14	20	14	18	24
Nonlinear Anal.	30	3500	6-12	12	6-18	13	18	19
Numer. Funct. Anal. Optim.	10	1200	7	4	9		***	
Numer. Math.	12	1744	10	10	20	13	14	15
Oper. Res.	6	1100	15	16	12-18	20	24	35
Pacific J. Math.	5	2000	7	13-14	12	13	15	20
Probab. Theor. Relat. Fields	12	1800	10	6	16	10	10	12
Proc. Amer. Math. Soc.	12	3520	5	16	21	19	20	20
Proc. London Math. Soc.	6	1440	10	11	18	12	13	13
Quart. Appl. Math.	4	800	2	32	32	35	36	38
Quart. J. Math. Oxford Ser. A (2)	4	512	9	14	18	6	22	23
Quart. J. Mech. Appl. Math.	4	650	6	10	15	10	10	14
Reliable Comp.	4	475	4	6	10		NA	
Results Math.	4	800	NR	NR	NR	4	7	8

Journal (Print)	Number issues per Year	Approximate Number Pages per Year	1997 Median Time (in Months) from: Submission to Final Acceptance	Acceptance to Final Publication	Editor's Estimate of Waiting Time for Paper Submitted Currently to be Published (in Months)	Observed Waiting Time in Latest Published Issue (in Months) Q_1	M	Q_3
Rocky Mountain J. Math.	4	1600	3	18	24	36	40	42
Semigroup Forum	6	816	NR	NR	NR	9	17	20
SIAM J. Appl. Math.	6	2000	10	15	NR	16	17*	17
SIAM J. Comput.	6	1800	21	23	NR	24	24*	26
SIAM J. Control Optim.	6	2180	14	14	NR	14	14*	15
SIAM J. Discrete Math.	4	680	21	13	NR	13	14*	14
SIAM J. Math. Anal.	6	1500	7	15	NR	14	15*	16
SIAM J. Matrix Anal. Appl.	4	1100	11	11	NR	11	12*	13
SIAM J. Numer. Anal.	6	2480	12	21	NR	17	18*	20
SIAM J. Optim.	4	1150	16	16	NR	16	17*	18
SIAM J. Sci. Comput.	6	2100	11	19	NR	20	20*	21
SIAM Rev.	4	800	8	17	14	12	16*	18
Theory Comput. Syst.	6	672	NR	NR	NR	7	9	10
Topology	6	1400	8	16	24	8	10	17
Topology Appl.	24	2400	12	6	18	10	11	22
Trans. Amer. Math Soc.	12	5000	12	13	25	23	27	28

Journal (Electronic)	Number of Article Posted in 1997	1997 Median Time (in days) from: Submission to Final Acceptance	Acceptance to Posting	Format(s)
Conform. Geom. Dyn. (www.ams.org/ecgd/)	7	116	58	html, pdf, ps, dvi, tex
Discrete Math. Theor. Comput. Sci. (dmtcs.thomsonscience.com)	16	176	21	pdf, ps
Doc. Math. (www.mathematik.uni-bielefeld.de/documenta/) (www.math.uiuc.edu/documenta/)	15	112	13	ps, dvi
Electron. J. Differential Equations (ejde.math.unt.edu) (ejde.math.swt.edu) (www.emis.de/journals/EJDE)	25	95	5	pdf, ps, dvi, tex
Electron. J. Linear Algebra (www.math.technion.ac.il/iic/ela/)	8	205	2	ps, tex
Electron. J. Probab. (www.math.washington.edu/~ejpecp/)	8	274	7	html, ps, dvi, tex
Electron. Res. Announc. Amer. Math. Soc. (www.ams.org/era/)	22	100	12	html, pdf, ps, dvi, tex
ESAIM Control Optim. Calc. Var. (www.emath.fr/cocv/)	15	243	122	ps, dvi
ESAIM Probab. Statist. (www.emath.fr/ps/)	16	365	91	ps, dvi
Geom. Topol. (www.maths.warwick.ac.uk/gt/index.html)	7	150	3	pdf, ps
J. Artificial Intelligence Res. (www.jair.org/)	19	77	91	html, pdf, ps
Math. Phys. Electron. J. (www.ma.utexas.edu/mpej)	5	91	2	ps

Journal (Electronic)	Number of Article Posted in 1997	1997 Median Time (in days) from: Submission to Final Acceptance	Acceptance to Posting	Format(s)
New York J. Math. (nyjm.albany.edu:8000/nyjm.albany.edu)	9	91	23	pdf, ps, dvi, other
Represent. Theory (www.ams.org/ert/)	15	125	43	html, pdf, ps, dvi, tex
Sem. Lothar. Combin. (cartan.u-strasbg.fr/~slc)	4	91	1	html, ps, dvi, tex, other
Sorites (www.filosoficas.unam.mx/~sorites)	6	61	122	html, ps, other
Southwest J. Pure Appl. Math. (rattler.cameron.edu/swjpam)	12	183	183	tex, other
Theory Appl. Categ. (www.tac.mta.ca/tac)	11	152	21	ps, dvi

NR means no response received.
NA means not available or not applicable.
* From date accepted.
** From date of meeting at which the paper was communicated.
*** Date of receipt of manuscript not given in this journal.
† Received dates were not given for two fo the five papers in this issue.

American Mathematical Society

Election of Officers for 1999

CONTENTS

1998 AMS Elections Special Section

Dear Colleagues:

Once again members of the Society are invited to vote for candidates for several of the Society's governing bodies. The candidates for election are presented to the Society in the material below. Also this year you are being asked to ratify several changes in the bylaws of the Society. This information and the official ballot will be sent to you in early September. The choices you make in the elections affect directly the direction that the Society takes.

The vice president and the members-at-large of the Council you elect will serve for three years on the Council of the Society. The Council determines membership on the editorial boards of the Society, makes nominations of candidates for future elections, appoints the treasurers and members of the Secretariat, creates committees, and determines all scientific policy of the Society. Each of these members of the Council will serve on a policy committee of the Society.

The trustees, of whom you will be electing one of five for a five-year term, have complete fiduciary responsibility for the Society. The person you elect will become the chair of the Board of Trustees in the fourth year of the term. The trustees determine the annual budget of the Society, determine the prices for journals, the salaries of the employees, the dues (in cooperation with the Council), the registration fees for meetings, and the investment policy for the Society's reserves.

The candidates presented to you were suggested to the Council by the Nominating Committee or by petition by members. While the Council has the final nominating responsibility, the groundwork is done by the Nominating Committee. Members of this committee are elected by you in this same election. The candidates were nominated by the current president, Arthur Jaffe. The three elected will serve a three-year term. The main work of the Nominating Committee takes place during the annual meeting of the Society, during which it has four sessions of face-to-face meetings, each lasting about three hours. The Committee then reports its suggestions to the Council, which makes the final nominations.

The Editorial Boards Committee is responsible for the operation of the editorial boards of the Society. Members are elected for three-year terms from a list of candidates nominated by the president. The Editorial Boards Committee makes recommendations for most all the editorial boards of the Society. Editors of those journals named in the bylaws are appointed by the Council upon recommendation by the Editorial Boards Committee. Associate editors and editors for all other editorial committees are appointed by the president upon recommendation by the Editorial Boards Committee.

According to the Society's bylaws amendments to them are recommended by the Council and approved by the members. In order to gain approval an amendment must have the affirmative vote of two-thirds of those voting in this mail ballot. The current amendments are corrective in nature. The first amendment (recommended by the January 1998 Council) changes the bylaws to reflect the fact that the Society no longer has a representative on the editorial board of the *American Journal of Mathematics*. The second amendment removes hyphens from the titles of officers and changes the title of the ex-president to "immediate past president". The Council urges you to vote on the matter. If you return a ballot and do not vote on the amendments, the effect is to vote "NO" on the amendments.

If past elections are a measure, about 12 percent of you will vote in this election. This is in line with voting participation in other professional organizations. This is not an excuse for you to throw the ballot into the trash. The other officers and members of the Council join with me in urging you to take a few minutes to review the election material, fill out your ballot, and mail it. The Society belongs to its members. You can influence the policy and directions it takes by voting.

If you are still reading this, then I also urge you to consider other ways to participate in the activities of the Society. The Nominating Committee, the Editorial Boards Committee, and the Committee on Committees are always anxious to learn of members who are willing to serve the Society in various capacities. Names are always welcome (a few added words of recommendation help) and can be sent directly to the secretary, who will forward them to the cognizant body.

PLEASE VOTE.

—Robert Fossum
Secretary

List of Candidates–1998 Election

Vice-President
(one to be elected)
James G. Arthur
James Serrin

Board of Trustees
(one to be elected)
Hyman Bass
Linda Keen

Member-at-Large of the Council
(five to be elected)
Jonathan M. Borwein
Haim Brezis
Robert Fefferman
Robert M. Hardt
Gloria Hewitt
Roger Howe
Anatole Katok
Donald G. Saari
Tatiana Toro
Nolan Wallach

Nominating Committee for 1999
(three to be elected)
William Browder
Philip Hanlon
Lisa Claire Jeffrey
Douglas Lind
Henri Moscovici
Marc Rieffel

Editorial Boards Committee for 1999
(two to be elected)
George E. Andrews
William Helton
Krystyna Kuperberg
Efim Zelmanov

Election Information

The ballot for election of officers, members of the Council, a trustee, and committee members will be mailed on or shortly after September 10, 1998, in order for members to receive their ballots well in advance of the November 10, 1998, deadline. A list of members of the Council and Board of Trustees serving terms during 1998 will appear in the "AMS Officers and Committee Members" section of the October issue of the *Notices* (and will be mailed with the election material sent to all members in September).

REPLACEMENT BALLOTS

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

To help alleviate this problem, the following replacement procedure has been devised: A member who has not received a ballot by October 10, 1998, or who has received a ballot but has accidentally spoiled it, may write after that date to the Secretary of the AMS, Post Office Box 6248, Providence, RI 02940, asking for a second ballot. The request should include the individual's member code and the address to which the replacement ballot should be sent. Immediately upon receipt of the request in the Providence office, a second ballot, which will be indistinguishable from the original, will be sent by first class or air mail. It must be returned in an inner envelope, which will be supplied, on the outside of which is the following statement to be signed by the member:

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

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signature

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

SUGGESTIONS FOR 1999 NOMINATIONS

Each year the members of the Society are given the opportunity to propose for nomination the names of those individuals they deem both qualified and responsive to their views and needs as part of the mathematical community. Candidates will be nominated by the Council to fill positions on the Council and Board of Trustees to replace those whose terms expire January 31, 1999. See the "AMS Officers and Committee Members" section of the October issue for the list of current members of the Council and Board of Trustees. Members are requested to write their suggestions for such candidates in the appropriate spaces below.

Council and Board of Trustees

Vice-President *(1)*

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Members-at-large of the Council *(5)*

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Member of the Board of Trustees *(1)*

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The completed form should be addressed to AMS Nominating Committee, Post Office Box 6248, Providence, RI 02940, to arrive no later than **November 10, 1998.**

Biographies of Candidates 1998

Biographical information about the candidates has been verified by the candidates, although in a few instances prior travel arrangements of the candidate at the time of assembly of the information made communication difficult or impossible. A candidate had the opportunity to make a statement of not more than 200 words on any subject matter without restriction and to list up to five of her or his research papers.

Abbreviations: American Association for the Advancement of Science (AAAS); American Mathematical Society (AMS); American Statistical Association (ASA); Association for Computing Machinery (ACM); Association for Symbolic Logic (ASL); Association for Women in Mathematics (AWM); Canadian Mathematical Society, Société Mathématique du Canada (CMS); Conference Board of the Mathematical Sciences (CBMS); Institute of Mathematical Statistics (IMS); International Mathematical Union (IMU); London Mathematical Society (LMS); Mathematical Association of America (MAA); National Academy of Sciences (NAS); National Academy of Sciences/National Research Council (NAS/NRC); National Aeronautics and Space Administration (NASA); National Council of Teachers of Mathematics (NCTM); National Science Foundation (NSF); Operations Research Society of America (ORSA); Society for Industrial and Applied Mathematics (SIAM); The Institute of Management Sciences (TIMS).

Each candidate had the opportunity to supply a photograph to accompany her or his biographical information.

A candidate with an asterisk (*) beside her or his name was nominated in response to a petition.

Vice-President

James G. Arthur

University Professor of Mathematics, University of Toronto.

Born: May 18, 1944, Hamilton, Ontario.

Ph.D.: Yale University, 1970.

AMS Offices: Member-at-Large of the Council, 1986–1988.

AMS Committees: Program Committee for National Meetings, 1989-1991; Committee on Committees, 1991–1992.

Selected Addresses: Invited Address, Providence, August 1978; Invited Speaker, International Congress of Mathematicians, Warsaw, 1983; Symposium on the Mathematical Heritage of Hermann Weyl, Durham, 1983; Invited Address, Joint Mathematics Meetings of AMS-CMS-MAA, Vancouver, August 1993 (Jeffery-Williams Lecture); Invited Speaker, International Congress of Mathematicians, Berlin, August 1998.

Additional Information: ***Awards and Fellowships:*** Alfred P. Sloan Fellowship, 1975–1977; Elected Fellow, Royal Society of Canada, 1980; E.W.R. Steacie Memorial Fellowship, 1982; Synge Award, Royal Society of Canada, 1987; Elected Fellow, Royal Society of London, 1992; CRM-Fields Institute Prize, 1997; Henry Marshall Tory Medal, Royal Society of Canada, 1997. ***Offices:*** Executive Committee, International Mathematical Union, 1991–1998; Board of Trustees, Institute for Advanced Study, 1997–2002. ***Member:*** AMS, CMS.

Selected Publications: 1. *The trace formula in invariant form*, Ann. of Math. **114** (1981), 1-74. MR **84a**:10031; 2. *A Paley-Wiener theorem for real reductive groups*, Acta Math. **150** (1983), 1-89. MR **84k**:22021; 3. with L. Clozel, *Simple algebras, base change, and the advanced theory of the trace formula*, Ann. of Math. Stud., vol. 120, Princeton University Press, Princeton, NJ, 1989. MR **91i**:22024; 4. *The L^2-Lefschetz numbers of Hecke operators*, Invent. Math. **97** (1989), 257-290. MR **91i**:22024; 5. *A local trace formula*, Inst. Hautes Études Sci. Publ. Math. **73** (1991), 5-96. MR **92f**:22029.

Statement: The mission of the AMS is the advancement of mathematics. First and foremost this means the encouragement and support of research. It also includes the promotion of education at all levels and the effort to explain the importance of mathematics to the general public.

There are many challenges. Research in fundamental areas is as strong as ever, and the applications of mathematics are increasing on an unprecedented scale. Yet mathematics is under serious pressure. We must work to ensure that mathematics receives its share of resources within universities and its share of funding from granting agencies.

We must work to provide employment opportunities for people at the early stages of their careers, to provide for the future vitality of the subject. We must cultivate an environment that will appeal to the most talented students in schools and universities. Finally, we must collectively keep sight of what surely brought us to the subject in the first place—the excitement of doing mathematics and the pleasure of communicating it to others.

James B. Serrin

Regents Professor of Mathematics, University of Minnesota.

Born: November 1, 1926, Chicago, Illinois.

Ph.D: Indiana University, 1951.

AMS Committees: Research Expository Journal Editorial Committee, 1975-1980; Committee on Prizes, 1977 (chair); Progress in Mathematics Committee, 1992-1994 (Chair, 1994).

Selected Addresses: Invited Address, Evanston, November 1964; International Congresses of Mathematicians: Nice, 1970, and Warsaw, 1983; Centenary, Circolo Matematico di Palermo, 1984; Volterra Lectures, University of Rome, 1992; International Workshop in Differential Equations and Applications, Technion, Israel, 1997.

Additional Information: ***Honors and Awards:*** Birkhoff Prize in Applied Mathematics, 1973; Member, National Academy of Sciences, 1980- ; Fellow, American Association for the Advancement of Science, 1980- ; Member, American Academy of Arts and Sciences, 1984- ; Foreign member, Finnish Academy of Sciences, 1995; Honorary doctorates: University of Sussex, 1972; Universitá di Ferrara, 1992; Universitá di Padova, 1992. ***Other Professional Activities:*** Head, School of Mathematics, University of Minnesota 1964-1965; President, Society for Natural Philosophy, 1969-1970. ***Organizing Committees:*** Conference on Partial Differential Equations, Berkeley, 1971; Workshop on Foundations of Thermodynamics, Minneapolis, 1983; Conference on Diffusion Equations and Their Equilibrium States, MSRI, 1986, and University College, Wales, 1987. CBMS Lecturer, 1978; Member, NRC David Committee on Resources for the Mathematical Sciences, 1984; Member, Scientific Advisory Board, MSRI, 1983-1986. ***Editorial Boards:*** *Archive Rational Mechanics and Analysis*, 1963- (co-editor, 1969-1986); *Journal of Differential Equations*, 1976- ; *Communications in Partial Differential Equations*, 1978-1995; *Bulletin of the American Mathematical Society*, 1978-1980; *Rendiconti Circolo Matematico di Palermo*, 1980- ; *Atti Seminario Matematico, Universitá di Modena*, 1985- ; *Asymptotic Analysis*, 1988-1998; *Electronic Journal Differential Integral Equations*, 1989- ; *Advances in Differential Equations*, 1995- ; *Differential Equations Electronic Journal*, 1995- .

Selected Publications: 1. *Mathematical principles of classical fluid mechanics*, Handbuch der Physik **8/1** (1959), 125-263. MR **21** #6836b; 2. *The problem of Dirichlet for quasilinear elliptic differential equations with many independent variables*, Philos. Trans. Royal Soc. London Ser. A **A264** (1969), 413-496. MR **43** #7772; 3. *The swirling vortex: Internal structure of tornados*, Philos. Trans. Royal Soc. London **A271** (1972), 325-360. 4. *Applied mathematics and scientific thought*, Lecture Notes in Math., vol. 1107, Springer, Berlin-New York, 1984, pp. 19-27. MR **86d**:00021; 5. with P. Pucci, *Critical exponents and critical dimensions for the polyharmonic operator*, J. Math. Pure Appl. **69** (1990), 55-83; 6. with H. Levine, *Global nonexistence theorems for quasilinear evolution equations with dissipation*, Arch. Rational Mech. Anal. **137** (1997), 341-361.

Statement: As we approach the end of this century of great mathematical achievements of enduring importance and beauty, we cannot afford to be overcome by the new challenges facing us. Even more, society cannot afford to see mathematics reduced to a point where it can no longer serve the needs of the country. The challenges are well known: finding opportunities where young mathematicians can use their talents to the fullest, improving mathematics learning at *all* levels, making sure that young people can enter mathematics with optimism about their future, and developing public awareness of the vital importance of science and mathematics.

The AMS cannot meet these challenges single-handedly, but it must remain a coherent center to formulate and coordinate sensible policies of action. These can include reaching out to users and potential users, both within and outside the universities, making school positions more accessible and attractive to gifted individuals who are interested in teaching careers, providing increased travel and conference funding to maintain high levels of achievement throughout the country, and creating other academic institutes like the IMA and MSRI.

Mathematics remains the queen of the sciences. We must do all in our power to maintain this enviable position.

Trustee

Hyman Bass

Adrain Professor of Mathematics, Columbia University.
Born: October 5, 1932, Houston, Texas.
Ph.D.: University of Chicago, 1959.
AMS Offices: Member-at-Large of the Council, 1969–1971; Vice-President, 1980–1981; Board of Trustees, 1995– .
AMS Committees: Bulletin (New Series) Editorial Committee, 1982–1986 (associate editor, Research-Expository Articles, 1982–1984, and chair, 1985); Committee on Long-Range Planning, Board of Trustees, 1985–1986; Executive Committee of the Council, 1985–1987; Committee on the Status of the Profession, 1994– (chair); Executive Committee and Board of Trustees, 1995– ; Electronic Research Announcements Editorial Board, 1995– ; Committee on Science Policy, 1995– (chair, 1996–); Liaison Committee with AAAS, 1996– (chair, 1997–); AMS-MAA Committee on Research in Undergraduate Mathematics, 1997–.
Selected Addresses: International Congresses of Mathematicians: Moscow, 1966, and Vancouver, 1974; MAA Hedrick Lecturer, 1968; Invited Address, Cambridge, October 1969; Colloquium Lectures, Atlanta, January 1978; Invited Address, Pretoria, June 1997; Phi Beta Kappa, National Visiting Scholar.
Additional Information: Van Amringe Book Award, Columbia University, 1969; Frank Nelson Cole Prize in Algebra, 1975. ***Member***: AMS; American Academy of Arts and Sciences; National Academy of Sciences; Chair, Mathematical Sciences Education Board, NAS.
Selected Publications: 1. *On the ubiquity of Gorenstein rings*, Math. Z. **82** (1963), 8–28. MR **27** #3669; 2. with J. Milnor and J.-P. Serre, *Solution of the congruence subgroup problem for* $SL_n(n \geq 3)$ *and* $Sp_{2n}(n \geq 2)$, Inst. Hautes Études Sci. Publ. Math. **33** (1967), 59–137. MR **39** #5574; 3. *Algebraic K-theory*, W.A. Benjamin, New York, 1968. MR **40**:2736; 4. with E. H. Connell and D. Wright, *The Jacobian conjecture: Reduction of degree and formal expansion of the inverse*, Bull. Amer. Math. Soc. (N.S.) **7** (1982), 287–330. MR **83K**:14028; 5. with R. Kulkarni, *Uniform tree lattices*, J. Amer. Math. Soc. **3** (1990), 843–902. MR **91k**:20034.
Statement: The core mission of the AMS has always been the promotion and support of research in mathematics. At the same time, the AMS has expanded its roles in response to fundamentally changing conditions: the vast expansion of mathematical knowledge and its uses; the influences of technology on both research and communication; the widening roles of mathematics in contemporary society; the expansion of our professional community and its attendant needs; the need to draw talented youth, especially from underrepresented groups, into our profession; the need for more effective outreach to the wider scientific community and to the public; and the increased responsibility and role of the mathematical community in mathematics education at all levels. These present the Society with a wide array of complex challenges in which it must maintain a balanced set of priorities and reconcile responsibility to the community with managerial prudence. As a trustee I would contribute to the oversight that assures that these conditions are met.

Linda Keen

Professor, Herbert H. Lehman College (CUNY).
Born: August 9, 1940, New York, New York.
Ph.D: New York University, 1964.
AMS Offices: Member-at-Large of the Council, 1981–1983; Vice-President, 1992–1995.
AMS Committees: ***Elected Committees***: Nominating Committee, 1983–1984 (chair, 1984); Editorial Boards Committee, 1989–1992 (chair, 1991). ***Appointed AMS Committees***: Committee on Professional Ethics, 1987–1989 (chair, 1988–1989); Program Committee for National Meetings, 1988; Committee to Select the Winner of the Satter Prize, 1991 (chair); Representative, Joint Policy Board on Mathematics, 1992–1995; Science Policy Committee, 1993–1995; Meetings and Conferences Committee, 1994; Ad Hoc Committee on Governance, 1994; Federal Policy Agenda Statement, 1994–1995. ***AMS Editorial Boards:*** Undergraduate Mathematics Education (UME) Trends Editorial Committee, 1989–1991; Proceedings Editorial Committee (Coordinating Editor), 1994– ; Managing Editor, *Conformal Geometry and Dynamics*: An Electronic Journal of the American Mathematical Society, 1997– .
Selected Addresses: Invited Address, Washington, D.C., January 1975; MAA Invited Hour Address, Boulder, August 1989; Invited Address, Finnish Mathematical Society, January 1991; Emmy Noether Lecturer, January 1993; AIM Conference in Honor of Lars Ahlfors, September 1997; London Mathematical Society-Irish Mathematical Society Invited Hour Address, May 1998.
Additional Information: ***Other Editorial Committees***: *Journal of Geometric Analysis* (associate editor), 1991– ; *Annales of Finnish Academy of Science*, 1996– . ***Other Organizations***: NSF Postdoctoral Fellowship, 1964; Member, IAS, 1964–1965; AWM President, 1985–1986; NYC Mayor's Commission for Science and Technology, 1985–1986; CBMS Executive Committee, 1985–1987; Steering Committee, ICM-86; Acting Associate Provost, Lehman College, 1987; NSF Visiting Professorship for Women, 1989–1990; Edwin S. Webster-Abby Rockefeller Mauze Award, MIT, 1990; MAA Merton Hasse Prize Committee, 1990–1992; U.S. delegate ICM-90, USNCM, 1990–1993; AWM Louise Hay Prize Committee Chair, 1997–1998. ***Selected Visiting Professorships:*** University of California at Berkeley, 1972; Columbia University, 1980–1981; Boston University, 1987; Princeton University, 1989–1990; MIT, 1991; Institute for Mathematical Sciences, State University of New York at Stony Brook, 1993.

Selected Publications: 1. *Intrinsic moduli on Riemann surfaces*, Ann. of Math. **84** (1966), 404–420. MR **34** #2859; 2. with L. Goldberg, *A finiteness theorem for a dynamical class of entire functions*, J. Ergodic Theory and Dynam. Sys. **6** (1986), 183–192. MR **88b**:58126; 3. with P. Blanchard and R. Devaney, *The dynamics of complex polynomials and* *automorphisms of the shift*, Invent. Math **104** (1991), 545-580. MR **92f**:58150; 4. with C. Series, *Pleating coordinates for the Maskit embedding of Teichmüller space for a punctured torus*, Topology **32** (1993), 719-749. MR **95g**:32030; 5. with J. Kotus, *Dynamics of the family $\lambda \tan z$*, Conform. Geom. Dynam. (1997), 28-57 (electronic).

Statement: In recent decades mathematics has burgeoned. New areas have opened and old problems have been solved. Tie-ins to physics, computer science, and economics have been found, enhancing both mathematics and the related fields. During the same period the stature of mathematicians (and scientists) has declined and support for research has decreased. The academic job market, always cyclical, has hit new lows.

To meet the widening needs of the profession, the AMS has traditionally sponsored meetings and published journals and books. These activities have broadened to include public relations and lobbying in Washington on the national front and the establishment of joint programs with other mathematical societies on the global front. The AMS should continue to be responsive to these needs and in particular to the needs of the younger generation: universities need to stop relying on temporary adjunct faculty and to replace retiring faculty; faculty have to learn how to help students find jobs outside of academe; women and members of minority groups need to be recruited and made more welcome. As trustee I will work to make sure these Society activities remain in proper balance.

Member-at-Large of the Council

Jonathan M. Borwein

Shrum Professor of Science, Simon Fraser University.

Born: May 25, 1951, St. Andrews, Scotland.

Ph.D.: Jesus College, Oxford, 1974.

Selected Addresses: Coxeter-James Lecturer, Canadian Mathematical Society, Vancouver, 1987; Harry H. Gehman Lecture, MAA/OMM Meeting, Queens University, Kingston, 1992; MAA-CMS Invited Lecture, Joint AMS/MAA/CMS Summer Meetings, University of British Columbia, 1993; Plenary Lecture, XVIII Symposium on Operations Research, Cologne, 1993; Principal Lecturer, Australian Mathematical Society Meeting, University of Tasmania, 1995.

Additional Information: ***Awards and Prizes***: Ontario Rhodes Scholarship, 1971-1974; Senior Killam Fellow, Dalhousie University, 1987-1988; Atlantic Provinces Council on the Sciences Gold Medal for Outstanding Achievement in Natural or Applied Science, 1988; Chauvenet and Hasse Prizes of the MAA, 1993; Fellow, Royal Society of Canada (Academy of Science), 1994; British Columbia/CUFA Academic of the Year (with P. Borwein), 1996. ***Professional Experience***: Member, Board of the Canadian Mathematical Society, 1984-1988; 1995- ; Member, Research Committee of the CMS, 1985-1988; Chair, NSERC Mathematics Grant Selection Committee, 1989-1991; Member, Steering Committee, Centre for Mathematical Research, Montreal, 1989-1993; Co-editor, Wiley CMS Series of Advanced Books, 1991- ; Member, NSERC Committee on Collaborative Research Initiatives, 1992-1996; Director, Simon Fraser Centre for Experimental and Constructive Mathematics, 1993- ; Chair, CMS Electronic Services Committee, 1995-1997; Member, Advisory Board for the Canada Institute for Scientific and Technical Information, National Research Council of Canada, 1997- ; Member, NATO Panel on Collaborative Research Grants, 1997- (chair, 1998); Member, Royal Society of Canada's Public Awareness of Science Committee, 1998- .

Selected Publications: 1. with D. Preiss, *A smooth variational principle with applications to subdifferentiability and to differentiability of convex functions*, Trans. Amer. Math. Soc. **303** (1987), 517-527. MR **88k**:49013; 2. with P. B. Borwein and D. H. Bailey, *Ramanujan, modular equations and pi, or how to compute a billion digits of pi*, Amer. Math. Monthly **96** (1989), 201-219. MR **90d**:11143; 3. with P. B. Borwein, *A cubic counterpart of Jacobi's identity and the AGM*, Trans. Amer. Math. Soc. **323** (1991), 691-701. MR **91e**:33012; 4. with H. H. Bauschke, *On projection algorithms for solving convex feasibility problems*, SIAM Rev. **38** (1996), 367-426. MR **98f**:90045; 5. with D. M. Bradley, *Empirically determined Apéry-like formulae for $\zeta(4n+3)$*, Experiment. Math. **6** (1997), 181-194.

Statement: I am interested equally in the health of our community as a researcher, teacher, and expositor. I believe that my diverse administrative and professional experience would allow me to play a constructive role in the continuing evolution of the AMS. I have held academic positions at Dalhousie, Carnegie Mellon, Waterloo, Simon Fraser, and many visiting positions. I am also a committed advocate of the informed use of technology and of the need for the mathematical community to be vigorously engaged with the outside world while defending its beautiful and timeless core.

Haim Brezis

Professor, Université Paris VI and Institut Universitaire de France; Visiting Distinguished Professor, Rutgers University.

Born: June 1, 1944, Riom-es-Montagnes, France.

Ph.D.: University of Paris, 1971.

Selected Addresses: International Congress of Mathematicians, Vancouver, 1974; AMS Symposium on the Mathematical Heritage of Henri Poincaré, Bloomington, 1980; Riviere Memorial Lecture, Minneapolis, 1983; Invited AMS Address, Progress in Mathematics, Boulder, 1989; AMS-MAA Invited Address, Baltimore, 1998.

Additional Information: Member, Académie des Sciences: Paris, 1988; Member, Academia Europaea, 1989; Foreign Honorary Member, American Academy of Arts and Sciences, 1994; Doctorate Honoris Causa: Catholic University of Louvain, 1996; Technion, Haifa, 1998. ***Visiting Professor***: University of Chicago, 1980; University of Wisconsin, 1981; Princeton University, 1983; MIT, 1985; Courant Institute, NYU, 1987. ***Chief Editor: Pitman Research Notes***; Birkhauser Series on Nonlinear Differential Equations. ***Member***: Scientific Committee of Scuola Normale Superiore, Pisa; Organizing Committee, Colloquium on Partial Differential Equations and Applications, National Academy of Sciences, 1999.

Selected Publications: 1. *Opérateurs maximaux monotones et semi-groupes de contractions dans les espaces de Hilbert*, North-Holland Math. Stud., no. 5, Amsterdam-London; American Elsevier Publishing Co., Inc., New York, 1973. MR **50** #1060; 2. with L. Nirenberg, *Positive solutions of nonlinear elliptic equations involving critical Sobolev exponents*, Comm. Pure Appl. Math. **36** (1983), 437–477. MR **84h**:35059; 3. with J.-M. Coron and E. Lieb, *Harmonic maps with defects*, Comm. Math. Phys. **107** (1986), 649–705. MR **88e**:58023; 4. with F. Bethuel and F. Hélein, *Ginzburg-Landau vortices*, Progress in Nonlinear Differential Equations and Their Applications, vol. 13, Birkhauser Boston, Inc., Boston, MA, 1994. MR **95c**:58044; 5. with L. Nirenberg, *Degree theory and BMO*, Selecta Math. **1** (1995), 197–263. MR **96g**:58023; *Degree theory and BMO*. II. *Compact manifolds with boundaries*, Selecta Math. **2** (1996), 1–60. MR **98a**:58024.

Statement: Since the beginning of my mathematical career I have been strongly involved with the American mathematical community through visits to American universities and long-term collaboration with American mathematicians. I have become aware that many of the basic problems facing American mathematicians also occur in other countries: stimulating mathematical talents, finding positions for mathematical activities, and enhancing the public image of mathematics.

In recent years the European community has been primarily active in building efficient European networks. As an example, I am involved in joint programs between France, Italy, Spain, the United Kingdom, the Netherlands, Romania, and Israel. I believe that it is now important to enhance the ties between Europe and the U.S., which has the world's strongest mathematical community. I would be delighted to share my experience and to help to promote cooperation in research and education.

Robert A. Fefferman

Louis Block Professor and Chair, Department of Mathematics, University of Chicago.

Born: July 20, 1951, Washington, D.C.

Ph.D.: Princeton University, 1975.

Selected Addresses: Invited Address, College Park, 1982; Friends of Mathematics Lecture, Kansas State University, 1993; Rubio de Francia Memorial Talks, Madrid, Spain, 1995; Missouri Lecture, 1996; Numerous special sessions at AMS meetings.

Selected Publications: 1. with A. Cordoba, *A geometric proof of the strong maximal theorem*, Ann. of Math. **102** (1975), 95–100. MR **52** #690; 2. with S. Y. Chang, *A continuous version of the duality of H^1 and BMO on the bidisc*, Ann. of Math. **112** (1980), 179–201. MR **82a**:32009; 3. *Harmonic analysis on product spaces*, Ann. of Math. **126** (1987), 109–130. MR **90e**:42030; 4. with C. Kenig and J. Pipher, *The theory of weights and the Dirichlet problem for elliptic operators*, Ann. of Math. **134** (1991), 65–124. MR **93h**:31010; 5. with J. Pipher, *Multiparameter operators and sharp weighted inequalities*, Amer. J. Math. **119** (1997), 337–369. MR **98b**:42027.

Statement: This is a period of constant challenge for our profession. With a smaller number of tenure-track jobs available and a decline in government support of universities and of core mathematics in particular, it is extremely important for the AMS to take a strong stand in favor of support for small-scale basic research in core mathematics. This is where the greatest advances in the field are achieved. At the same time, we should not be hesitant to support new programs which represent valuable applications of mathematics to areas outside the university and to take responsibility for improved mathematics education at all levels. We should be sensitive to and support the missions of different types of universities and the diversity present in the membership of the AMS, which goes outside of the universities. We should continue to search for new ways to encourage underrepresented groups to enter the profession and for mathematicians from such groups to achieve the greatest productivity and recognition.

Robert M. Hardt

William Moody Professor of Mathematics, Rice University.

Born: June 24, 1945, Pittsburgh, Pennsylvania.

Ph.D.: Brown University, 1971.

Selected Addresses: International Congress of Mathematicians, Berkeley, 1986; Invited Address, San Antonio, January 1987; University of Iowa Distinguished Visitor's Lecture Series, December 1993; Lecture series, International Centre for Theoretical Physics, Trieste, August 1995; Texas A&M Frontier Lecture Series, April 1996.

Additional Information: ***Associate Editorships***: *Annales de l'Institut Henri Poincaré*, 1991–1995; *Journal of Geometric Analysis*, 1992– ; *Houston J. of Mathematics*, 1993– . ***Organizing Committees***: Special Session on Partial Differential Equations, Minneapolis, November 1983; AMS Summer Symposium on Geometric Measure Theory, Arcata, June 1984; IMA Miniconference on Liquid Crystals, Bloomington, March 1987; Oberwolfach Conference on Calculus of Variations, July 1990; Park City Mathematics Institute, July 1992; Undergraduate Conference on the Calculus of Variations, Rice, October 1996; Texas Geometry-Topology Conference, Rice, March 1990, April 1993, and November 1996; ten Ph.D. theses supervised.

Selected Publications: 1. *Slicing and intersection theory for chains associated with real analytic varieties*, Acta Math. **129** (1972), 75–136. MR **47** #4110; 2. with L. Simon, *Boundary regularity and embedded solutions for the oriented Plateau problem*, Ann. of Math. **110** (1979), 439–486. MR **81i**:49031; 3. with D. Kinderlehrer and F. H. Lin, *Existence and partial regularity of static liquid crystal configurations*, Comm. Math. Phys. **105** (1986), 547–570. MR **88a**:35207; 4. with D. Sullivan, *Variation of the Green's function on Riemann surfaces and Whitney's holomorphic stratification conjecture*, Inst. Hautes Études Sci. Publ. Math. **68** (1989), 115–138. MR **91d**:32054; 5. with F. H. Lin and C. Y. Wang, *Singularities of p-energy minimizing maps*, Comm. Pure Appl. Math. **50** (1997), 399–447.

Statement: The primary purpose of the AMS is to support and encourage mathematical research and scholarship. It should continue to improve its many well-established structures (publications, meetings, etc.) while considering new ways to enhance communication within the mathematical community and between mathematicians and the public. The appearance and development of exciting, important mathematics, pure and applied, should significantly influence funding agencies, educational institutions, and nonacademic employers of mathematicians. The AMS has a crucial role in effecting this communication.

Gloria C. Hewitt

Professor and Chair, Department of Mathematical Sciences, The University of Montana, Missoula.

Born: October 26, 1935, Sumter, South Carolina.

Ph.D.: University of Washington, 1962.

Selected Addresses: ***Invited Addresses/Colloquium Lectures***: Category Theory and Automata, Cleveland, 1981; Generalized Noetherian Rings, Montana, 1989; Polynomial Rings: China, 1990, and Portland, 1997.

Additional Information: *MAA*: Distinguished Teaching Award Committee, Pacific Northwest Section, 1991–1993; Subcommittee on Assessment, 1993; Board of Governors, 1995–1998; Minority Graduate Students Survey Consultant, 1996–1997; GRE Committee of Examiners, 1984–1997 (chair, 1984–1986); College Board Advanced Placement Calculus Development Committee, 1987–1991; GRE Technical Advisory Committee; GRE General Test, 1992–1995; Advisory Panel for the NSA Mathematical Sciences Program, 1993–1996; NAM Board of Directors, 1997– .

Selected Publications: 1. *The existence of free unions in classes of abstract algebras*, Proc. Amer. Math. Soc. **14** (1963), 417–422. MR **26** #6098; 2. *Limits in certain classes of abstract algebras*, Pacific J. Math. **22** (1967), 109–115. MR **35** #1529; 3. with F. Hannick, *Characterizations of generalized Noetherian rings*, Acta Math. Hungar. **53** (1989), 61–73. MR **90g**:16039.

Statement: The AMS should continue to increase its efforts on issues relating to diversity, making the profession one which welcomes women and minorities, engaging in activities which inform the mathematical community on ways to accomplish this, and encouraging the community to do so.

Roger Howe

F. P. Rose Professor of Mathematics, Yale University.

Born: May 23, 1945, Chicago, Illinois.

Ph.D.: University of California, Berkeley, 1969.

AMS Committees: Bulletin Editorial Committee (associate editor, Research Announcements), 1985–1986; Bulletin (New Series) Editorial Committee, 1987–1990 (chair, 1989); AMS Area Resource Group for Revision of the NCTM Standards, 1996– .

Selected Addresses: International Congress of Mathematicians, Vancouver, 1970; Summer Institute on Harmonic Analysis on Homogeneous Spaces, Williamstown, August 1972; Hermann Weyl Centennial Symposium, Durham, 1983; Invited Address, Denver, January 1983; Invited Address, AMS Centennial, Providence, August 1988.

Additional Information: Guggenheim Fellow, 1983; Fellow, Japan Society for the Promotion of Science, 1993. ***Editorial Boards***: *Mitwirker, Crelle's Journal*, 1985–1997; *Mathematics Research Letters*, 1993–1997; *Transformation Groups*, 1995– ; *Advances in Mathematics*, 1995– . Mathematical Sciences Education Board, 1995– ; Board of Directors, Connecticut Academy for Education in Mathematics, Science, and Technology, 1995– ; Phi Beta Kappa Visiting Scholar, 1996–1997. ***Member***: AMS, MAA, NCTM, American Academy of Arts and Sciences, Connecticut Academy of Science and Engineering, National Academy of Sciences.

Selected Publications: 1. with J. W. Helton, *Traces of commutators of integral operators*, Acta Math. **136** (1976), 271–305. MR **55** #1110; 2. *θ-series and invariant theory*, Proc. Sympos. Pure Math., vol. 33, Amer. Math. Soc., Providence, RI, 1979, pp. 275–286. MR **81f**:22034; 3. with C. Moore, *Asymptotic properties of unitary representations*, J. Funct. Anal. **32** (1979), 72–96. MR **80g**:22017; 4. with A. Moy, *Harish-Chandra homomorphisms for $\mathfrak{p}$-adic groups*, CBMS Regional Conf. Ser. in Math., vol. 59, Amer. Math. Soc., Providence, RI, 1985. MR **87h**:22023; 5. *Remarks on classical invariant theory*, Trans. Amer. Math. Soc. **313** (1989), 539–570. MR **90h**:22015a.

Statement: The AMS needs to foster new institutional structures that will allow the mathematics research community to contribute effectively and efficiently to ongoing debates on education, research funding, the role of universities, and other issues which will affect mathematical research over the long term.

Anatole Katok

Professor, Department of Mathematics, Pennsylvania State University.

Born: August 9, 1944; Washington, D.C.

Ph.D.: Moscow State University, 1968.

AMS Committees: Committee on Translations, 1988–1992; Presidential Task Force on Membership, 1998– .

Selected Addresses: AMS Invited Address, Birmingham, 1979; Frank J. Hahn Lectures, Yale University, 1980; Rufus Bowen Memorial Lectures, Berkeley, 1982; International Congress of Mathematicians, Warsaw, 1983; Symposium on Mathematics in the Sciences, Leipzig, 1998.

Additional Information: NSF Advisory Committee in Mathematical Sciences, 1983–1986; MSRI: Trustee, 1985–1991, Scientific Advisory Council, 1989–1993; IMA: Board of Governors, 1993–1996; Raymond N. Shibley Professor of Mathematics, 1996– .

Selected Publications: 1. with B. Hasselblatt, *Introduction to the modern theory of smooth dynamical systems*, Cambridge University Press, Cambridge, 1995. MR **96c**:58055; 2. with A. M. Stepin, *Approximations in ergodic theory*, Uspehi Mat. Nauk **22**, no. 5 (1967), 81-106. MR **36**#2776; 3. *Lyapunov exponents, entropy and periodic points of diffeomorphisms*, Inst. Hautes Études Sci. Publ. Math. **51** (1980), 137-173. MR **81i**:28022; 4. *Entropy and closed geodesics*, Ergodic Theory Dynamical Systems **2** (1982), 339-366. MR **85b**:53047; 5. with R. Spatzier, *Differential rigidity of Anosov actions of higher rank Abelian groups and algebraic lattice actions*, Dynamical Systems and Related Topics (volume dedicated to D. V. Anosov), Proc. Steklov Math. Inst. **216** (1997), 287-314.

Statement: The mathematical community in the United States faces an important double challenge. On one hand, mathematics is not very popular as a career choice for undergraduates, in particular among those with sufficient talent and aptitude. On the other hand, prevailing academic employment patterns make many Ph.D. students who are successful in their research uncertain and pessimistic about their further careers.

I consider developing creative and effective responses to these challenges to be the central task for the profession as a whole and by implication for the AMS, its main professional organization. We should develop and implement effective mechanisms for exposing the most talented undergraduate students to the beauty, excitement, and power of mathematical thinking and for bringing them into close and fruitful contact with various layers of the professional mathematical community, from graduate students up to the most senior researchers. An effective response to the second challenge may include a creative and aggressive promotion of the value and effectiveness of mathematical thinking in a wide variety of contexts both in and outside academia.

Donald G. Saari

Pancoe Professor of Mathematics, Northwestern University.

Born: March 9, 1940, Ironwood, Michigan.

Ph.D.: Purdue University, 1967.

Additional Information: National Committee for Mathematics; Department Chair, Northwestern University, 1981-1984; Consultant, Commission on Celestial Mechanics, International Astronomy Union, 1985-1991; Guggenheim Fellow, 1988; Doctorat Honoris Causa, Purdue University, 1989, Université de Caen, France, 1998; Public Information Advisory Committee, JPBM, 1989-1994; Duncan Black Research Prize, Public Choice Society, 1991; Honorary Professor, Nanjing University, 1995; associate editor for several mathematics, celestial mechanics, and economics journals. ***MAA***: Ford Prize, 1985; MAA Notes Board, 1993- ; Chauvenet Prize, 1995. ***SIAM***: Editor, *SIAM Journal on Mathematical Analysis*, 1981-1986; Organizing Committee, SIAM National Meeting, 1988; SIAM Committee on Committees, 1995-1997. Chief Editor, *Bulletin of the American Mathematical Society*, 1999- . ***Member***: AMS, MAA, SIAM, Division of Dynamical Astrononomy (AAS).

Selected Publications: 1. with Z. Xia, *Off to infinity in finite time*, Notices Amer. Math. Soc. **42** (1995), 538-546. MR **95m**:70002; 2. with Z. Xia, *Hamiltonian dynamics and celestial mechanics*, Contemp. Math., vol. 198, Amer. Math. Soc., Providence, RI, 1996. MR **97c**:70001; 3. *Mathematical complexity of simple economics*, Notices Amer. Math. Soc. **42** (1995), 222-230. MR **95m**:90029; 4. *A chaotic exploration of aggregation paradoxes*, SIAM Rev. **37** (1995), 37-52. MR **97a**:90008; 5. *Basic geometry of voting*, Springer-Verlag, Berlin, 1995. MR **98d**:90040.

Statement: "It was the best of times; it was the worst of times" describes contemporary mathematics. I can't think of a more exciting, delightful time to be an active mathematician. Just consider the wide variety of major results resolved in the last two decades, the new directions of mathematics, and the increased mathematical sophistication of associated academic areas. But in the midst of this excitement we also face continued employment difficulties, particularly for graduating Ph.D.s: problems in attracting sufficient numbers of bright students (particularly minorities and women) into mathematics, funding difficulties, demands for educational reform, changes in tenure rules, and a continued lack of understanding and appreciation from others about what it is that we do, a problem which can negatively affect the allocation of resources within universities and at the governmental level.

If elected, I will do my best to address the challenging mix of problems while assisting the AMS to continue its excellent performance in disseminating research information through publications, meetings, and electronic media.

Tatiana Toro

Assistant Professor, University of Washington, Seattle.

Born: July 5, 1964, Bogotá, Colombia.

Ph.D.: Stanford University, 1992.

Selected Addresses: Special Session on Singularities of Geometric Partial Differential Equations, Salt Lake City, April 1993; Southeastern Geometry Conference, University of Georgia, Athens, April 1994; Southern California Analysis and Partial Differential Equations Seminar, University of California, San Diego, April 1995; Midwest Partial Differential Equations Seminar, Northwestern University, Evanston, November 1995; Special Session on Harmonic Maps, University of Southern California, Los Angeles, November 1995; Julia Robinson Celebration of Women in Mathematics, MSRI, Berkeley, July 1996; Co-organizer (with C. Kenig), Special Session on Analysis and Geometry, Detroit, May 1997;

Sixth Annual Southern California Geometric Analysis Seminar, University of California, Irvine, May 1997.
Additional Information: National Science Foundation Mathematical Sciences Postdoctoral Research Fellowship, 1994–1998; Alfred P. Sloan Research Fellowship, 1996.
Selected Publications: 1. *Surfaces with generalized second fundamental form in L^2 are Lipschitz manifolds*, J. Differential Geom. **39** (1994), 65–101. MR **95b**:49066; 2. *Geometric conditions and existence of bi-Lipschitz parameterizations*, Duke Math. J. **77** (1995), 193–227. MR **96b**:28006; 3. with C. Kenig, *Harmonic measure on locally flat domains*, Duke Math. J. **87** (1997), 509–551; 4. *Doubling and flatness: geometry of measures*, Notices Amer. Math. Soc. **44** (1997), 1087–1094.
Statement: I would like to mention two topics I believe the AMS should be concerned with in order to preserve and improve the health of our mathematical community. First, we need to improve our public image in order to survive in an atmosphere where quick results are expected and therefore pure research is not recognized as a worthwhile investment. Though interdisciplinary enterprises may often improve our image, they are not an accurate reflection of what a large percentage of us do. A "historical" approach would help convey the fact that abstract mathematical ideas which were developed many years ago are now fundamental to modern technology. This would help justify the benefit of increased investment in fundamental mathematics research.

Second, the widespread short-term employment of young mathematicians is alarming. After a long string of one- and two-year jobs many talented mathematicians have quit academia. This phenomena is also tied to two negative tendencies: on one hand, the pool of applicants to graduate programs in mathematics has shrunk substantially; on the other hand, many departments are being downsized. Not hiring at the tenure-track level, either because of administrative constraints or for other reasons, is creating a large generational gap in many departments. This is clearly a problem that requires attention.

Nolan R. Wallach

Professor, Department of Mathematics, University of California, San Diego.
Born: August 3, 1940, Brooklyn, New York.
Ph.D.: Washington University, St. Louis, Missouri, 1965.
AMS Committees: Editorial Boards Committee, 1991–1993 (chair, 1992); Bulletin Editorial Committee (associate editor, Research-Expository Surveys), 1995– .
Selected Addresses: Invited Address, Washington, D.C., January 1975; International Congress of Mathematicians, 1978; AMS-MAA Joint Lecture, Louisville, January 1990.
Additional Information: Alfred Sloan Fellowship, 1972–1974; National Mathematics Committee, 1985–1992; associate editor, *Annals of Mathematics*, 1997– .
Selected Publications: 1. *Compact homogeneous Riemannian manifolds with strictly positive curvature*, Ann. of Math. **96** (1972), 277–295. MR **46** #6243; 2. *Real reductive groups*. I. Academic Press, Inc., Boston, MA, 1988. MR **89i**:22029; and *Real reductive groups*. II., Academic Press, Inc., Boston, MA, 1992. MR **93m**:22018; 3. *Invariant differential operators on a reductive Lie algebra and Weyl group representations*, J. Amer. Math. Soc. **6** (1993), 779–816. MR **94a**:17014; 4. with R. Goodman, *Representations and invariants of the classical groups*, vol. 68, Cambridge University Press, Cambridge, 1998.
Statement: One of the main forces that propels the information age is mathematics. The abstractions of my youth have become the applied mathematics of my middle age. Examples abound demonstrating the critical role of mathematics to our daily lives. However, we are told that we must change the way mathematics is taught at the graduate level, we must change how mathematical research is funded, we must change the role of the mathematics department in the university. With the highest teaching loads and the lowest salaries, mathematicians are the poor relations among academic scientists. It is my opinion that this unenviable situation for mathematics in such prosperous times is mainly our own fault.

Much of the real mathematics that appears in nonmathematical journals is derived independently of the mathematical literature. The nonmathematician finds it easier to "reinvent the light bulb" than to try to penetrate our literature or to understand our explanations. We must work to bring down the "Tower of Babel" that separates mathematics from other sciences.

The American Mathematical Society must communicate to the scientific community and to the general public about real mathematics, taking pointers from the other sciences as to how to handle the advertising.

Nominating Committee

William Browder

Professor, Princeton University.
Born: January 6, 1934, New York, New York.
Ph.D.: Princeton University, 1958.
AMS Offices: Member-at-Large of the Council, 1967–1969, 1972–1974; Vice-President, 1977–1978; President, 1989–1990; Board of Trustees, 1989–1990.
AMS Committees: Proceedings Editorial Committee (associate editor), 1963–1965; Committee to Select Hour Speakers for Summer and Annual Meetings, 1967–1968; Committee on Summer Institutes, 1973; Executive Committee, 1973, 1977–1978, 1991; Committee on Russian Reprinting Rights, 1974; Organizing Committee, Summer Institute on Algebraic and Geometric Topology, July 1976; Committee on National Awards and Public Representation, 1984-1985, 1988-1991 (chair, 1990); Liaison Committee, 1989-1990 (chair); Agenda and Budget Committee, 1989–1990; Committee on Committees, 1989–1990; Committee on Science Policy, 1989–1991; Committee to Select the Winner of the Award for Public Service, 1992–1995; Colloquium Lectures Committee, 1993–1998 (chair).
Selected Addresses: Half-Hour Address, International Congress of Mathematicians, Moscow, 1966; Summer Research Institute on Algebraic Topology, Madison, July 1970; Hour Address, International Congress of Mathematicians, Nice, 1970; Summer Research Institute on Algebraic and Geometric Topology, Stanford, August 1976; Colloquium Lecturer, St. Louis, January 1977; Symposium on the Math-

ematical Heritage of Henri Poincaré, Bloomington, April 1980; Special Session on Topology of Algebraic and Analytic Varieties, College Park, October 1982.
Additional Information: Editor, *Annals of Mathematics*, 1969–1980; Office of Mathematical Sciences, National Research Council, 1979–1983 (chair). ***Member*** : AMS, American Academy of Arts and Sciences, Finnish Academy of Arts and Sciences, National Academy of Arts and Sciences.
Statement: I would look for candidates who, while having a strong research orientation, have the political skills to contribute to both the smooth running of the organization and to the ongoing efforts to communicate the importance of mathematics to policymakers and to the general public. The building of such a group of people is important to the long-term health of our subject. They should be representative of the diverse interests of the membership, both in mathematical questions and in political and social viewpoints relevant to our community.

Philip Hanlon

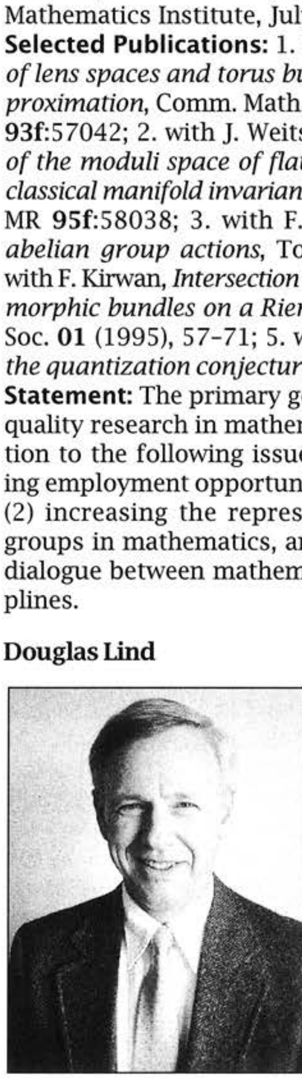
Professor of Mathematics, University of Michigan.
Born: April 10, 1955, Gouverneur, New York.
Ph.D.: California Institute of Technology, 1981.
AMS Committees: Mathematical Reviews Editorial Committee, 1992–1995 (chair); Transactions and Memoirs Editorial Committee, 1992– .
Selected Addresses: AMS Invited Address, Atlanta, January 1988; Hour Address, CMS National Meeting, July 1992.
Additional Information: ***Honors, Awards, and Invited Addresses***: Alfred P. Sloan Fellowship, 1986–1988; NSF Presidential Young Investigator Award, 1987–1992; Henry Russel Award, 1990; CMS Plenary Speaker, 1992; John Simon Guggenheim Fellowship, 1993; Michigan Society of Fellows, 1993–1996; LS & A Excellence in Education Award, 1997.
Selected Publications: 1. with R. P. Stanley and J. R. Stembridge, *Some combinatorial aspects of the spectra of normally distributed random matrices*, Contemp. Math., vol. 138, Amer. Math. Soc., Providence, RI, 1992, 151–174. MR **93j**:05164; 2. with M. Wachs, *On Lie k-algebras*, Adv. Math. **113** (1995), 206–236. MR **96h**:17006; 3. with G. Denham, *On the Smith normal form of the Varchenko bilinear form of a hyperplane arrangement*, Pacific J. Math., Special Issue in Memory of Olga Taussky-Todd (1997), 123–146; 4. with R. P. Stanley, *On the action of a q-deformation of the trivial idempotent on the group algebra of the symmetric group*, Trans. Amer. Math. Soc., to appear; 5. with J. Friedman, *On the Betti numbers of chessboard complexes*, J. Alg. Combin., to appear; 6. with P. Bidigare and D. Rockmore, *A combinatorial description of the spectrum for the Tsetlin library and its generalization to hyperplane arrangements*, Duke Math. J., to appear.

Lisa Claire Jeffrey

Professor, University of Toronto.
Born: January 5, 1965, Fort Collins, Colorado.
Ph.D.: Oxford University, 1991.
Selected Addresses: Geometry Festival, New York, New York, April 1992; Special Session on Geometry, Topology, and Quantum Field Theory, Boston, MA, October 1995; Special Session on Moduli Spaces of Vector Bundles over Curves with or without Additional Structure, Lawrenceville, NJ, October 1996; Special Session on Lie Groups and Physics, Columbia, MO, November 1996; Invited Address, College Park, MD, April 1997; Organizer, Special Session on Symplectic Geometry, Moduli Spaces and Integrable Systems, College Park, MD, April 1997.

Additional Information: NSF Postdoctoral Fellow, 1993–1996; Member, Institute for Advanced Study, 1991–1992, 1996–1997; Aisenstadt Prize, 1996; Sloan Fellow, 1997– ; Member, NSERC Council, Canada, 1997– ; Lecturer, Park City Mathematics Institute, July 1997.
Selected Publications: 1. *Chern-Simons-Witten invariants of lens spaces and torus bundles, and the semiclassical approximation*, Comm. Math. Phys. **147** (1992), 563–604. MR **93f**:57042; 2. with J. Weitsman, *Half density quantization of the moduli space of flat connections and Witten's semiclassical manifold invariants*, Topology **32** (1993), 509–529. MR **95f**:58038; 3. with F. Kirwan, *Localization for nonabelian group actions*, Topology **34** (1995), 291–327; 4. with F. Kirwan, *Intersection pairings in moduli spaces of holomorphic bundles on a Riemann surface*, ERA Amer. Math. Soc. **01** (1995), 57–71; 5. with F. Kirwan, *Localization and the quantization conjecture*, Topology **36** (1997), 647–693.
Statement: The primary goal of the AMS is to foster high-quality research in mathematics. It should also pay attention to the following issues: (1) developing and monitoring employment opportunities for young mathematicians, (2) increasing the representation of underrepresented groups in mathematics, and (3) fostering interaction and dialogue between mathematics and other scientific disciplines.

Douglas Lind



Professor, University of Washington.
Born: August 11, 1946, Arlington, Virginia.
Ph.D.: Stanford University, 1973.
AMS Committees: AMS Centennial Fellowship Committee, 1991–1993; Electronic Research Announcements Editorial Board, 1995–1997; AMS Task Force on Excellence in Mathematical Scholarship, 1995– .
Selected Addresses: ***Invited Speaker*** : Conference on Symbolic Dynamics and Its Applications, Yale University, July, 1991; Conference on Algebraic Systems, CIRM, Luminy, June 1993; Warwick Symposium on $\mathbf{Z}^d$-actions, June 1–30, 1994; Invited Principal Speaker, Conference on Ergodic Theory and Dynamics,

Technical University of Delft, Holland, July 15-30, 1994; Special Session on Symbolic Dynamics, San Diego, 1997.
Additional Information: Vice Chair, Board of Trustees, Mathematical Sciences Research Institute, Berkeley, 1989-1995; Organizing Committee, Program in Symbolic Dynamics, Mathematical Sciences Research Institute, September-December 1992; Professeur Invité, Université Aix-Marseilles, June 1993; Department Chair, 1993-1998; Member, Mathematics Education Reform Task Force, 1993- ; Co-organizer: Conference on Number Theory and Dynamics, CIRM, Luminy, France, July 4-8, 1995; Co-organizer, Symposium on the Riemann Hypothesis, University of Washington, Seattle, August 12-15, 1997; Member, Advisory Board, American Institute of Mathematics, 1997- .
Selected Publications: 1. with M. Boyle and D. Rudolph, *The automorphism group of a shift of finite type*, Trans. Amer. Math. Soc. **306** (1988), 71-114. MR **89m**:54051; 2. with K. Schmidt and T. Ward, *Mahler measure and entropy for automorphisms of compact groups*, Invent. Math. **101** (1990), 593-629. MR **92j**:22013; 3. with B. Marcus, *An introduction to symbolic dynamics and coding*, Cambridge University Press, Cambridge, 1995. MR **97a**:58050; 4. with M. Boyle, *Expansive subdynamics*, Trans. Amer. Math. Soc. **349** (1997), 55-102. MR **97d**:58115; 5. with K. Schmidt, *Homoclinic points for algebraic* $\mathbf{Z}^{\mathbf{d}}$*-actions*, J. Amer. Math. Soc., to appear.

Henri Moscovici
Professor of Mathematics, The Ohio State University.
Born: May 5, 1944, Tecuci, Romania.
Ph.D.: University of Bucharest, 1971.
AMS Committees: Central Section Program Committee, 1997- .
Selected Addresses: College de France Lectures, Paris, May-June 1986; International Congress of Mathematicians, Kyoto, 1990; Special Session Commemorating the First Fifty Years of C^*-Algebra Theory, San Antonio, January 1993; The Issai Schur Memorial Lectures, Tel Aviv University, December 1995; Invited Address, Milwaukee, October 1997.
Additional Information: Lady Davis Postdoctoral Fellowship, 1973; G. Tzitzeica Prize of the Academy of Sciences of Romania, 1975; College de France Medal, 1986; Sackler Scholar, Institute of Advanced Studies, Tel Aviv, 1995; Guggenheim Fellow, 1995-1996.
Selected Publications: 1. with A. Connes, *The* L^2*-index theorem for homogeneous spaces of Lie groups*, Ann. of Math. **115** (1982), 291-330. MR **84f**:58108; 2. L^2*-index of elliptic operators on locally symmetric spaces of finite volume*, Operator algebras and K-theory, Contemp. Math., vol. 10, Amer. Math. Soc., Providence, RI, 1982, pp. 129-137. MR **83m**:58072; 3. with A. Connes, *Cyclic cohomology, the Novikov conjecture and hyperbolic groups*, Topology **29** (1990), 345-388. MR **92a**:58137; 4. with R. J. Stanton, *R-torsion and zeta functions for locally symmetric manifolds*, Invent. Math. **105** (1991), 185-216. MR **92i**:58199; 5. with A. Connes, *The local index theorem in noncommutative geometry*, Geom. Funct. Anal. **5** (1995), 174-243. MR **96e**:58149.

Marc A. Rieffel
Professor, University of California, Berkeley.
Born: December 22, 1937, New York, New York.
Ph.D.: Columbia University, 1963.
AMS Offices: Member-at-Large of Council, 1987-1990, 1992-1994; Executive Committee of the Council, 1994-1998.
AMS Committees: Committee on Committees, 1982-1984; Committee on the Proposed Structure of the JPBM, 1987-1988; AMS-MAA-SIAM Joint Committee on Employment Opportunities, 1989-1991; Mathematical Surveys and Monographs Editorial Committee, 1991-1994 (chair, 1992-1994); Committee on Long-Range Planning, 1995-1997 (chair, 1996-1997); Committee on Committees, 1995- ; Search Committee for the Secretary, 1997; Member, AMS e-Journal Review Committee, 1997; Committee on Steele Prizes, 1997- .
Selected Addresses: Integrable and Proper Actions of Groups on C*-Algebras, International Conference on Operator Algebras and Operator Theory, Shanghai, July 1997; Questions on Quantization, Conference on *E*-Theory, Quantization, and Deformations, Dartmouth College, September 1997; Non-commutative Tori and Deformation Quantization, Institute for Theoretical Physics, University of California, Santa Barbara, March 1998; Non-commutative Tori and String Theory, Great Plains Operator Theory Seminar, Kansas State University, May 1998.
Additional Information: Member: AMS, MAA.
Selected Publications: 1. *Critical points of Yang-Mills for non-commutative two-tori*, J. Differential Geom. **31** (1990), 535-546. MR **91b**:58014; 2. *Deformation quantization for actions of* R^d, Mem. Amer. Math. Soc. **106** (1993). MR **94d**:46072; 3. K*-groups of* C^**-algebras deformed by actions of* R^d, J. Funct . Anal. **116** (1993), 199-214. MR **94i**:46088; 4. *Non-compact quantum groups associated with Abelian subgroups*, Comm. Math. Phys. **171** (1995), 181-201. MR **96g**:46066; 5. *On the operator algebra for the space-time uncertainty relations*, Operator Algebras and Quantum Field Theory, International Press, Cambridge, MA, 1997, pp. 374-382.
Statement: The AMS is presently quite healthy. But the AMS faces substantial challenges in the near future, and the AMS must always seek ways to improve its services to its members. The AMS needs as leaders individuals with wisdom and creativity who are willing to devote a substantial amount of their energy to the AMS during their terms of office. (In particular, vice-presidents and members-at-large of the Council must be willing to contribute strong leadership on one of the five AMS policy committees, in addition to their duties on the Council.)

The leadership of the AMS should also be selected to reflect the diversity of the membership of the AMS. If I am elected to the Nominating Committee, I will seek candidates for AMS elective positions according to the above criteria.

Editorial Boards Committee

George E. Andrews
Evan Pugh Professor of Mathematics, The Pennsylvania State University.
Born: December 4, 1938.

Ph.D.: University of Pennsylvania, 1964.
AMS Committees: Library Committee, 1994-1996; History of Mathematics Editorial Committee, 1996– ; AMS-MAA Committee on Research in Undergraduate Mathematics Education, 1998– ; AMS-MAA-SIAM Morgan Prize Committee for Outstanding Research in Mathematics by an Undergraduate Student, 1998– .
Selected Addresses: Hedrick Lecturer, MAA, Ann Arbor, 1980; CBMS Regional Conference Principal Lecturer, Arizona State University, 1985; Invited Lectures: American Association for the Advancement of Science, Chicago, 1987, and Baltimore, 1996; J.S. Frame Lecturer, Pi Mu Epsilon, Vancouver, 1993; International Congress of Mathematicians, 1998; Participant in a debate on mathematics instruction, Berlin.
Additional Information: Guggenheim Fellow, 1982–1983; Allegheny Region Distinguished Teaching Award, MAA, 1993; Elected Member, AAAS, 1997; Honorary Degree, University of Parma, 1998.
Selected Publications: 1. *Number theory*, W.B. Saunders Co., Philadelphia, PA, 1971. MR **46** #8943 (Reissued, Dover, 1995); 2. *Euler's "exemplum memorabile inductionis fallacis" and q-trinomial coefficients*, J. Amer. Math. Soc. **3** (1990), 653–669. MR **91b**:05011; 3. *The death of proof? Semi-rigorous mathematics? You've got to be kidding!* Math. Intelligencer **16** (1994), 16–18. MR **95h**:00011; 4. *Plane partitions. V. The TSSCPP conjecture*, J. Combin. Theory Ser. A **66** (1994), 28–39. MR **95g**:05010; 5. *The theory of partitions*, Encyclopedia of Mathematics and Its Applications, vol. 2, Addison-Wesley Publishing Co., Reading, MA, 1976. MR **85f**:11001 (Third edition, Cambridge University Press, 1998).
Statement: Obviously there are countless tactical matters that face the AMS concerning journal publication. Electronic publication and maintaining reasonable prices for paper journals are two large issues. It is my belief that the central issue before the Editorial Boards [Committee] is the maintenance of high editorial standards primarily through the careful selection of editors with high standards. If this fundamental duty is fulfilled responsibly, it should be possible to respond adequately to the tactical problems.

J. William Helton
Professor of Mathematics, University of California, San Diego.
Born: November 1944, Jacksonville, Texas.
Ph.D.: Stanford University, 1968.
AMS Committees: Committee to Select Hour Speakers for Far Western Sectional Meetings, 1982–1983.
Selected Addresses: *Plenary Addresses:* AMS Invited Address, San Antonio, January 1980; European Conference on Circuit Theory and Design, 1981; Principal Lecturer, CBMS Regional Conference, 1985; SIAM Conference, LASSC, 1986; Great Plains Operator Theory Symposium, 1992; Mathematical Theory of Networks and Systems: 1979, 1983, 1989, 1993, 1996 (semiplenary); a half dozen conference talks given per year.

Additional Information: Guggenheim Fellow, 1985; Outstanding paper, IEEE Control Society, 1986; associate editor of six journals and two book series.
Selected Publications: 1. *Discrete time systems, operator models, and scattering theory*, J. Funct. Anal. **16** (1974), 15–38. MR **56** #3652; 2. with R. Howe, *Traces of commutators of integral operators*, Acta Math. **135** (1975), 271–305. MR **55** #11106; 3. with J. A. Ball, C. R. Johnson, and J. N. Palmer, *Operator theory, analytic functions, matrices, and electrical engineering*, CBMS Regional Conf. Ser. in Math., no. 68, Amer. Math. Soc., Providence, RI, 1987. MR **89f**:47001; 4. with O. Merino, *Classical control using H^∞ methods*, SIAM, August 1998, 292 pages; 5. with M. Stankus and J. J. Wavrik, *Computer Simplification of Formulas in Linear Systems Theory*, IEEE Trans. Automat. Control **43** (Mar. 1998), number 3, pp. 302–314.
Statement: The committee is charged with appointing editors for AMS journals, and I shall try to find good ones. Strong AMS editors are increasingly important because the nature of scientific journals is changing. As electronic distribution becomes widespread, we must find editors committed to high quality in this new environment. Expensive journals may well start going out of business also, which places more responsibility on the journals of professional societies.

Krystyna M. Kuperberg
Alumni Professor, Auburn University.
Born: July 17, 1944, Tarnów, Poland.
Ph.D.: Rice University, 1974.
AMS Offices: Member-at-Large of the Council, 1996– .
AMS Committees: Electronic Research Announcements Editorial Committee, 1995– ; Southeastern Section Program Committee, 1996–1998; Committee on the Profession, 1996– .
Selected Addresses: Mathematical Sciences Research Institute-Evans Lecture, Berkeley, September 1994; AMS Invited Address, Orlando, March 1995; MAA Invited Address, Orlando, January 1996; ICM Invited Speaker, Berlin, Germany, August 1998; Noether Lecture, San Antonio, January 1999.
Additional Information: Auburn University Alumni Professorship, 1994– ; Alfred Jurzykowski Foundation Award, 1995; Auburn University Science and Mathematics Research Excellence Award, 1996.

Selected Publications: 1. *A smooth counterexample to the Seifert conjecture*, Ann. of Math. **140** (1994), 723–732. MR **95g**:57040; 2. *Collected works of Witold Hurewicz* (editor), Amer. Math. Soc., Providence, RI, 1995. MR **97m**:01105; 3. with A. Bezdek and W. Kuperberg, *Mutually contiguous translates of a plane disk*, Duke Math. J. **78** (1995), 19–31. MR **96b**:52030; 4. with G. Kuperberg, *Generalized counterexamples to the Seifert conjecture*, Ann. of Math. **144** (1996), 239–268. MR **97k**:57031; 5. *A knotted minimal tree*, Mathematics Archive, e-Print math.MG/9806080 (available at `http://front.math.ucdavis.edu/math.MG/9806080`).
Statement: Publications of the AMS serve the whole mathematical community; hence the Editorial Boards [Committee] should represent the broadest possible spectrum of mathematical areas. The standards for papers' acceptance should be uniformly high across the fields, based on mathematical merit, and immune to politics. The editors should be accomplished mathematicians, highly regarded and respected by their peers. While being aware of the importance of traditional paper publishing and of the services provided by libraries, they should also have a realistic view on the growing trend to disseminate mathematical literature by electronic means.

Efim Zelmanov

Professor, Yale University.
Born: September 7, 1955, fSU.
Ph.D.: Institute of Mathematics, Novosibirsk, 1981.
AMS Committees: Transactions and Memoirs Editorial Committee, 1994–; Electronic Research Announcements Editorial Committee, 1995– .
Selected Addresses: International Congresses of Mathematicians: Warsaw, 1983; Kyoto, 1990; and Zurich, 1994; Invited Address, Chicago, March 1995.
Additional Information: Fields Medal, International Union of Mathematicians, 1994; Member, American Academy of Arts and Sciences, 1996– .
Selected Publications: 1. with K. McCrimmon, *The structure of strongly prime quadratic Jordan algebras*, Adv. in Math. **69** (1988), 133–222. MR **89k**:17052; 2. *Solution of the restricted Burnside problem for groups of odd exponent*, translation in Math. USSR-Izv. **36** (1991), 41–60. MR **91i**:20037; 3. *Solution of the restricted Burnside problem for 2-groups*, Mat. Sb. (N. S.) **4** (1991), 568–592. MR **93a**:20063; 4. *On periodic compact groups*, Israel J. Math. **77** (1992), 83–95. MR **94j**:20019; 5. *Nil rings and periodic groups*, KMS Lecture Notes in Mathematics, Korean Mathematical Society, Seoul, 1992. MR **94c**:16027.
Statement: I think that the primary mission of the AMS is to encourage mathematical research. The AMS is also well suited to address issues that are important for the whole mathematical community, such as mathematical education, employment, research funding, and public appreciation of mathematics.

Proposed Amendments to the Bylaws

The Council has approved two amendments to the bylaws for ratification by the membership in the election this fall (October 1998). These amendments will be printed in the election material that will be sent with the ballot to all members of the Society in September 1998. The full text of the bylaws of the Society appears in the November issue of the *Notices* in odd-numbered years. The amendments approved in the November election are not reflected in the printed version of the bylaws.

The ballot will require two votes, since there are two substantially different items.

Amendment Concerning the *American Journal of Mathematics*

Amendment I: When the Society and Johns Hopkins University terminated the agreement under which the Society co-sponsored the *American Journal of Mathematics*, some remnants of the agreement remained in the bylaws. The amendments proposed below are "house cleaning" in that they remove references to the *American Journal* from the bylaws. The relevant article is Article XI. In what follows, text in [brackets] denotes text that is to be deleted from the bylaw. Text in ***bold italic*** is text that is to be added to the bylaw (there is none in Amendment I).

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 cooperate in the conduct of the *American Journal of Mathematics*.] 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*, [and the participation of the Society in the editorial management of the *American Journal of Mathematics*] 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.

Amendment Concerning the Titles of Officers

Amendment II: Names of officers in the current bylaws are hyphenated, for example: vice-president, member-at-large, and president-elect. Accepted usage is: vice president, member at large, and president elect. The amendment below changes the current usage to the accepted usage and is editorial in nature except that the name of the officer who has just served as president is changed from ex-president to immediate past president.

In the changes below, the current wording is indicated in [brackets], and the changes proposed are indicated by ***bold italic text.***

Article I. Officers

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

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] ***president elect*** (during even-numbered years), and the [ex-president] ***immediate past president*** (during odd-numbered years).

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] ***president elect*** and the [ex-president] ***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] ***vice presidents*** and [members-at-large] ***members at large*** of the Council, one [vice-president] ***vice president*** and five [members-at-large] ***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] ***president elect*** and [ex-president] ***immediate past president***) shall continue to serve until their successors have been duly elected or appointed and qualified.

Section 2. The [president-elect] ***president elect***, the [vice-presidents] ***vice presidents***, the trustees, and the [members-at-large] ***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 [ex-president] ***immediate past president*** at the end of the term of office and the [president-elect] ***president elect*** becomes president.

Section 5. The president and [vice-presidents] ***vice presidents*** shall not be eligible for immediate re-election to their respective offices. A [member-at-large] ***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] ***member at large*** of the Council.

Section 6. If the president of the Society should die or resign while a [president-elect] ***president elect*** is in office, the [president-elect] ***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] ***president elect*** is in office, the Council, with the approval of the Board of Trustees, shall designate one of the [vice-presidents] ***vice presidents*** to serve as president for the balance of the regular presidential term. If the [president-elect] ***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] ***president elect***, and the Society shall, at the next annual meeting, elect a president for a two-year term. If the [ex-president] ***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 [ex-president] ***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] ***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 8. If any [member-at-large] ***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.

Acknowledgment of Contributions

AMS Mission

The AMS, founded in 1888 to further the interests of mathematical research and scholarship, serves the national and international community through its publications, meetings, advocacy, and other programs, which

- promote mathematical research, its communication and uses,
- encourage and promote the transmission of mathematical understanding and skills,
- support mathematical education at all levels,
- advance the status of the profession of mathematics, encouraging and facilitating full participation of all individuals,
- foster an awareness and appreciation of mathematics and its connections to other disciplines and everyday life.

Thomas S. Fiske Society

The Executive Committee and Board of Trustees have established the Thomas S. Fiske Society to honor those who have made provisions for the AMS in their estate plans. For further information contact Tim Goggins at 800-321-4AMS, or tjg@ams.org.

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The officers and staff of the Society acknowledge with gratitude the following donors whose contributions were received during the past year. The names which follow represent donors who contributed during the period April 1, 1996—March 31, 1997.

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The names of donors who have given for three years consecutively (1994-1996) are marked with an asterisk. Donors whose contributions total $1,000 or more annually are recognized with their names affixed to a plaque in the lobby of the Society's Providence office.

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Established by a gift from The Morita Family
Albert Leon Whiteman Prize (for excellence in exposition on the History of Mathematics)
Established by a gift from Sally Whiteman
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Memorial and commemorative gifts are a distinctive and thoughtful way to memorialize or honor a colleague, friend, or family member, and to support the Society's work to promote mathematical scholarship and research.

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- Adamson, Iain T. A. C.
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- Ahn, Jae Moon
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- Akamatsu, Masayuki
- Akin, Ethan J.
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- Anderson, Laura M.
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- Andre, Peter P.
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- Artola, Michel
- Arveson, William B.
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- Bae, Soon-Sook
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- Baker, Kirby A.
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Balbes, Raymond
Balder, Erik Jan
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Bales, John W.
Balibrea, Francisco
Balint, Vojtech
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Ball, Mary Ann
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Ballou, Donald H.
Banchoff, Thomas F.
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Banerjee, Utpal
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Baouendi, M. Salah
Barakat, Mohamed
Barbanson, Gerard
Barbeau, Edward J., Jr.
Barber, S. F.
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Bardos, Claude W.
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Barlow, Jesse L.
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Barquero, Pedro Benjamin
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Barrett, David E.
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Barth, Karl F.
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Barton, Thomas J.
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Baruth, Ruth M.
Barvinok, Alexander
Bass, D.
Bass, Hyman
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Bateman, Felice D.
Bateman, Paul T.
Batt, Jürgen O.
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Bauer, Heinz
Baum, Paul F.
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Baur, Lynne A.
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Bean, Ralph J.
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Bechtel, Robert D.
Beck, William A.
Beckenstein, Edward
Becker, Eberhard
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Bekiranov, Daniella
Bell, Janie L.
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Bellamy, David P.
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Belshoff, Richard G.
Bencsáth, Katalin A.
Bendat, Julius S.
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Benedicks, Michael
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Benham, James W.
Benilan, Philippe M. A.
Ben-Israel, Adi
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Benson, David Bernard
Benson, Donald C.
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Bergelson, Vitaly
Berger, Agnes
Berger, Clemens
Berglund, John F.
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Bergmann, Peter G.
Bergstrand, Deborah J.
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Berlekamp, Elwyn R.
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Bernardi, Salvatore D.
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Bernstein, Joseph
Berresford, Geoffrey C.
Berzi, Vittorio
Beschler, Edwin F.
Betancourt, Carlos M.
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Beyer, William A.
Beylkin, Gregory
Bezak, Nicholas J.
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Bhathena, Dinyar Barjor
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Bidwell, Leonard N.
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Billera, Louis J.
Bilodeau, Gerald G.
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Birge, John R.
Birnir, Bjorn
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Bishop, Alan A.
Bishop, Richard L.
Bishop, Wayne
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Black, Elena V.
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Blackall, Clair J.
Blackmore, Denis L.
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Blair, William D.
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Blum, Lenore
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Bolger, Robert Edwin
Bolis, Theodore S.
Bolker, Ethan D.
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Bonacci, Richard
Bonahon, Francis
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Bonk, Mario
Bonnet, Jean Louis
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Booth, Raymond S.
Boothby, William M.
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Borgnet, Eric N. O.
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Borisov, Lev A.
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Borwein, Jonathan M.
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Bosello, Carlo Alberto
Boswell, Rupert D., Jr.
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Botts, Truman A.
Bouleau, Nicolas
Bousfield, Aldridge K.
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Bouwsma, Ward D.
Bouzar, Nadjib
Bowditch, Brian H.
Bower, Julia W.
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Boyce, William E.
Boyle, Mike
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Brady, Wray G.
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Brauer, Fred
Brauer, George U.
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Brechner, Beverly L.
Breckenridge, John C.
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Bresinsky, Henrik
Bressler, David W.
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Brickman, Louis
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Bro, Per
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Broere, Izak
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Browder, William
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Brown, George B.
Brown, Jack B.
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Brown, Lawrence G.
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Brown, Richard K.
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Brown, Robert F.
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Brown, William G.
Brownawell, W. Dale
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Bruckner, Andrew M.
Brun, Morten
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Bruni, Anthony J.
Brunk, Hugh D.
Bruter, Claude P.
Bryant, Billy F.
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Brylinski, Jean-Luc
Brylinski, Ranee Kathryn
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Buckley, Joseph T.
Bucy, Richard S.
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Buehler, Royce E.
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Bugajska, Krystyna M.
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Bulger, Leonard L.
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Bumby, Richard T.
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Buraczewski, Adam
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Burghduff, John Brian
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Burke, Mary Ann
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Burlet, Oscar
Burling, James P.
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Buser, Peter J.
Bushnell, Colin J.
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Butcher, Ralph Stevens
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Byrd, Kenneth A.
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Byrnes, James S.
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Caballero, Maria-Emilia
Cable, Charles A.
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Cahill, Rotraut G.
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Caldwell, Thomas E.
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Cannon, James W.
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Capogna, Luca
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Carlson, Jon F.
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Casler, Burtis G.
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Caviness, B. F.
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Cendra, Hernan
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Chakerian, Gulbank D.
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Chandra, Jagdish
Chang, Chao P.
Chang, Kun Soo
Chang, Yu
Channell, Paul Jackson
Chapa-Vergara, Sergio V.
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Chapman, Charles A.
Chapman, Robin John
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Chavez, John E.
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Chee, Pak Soong
Chein, Orin N.
Chen, Concordia C.
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Chen, J-P Jeff
Chen, Kwan-Wei
Chen, Pei-Li
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Cheng, Raymond Che-Man
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Chern, Shiing S.
Chernoff, Paul R.
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Chichilnisky, Graciela
Chihara, Theodore S.
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Chinn, William G.
Chit, Poon
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* Choe, Geon Ho
Choi, Junesang
* Choi, Younggi
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Choquet, Gustave
Chosid, Leo
Chou, Mo-Hong
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Christilles, William E.
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Chung, Kyung Taek
Church, Philip T.
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Ciarlet, Philippe G.
Citrin, Stuart
Civin, Paul
Clark, Jeffrey W.
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Clayman, Andrew Theodore
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Clemens, Charles Herbert
Clement, Philippe P.
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de los Cobos Silva, Sergio
Cochran, James A.
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Coffee, Terence
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Cogburn, Robert F.
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Cogswell, Kurt D.
Cohen, Albert A.
Cohen, Arjeh M.
Cohen, Daniel I. A.
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Cohen, Martin J.
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Cohn, Donald L.
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Cole, Charles A.
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Coleman, A. John
Coleman, Courtney S.
* Coleman, Robert
* Colley, Susan Jane
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Colonius, Fritz
Colpi, Riccardo
Colson, Henry D.
Comenetz, Daniel
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Conlon, Lawrence W.
Connell, Ian
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Conner, Pierre E., Jr.
Connor, Jeffery S.
Constantin, Peter S.
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Cootz, Thomas A.
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Cordes, Heinz O.
Corduneanu, Constantin
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Correia, Frank B.
Corsi Tani, Gabriella
Costenoble, Steven R.
Costin, Ovidiu
Cote, Louis J.
Cotlar, Mischa
Cotton, Robert M.
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Couty, R.
Cowen, Carl C.
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Cowens, J. Wayne
Cox, Raymond H.
Coxeter, H. S. MacDonald
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Craggs, Robert F.
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Crandall, Michael G.
Crandall, Stephen H.
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Crawford, James P.
Creese, Thomas M.
Criscenti, Jacqueline P.
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Crouzeix, Jean-Pierre
Crow, Edwin L.
Cude, Joe E.
Culler, Marc E.
Cunningham, Frederic, Jr.
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Curtis, Philip C., Jr.
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Daly, John T.
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Dana, Martin P.
Daney, Charles G.
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Das, Peter
Datskovsky, Boris A.
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Daum, Fred
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Davis, Martin D.
Dawes, A. M.
Dawkins, Paul T.
Dawson, Donald A.
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Daybell, Dorothy A.
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Deering, Felix Leander
DeFacio, Brian
De Figueiredo, Djairo G.
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Deguchi, Tetsuo
Dehesa, Jesus Sanchez
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Delahunty, Michael D.
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De la Penña, J. Antonio M.
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De Leone, Renato
De Loura, Luis
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Del Vecchio, Joseph
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DeMarr, Ralph E.
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Dent, Elliod
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De Primo, Guy M.
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DeShalit, Ehud
Desjardins, Sylvie
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Destina, Mones P.
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Deutsch, Emeric
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Dibner, Steve
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Dietsche, H. J.
Digre, Mark K.
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Dimsdale, Bernard
Dincbas, Mehmet
Dinneen, Gerald P.
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Doering, Boro
Dokken, Douglas Paul
Doku, Isamu
Dolan, James M.
Dolbeault, Pierre E.
Dold, Albrecht E.
Dolgachev, Igor
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Dominici, Paolo
Donaldson, Simon K.
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Donoho, David Leigh
Doob, Joseph L.
Doppel, Karl
Doran, Robert S.
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Dossey, John A.
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Douady, Raphael
Douglas, Jim, Jr.
Douglas, Ronald G.
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Dowd, Martin J.
Dowd, Robert E.
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Dranishnikov, Alexander N.
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Driver, Bruce K.
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Drumm, Todd A.
Druskin, Vladimir L.
Dubisch, Roy
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Dudley, Richard M.
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Duff, Marcus
Duggal, Krishan Lal
Dukelow, James S., Jr.
Dunham, Douglas J.
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Dupilka, Chris Edward
Duplij, Steven
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Duren, Peter L.
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Duskin, John W., Jr.
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Dwork, Bernard M.
Dyer, Matthew J.
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Eckert, Robert Nord
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Eddy, Robert P.
Edet, Silas B.
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Edwards, C. M.
Edwards, Charles H., Jr.
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Eells, James
Eenigenburg, Paul J.
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Ehrlich, Albert J.
Eigel, Edwin G., Jr.
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Eiriksson, Thorarinn Arni
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Eldridge, Klaus E.
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Elliott, George A.
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Engler, Hans P.
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Epkenhans, Martin
Epp, Susanna S.
Epstein, Benjamin
Epstein, Bernard
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Epstein, David B. A.
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Ericksen, Wilhelm S.
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Eswaran, Kumar
Etchegoyen, Marcelo
Evangelatos, Dionyssis S.
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Ewer, John Patrick
Ewert, Heiko
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Ewy, Daniel J.
Fack, Veerle
Falbo, Clement E.
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Fan, Ky
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Farina, Bruno
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Fauntleroy, Amassa C.
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* Favro, Ruth G.
Feeman, George F.
Feferman, Solomon
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Fein, Burton I.
Fein, Michael Bertrand
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Feinsilver, Philip
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Feit, Walter
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Feldman, Chester
Feldman, Jacob
Feldman, Norman
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Fellah, Dominique
Fenstad, Jens E.
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Ferguson, Helaman
Ferguson, Pamela A.
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Fernandez, Edgardo Luis
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Ferris, Ian M.
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Field, Michael J.
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Fill, James Allen
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Fink, James P.

Finkelstein, Leib
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Finol, Carlos E.
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Fischer, Ismor
Fishback, William T.
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Fixman, Uri
Flaherty, Francis J.
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Fleishman, Bernard A.
Fleming, Daniel J.
Fleming, Richard J.
Flesner, Harold E.
Florence, John B.
Florides, Petros Serghiou
Flusser, Peter R.
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Fong, Paul
Fontaine, Marc F.
Fontenot, Robert A.
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Foote, S. Ashby
Forman, Robin
Formanek, Edward W.
Forni, Giovanni
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* Francis, Kevin J.
* Franks, John M.
* Frawley, Timothy J.
* Frazier, Michael W.
Fredrickson, Elvy L.
Free, Norman S.
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Freed, Rod A.
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Freeman, Robert S.
Freese, Ralph S.
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Freitag, Herta T.
Freyd, Peter J.
Fridy, John A.
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Friedman, Eugene M.
Friedman, Joyce B.
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Frizzoni, Piero F. G.
Frohardt, Daniel E.
Frosini, Patrizio
Fu, Chin-Mei Kau
Fuad, T. Simonthy R.
Fuchs, Peter Rudolf
Fuchssteiner, Benno
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Fujisaki, Rieko
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* Fukushima, Masatoshi
Fuller, William R.
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* Funabashi, Shoichi
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Fusaro, B. A.
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Gaal, Lisl Novak
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Gaborovic, Svitan
Gabriel, Richard F.
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Galbiati, Margherita
Gale, David
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Galeano, Andrades Rafael
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Gallier, Jean H.
Galliher, Herbert P.
Ganelius, Tord H.
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Ganser, Carl C.
Gantner, Thomas E.
Gantos, Richard L.
Garb, Regina H.
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Garcia, Miguel A.
Garciadiego, Alejandro R.
Garfunkel, Solomon A.
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Garma, Santiago
Gass, Clinton B.
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Gatterdam, Ronald W.
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Gautschi, Walter
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Gehring, Frederick W.
Geisler, Fred H.
Geissinger, Ladnor D.
Geller, Daryl Neil
Genensky, Samuel M.
Genet, Jean Raymond
Genser, Milton
Gentili, Graziano
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Georghiou, Constantinos
Georgiou, John C.
Gerhardt, C.
Gerlach, Eberhard G. P.
Germain, Paul
Germani, Alfredo
Gershenson, Hillel H.
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Gessaman, Margaret P.
Gessel, Ira M.
Ghaleb, Ahmed F.
Ghent, K. S.
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Ghitza, Alexandru Edgar
Giffen, Charles H.
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* Gilbert, Richard C.
Gill, Abraham
Gill, Tepper L.
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Gillman, David S.
Gilmer, Gloria
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Gioia, Anthony A.
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Gloden, Raoul F.
Glonti, Omar A.
Glowinski, Roland
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Goddard, J. D.
Godefroy, Gilles B.
Godfrey, Colin
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Goldberg, Seymour
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Goldhaber, J. K.
Goldman, Jerry
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Goldstein, Richard Z.
Goldstine, Herman H.
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Gómez Pardo, José Luis
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Gomonov, Sergej Anatolyevich
Gompf, Robert E.
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González-Barrios, José M.
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Good, Joseph H.
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Goodman, A. W.
Goodman, Roe W.
Goodman, Sue E.
Gopal, Mangalam R.
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Gorisson, Cyril Walther
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Gosselin, Richard P.
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Goth, John A.
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Goto, Midori S.
* Goto, Shiro
Göttfert, Rainer
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Goutier, Claude
Gouvêa, Fernando Quadros
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Gramchev, Todor V.
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Granja, Gustavo
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Granville, Andrew J.
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Graver, Jack E.
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Gray, Jeremy John
Gray, John W.
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Gray, Samuel Hutchison
* Greaves, George
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* Green, William L.
Greenberg, Ralph
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Greene, John Robert
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Gregoriou, John
Gregory, David A.
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Greller, Larry David
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Griffin, E. L., Jr.
Grigni, Michelangelo
Grimland, Joseph Fort, Jr.
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Gross, Mark William
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* Grossman, Marvin W.
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Grove, K.
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Gruenhage, Gary F.
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Gu, Weiqing
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Gudder, Stanley P.
Guenard, Francois
Guenette, Robert
Guerin, Esther E.
Guerrini, Luca
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Guilbault, Craig R.
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Guillemin, Victor W.
Guillerault, Michel
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Guitard, Thierry
Gulden, S. L.
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Guterman, Martin M.
Gyamfi Owusu, John Bernard
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Ha, Ki Sik
Ha, Kwang Chul
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Haag, Vincent H.
Haake, Daniel
Haber, Seymour
Haberl, Josef
Habetha, Klaus
Hackenbroch, Wolfgang
Haddad, Labib S.
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Haefliger, Andre
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Hagglund, Lee O.
Hagis, Peter, Jr.
Hagler, James N.
Haglund, Jim
Hahn, Alexander J.
Hahn, Sang-Geun
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Haiman, Mark
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Haines, Matt J.
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Hakberg, Bengt
Haken, Wolfgang
* Håland, Inger J.
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Hale, Jack K.
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Hall, Brian C.
Hall, James E.
Hall, Mark Edwin
Haller, Thomas
Halverson, Thomas M.
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Hammer, Carl
Hammett, Michael E.
Hammond, William F.
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Handel, David
Hanes, Kit
Hanisch, Herman
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Hanlon, Philip J.
Hann, Kathleen Marie
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Hano, Jun-ichi
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Hansen, Keven R.
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Hao, Zhifeng
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Harada, Shigeharu
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Harborth, Heiko
* Harbourne, Brian
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Hardy, Darel W.
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Harmsen, Betty Jean
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* Harris, Desmond J.
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Harris, John C.
Harris, Theodore E.
Harris, Timothy S.
* Harrison, John Watkins
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Härtler, Gisela Rosemarie
Hartshorne, Robin
Hartzstein, Silvia Ines
Hasselblatt, Boris
Hastings, Harold M.
Hastings, Stuart P.
Hasumi, Morisuke
Hatcher, Theodore R., Jr.
Hatori, Osamu
Hattori, Akio
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Hautau, Ralph H.
Haviar, Miroslav
Hay, George E.
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* Hayashida, Tsuyoshi
* Hayden, John L.
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Hayes, David R.
Hazama, Fumio
Healy, Douglas
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Hebey, Emmanuel
Hecht, Henryk
Hecker, David A.
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Hedlund, James H.
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* Heins, Maurice H.
Helgason, Sigurdur
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* Heller, Alex
Heller, Dorothy M.
* Hellerman, Leo
Hellerstein, Simon
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Hemminger, Robert L.
Hemmingsen, Erik
Hempel, J. A.
Hempel, John P.

Hemstead, Robert J.
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Henkin, Leon A.
Henrich, Christopher J.
Henriques, Anna S.
Hensley, Douglas A.
Henstock, Ralph
Her, Min
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Hermida-Alonso, Jose A.
Hernandez, Fernandez Teresa
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* Hernández Ruipérez, Daniel
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Herschorn, Michael
Hertzlinger, Joseph
Herwitz, Paul S.
Hesselholt, Lars
Hethcote, Herbert W.
Hetzer, Georg
Heuer, Gerald A.
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* Heuver, John G.
Hewett, Thomas James
* Hicks, Robert L.
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Hida, Takeyuki
Higgins, John A.
Higgins, John R.
Higman, Donald G.
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Hijab, Omar
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Hilden, Hugh M.
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Hill, Shirley A.
Hillman, Abraham P.
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Hindman, Neil B.
Hines, Gwendolen
Hingston, Nancy
Hinman, Peter G.
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Hirano, Norimichi
Hirashita, Yukio
Hirsch, Michael D.
Hirsch, Robert Daniel
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Hirschfelder, Rosemary
Hirzebruch, F. E. P.
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Hitotsuyanagi, Nobuo
Hobart, Robert H.
Hochschild, Gerhard P.
Hochstadt, Harry
Hochster, Melvin
Hodges, Lucille M.
Hodges, Wilfrid
Hodgson, Jonathan P. E.
Hoefer, Edwin T.
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Hofer, Robert D.
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Hoffman, William C.
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Hoffmann-Jorgensen, Jorgen
Hofmann, Karl H.
Hogan, Peter A.
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Holberton, John V.
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Holland, Samuel S., Jr.
Holland, W. Charles
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Holmes, Charles S.
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Holmström, Lasse L.
Holvoet, Roger
Homer, Roger H.
Honda, Kin-Ya
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Hoobler, Raymond T.
* Hoover, Thomas B.
Horie, Hitoshi
* Horn, Alfred
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Horn, Werner
Horrigan, Timothy J.
Horrocks, Geoffrey
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Hosack, John M.
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Hotzel, Eckehart
House, Roger Forrest
Houston, Evan G.
Houston, Raymond S.
Howard, Edgar J.
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Howard, Paul E.
Howe, Roger E.
Hoyt, W. L.
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Hsiung, Chuan C.
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Hu, S. T.
Huang, Wu-Hsiung
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Hubbart, Wayland M.
Huber, Alfred O.
Huber, Birkett T.
Huber, Heinz
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Huddleston, James R.
Hudelson, Matthew G.
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Huebschmann, Johannes
Huet, Denise
Huff, Charles W.
Huffman, Louie C.
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Hughes, Anne
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Huige, Gustavus E.
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Hulkower, Neal D.
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Hummel, James A.
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Humphreys, M. Gweneth
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Hunt, Fern Y.
Hunt, Karen C.
Hunt, Walker E.
Hunte, Beryl E.
Hunzeker, Hubert L.
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* Hurley, Donal J.
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Hurtubise, David E.
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Hurwitz, Solomon
Huskova, Marie
Husseini, Sufian Y.
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Hutchinson, Joan P.
Hutton, Edward L.
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Hyllengren, Anders R.
Iarrobino, Anthony A., Jr.
Ibanez, Raul
Ibeagwa, Christian C.
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Iglehart, Patricia Ann
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Iio, Tutomu
Ikeda, Kazim Ilhan
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Im, Sanghi
* Imayoshi, Yoichi
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Imrich, Wilfried
Infante, Ettore
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Inoue, Junko
Invernizzi, Sergio
Ionin, Yury J.
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Iranmanesh, Ali
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Isaac, Richard E.
Isaacs, Godfrey L.
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* Isaacson, Eli
Iseki, Kiyoshi
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Ishii, Shihoko
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Ito, Kiyosi
Ito, Noboru
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Itokawa, Yoe
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Iwasawa, Kenkichi
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Iwata, Koichi
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Jablow, Eric Robert
Jackins, Harvey
Jackson, Lloyd K.
Jaco, William H.
Jacob, Henry G.
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* Jacobs, Harold
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Jacobson, Nathan
Jacquet, Hervé M.
Jaffa, Robert E.
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Jaffe, William J.
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Jahandideh, Mohammad Taghi
Jain, Naresh C.
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James, Robert C.
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Jans, James P.
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Jarvis, Trevor M.
Jazar, Mustapha
Jea, Kang Cecilia
Jeanquartier, Pierre
Jennings, Franklin
Jennings, George A.
Jennings, Kristofer
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Jepsen, Charles H.
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Jerrard, Robert Leon
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Jia, Bao Ping
Jirku, Petr
Johanson, Arnold A.
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Johns, Kathryn Daniels
Johnsen, Eugene C.
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Johnson, Barry E.
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Johnson, Donald G.
Johnson, Guy, Jr.
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Johnson, K. G.
Johnson, Norman W.
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Johnson, Rodney W.
* Johnson, Theodore D.
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Jones, Charles H.
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Jones, Mark C. W.
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Jones, William B.
Jónsd'ottir, Kristin Halla
Jónsson, Bjarni
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Jordan, Steven L.
Jorge, Luquesio P.
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Jory, Virginia V.
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Jurca, Dan
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Justice, James H.
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Kahn, Peter J.
Kaijser, Sten
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Kalisch, Gerhard K.
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Kamada, Seiichi
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Kamin, Shoshana
Kaminker, Jerry
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Kammler, David W.
Kamowitz, Herbert M.
Kanai, Masahiko
Kanda, Mamoru
Kaneyuki, Soji
Kang, Young Yug
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Kanno, Tsuneo
Kaplan, Edward L.
Kaplan, Samuel R.
Kaplan, Stanley
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Karatzas, Ioannis
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Karle, Jerome
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Karpeshina, Yulia
Karrer, Guido
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Kasriel, Robert H.
Kates, Louis K.
Kato, Tosio
Katsnelson, Victor E.
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Katz, Victor J.
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Kauffman, Louis H.
Kauffman, Robert M.
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Kaushanski, Anatole
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Keller, Charles Lewis
Keller, Edward L.
Keller, Wilfrid
Kelliher, James P.
Kelly, John B.
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Keown, R.
Keppelmann, Edward C.
Kerckhove, Michael George
Kerov, Serge V.
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Keyfitz, Barbara L.
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Kharshiladze, Alexander F.
Khasminskii, Rafail Z.
Khots, Boris S.
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Kieboom, Rudger W.
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Killpatrick, Allen R.
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Kim, Hee Sik
Kim, Hong-Chul
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Kim, Jeong Han
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Kim, Wan Se
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King, Donald R.
King, James R.
King, L. Richardson
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Kingston, Paul L.
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Kirk, David B.
Kirk, William Art
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Kisynski, Jan
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Kitada, Hitoshi
Kitada, Yasuhiko
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Kiyohara, Mineo
Klain, Daniel A.
Klatman, David S.
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Klein, Rupert
Kleiner, Alexander F., Jr.
Kleiner, Bruce A.
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Kliemann, Wolfgang H.
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Kneece, Roland R., Jr.
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Knoerr, Alan P.
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Knopp, Marvin I.
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Knutson, Donald I.
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Kocan, Daniel
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Koch, Richard M.
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Koditschek, Daniel Eliezar
Koestner, Alfred
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Kolkwitz, Bernd
Komatsu, Hikosaburo
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Komm, Horace
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Konno, Yasuko
Koo, Ja-Kyung
Kopperman, Ralph D.
Korányi, Adam
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Kose, Tairoku
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Kroon, Ferry J.
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Kunle, Heinz *resigned
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LaBudde, Christian D.
Ladas, Gerasimos
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Lampe, William A.
Lampert, David S.
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Landin, Joseph
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Landucci, Mario
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Lapidus, Arnold
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Larson, Edward H.
Larson, Jean A.
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Lassettre, Edwin R.
Latushkin, Yuri D.
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Laudenbach, Francois
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Laush, George
LaValle, Irving H.
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Lawerence, Albert F.
Lawrence, John W.
Lawrence, K. Mark
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Lawson, Terry Curtis
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Lawther, Ross
Lawton, Wayne M.
Lawvere, F. William
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Lee, Dong Hoon
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Lee, Kee Young
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Leggett, Robert N., Jr.
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Lehrer, Gustav I.
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Leighton, Frank Thomson
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Leipnik, Roy B.
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Lemos, Manoel Jose M. S.
Lenard, Andrew
Lengyel, Bela A.
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Leon, Ralph D., Jr.
Leonard, Henry S., Jr.
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Lesieur, Leonce
Leslie, Arthur S.
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Leung, Lisa
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LeVeque, William J.
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Levin, Jacob J.
Levin, Richard G.
Levine, Harold I.
Levy, Gary B.
Levy, Joel
Lewin, Myrtle H.
Lewis, Albert C.
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Lewis, H. L.
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L'heureux, James E.
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Libera, Richard J.
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Lichtenbaum, Stephen
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Lieberman, David I.
Lieberman, Gary M.
Light, F. W., Jr.
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Lima de Sa, Eduardo
Lin, Shen
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Lind, Douglas A.
Lindenstrauss, Joram
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Lipschutz-Yevick, Miriam A.
Lipsey, Sally Irene
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Lister, William G.
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Little, Leigh J.
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Liu, Xiaoyan
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Livingston, Albert E.
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Lloyd, Stuart P.
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Lobo-Pereira, Fernando M. F.
Lochak, Pierre
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Loeb, Peter A.
Lofquist, George W.
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Lolli, Gabriele
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López, Antonio Fernández
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López-Escobar, Edgar G. K.
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Lorentz, George G.
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Lototsky, Sergey V.
Louboutin, Roland
Loud, Warren S.
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Low, Emmet F., Jr.
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Lubinsky, Doron S.
Luca, Florian
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Ludden, Gerald D.
Luehr, Charles P.
Luke, Jonathan H. C.
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Lundell, Albert T.
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Lyon, Herbert C.
Lyon, Stephen Arthur
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Lysko, Janusz M.
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Mackenzie, Kirill C. H.
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Mader, Adolf
Madison, Bernard L.
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Maeda, Yoshiaki
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Magenes, Enrico
Magill, Kenneth D., Jr.
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Mahdavi, Mehran
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Maier, Lucille
Maione, Vincent
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Makepeace, Coline M.
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Makrakis, George Nick
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Malek, Alaeddin
Malkevitch, Joseph
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Malonek, Helmuth R.
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Maltese, George J.
Mamelak, Joseph S.
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Manilow, Matthew
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Marathe, Kishore B.

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Marchand, Margaret O.
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Marcus, Leo G.
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Marhuenda, Francisco
Maria, May H.
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Marlin, Joe A.
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Marten, Wolfgang
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Martin, E. Dale
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Martin, George E.
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Martin, Nathaniel F. G.
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Martins, Luiz C.
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Mastroianni, Giuseppe
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Masuoka, Akira
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Mathsen, Ronald M.
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Mattuck, Arthur P.
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Matveev, Eugene M.
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Maurer, Stephen B.
Mawengkang, Herman
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Maxfield, John E.
Maxson, Carlton J.
Maxwell, Charles N.
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Mayer, Andrew J.
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Mayer-Wolf, Eddy
Mazur, Barry
Mazzarella, James K.
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McAllister, Byron L.
McArdle, Kevin R.
McArthur, C. W.
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McBrien, Vincent O.
McCann, Robert J.
McCarthy, John
McCarty, George S.
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McCormick, Ferris E.
McCoy, N. H.
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McCree, Paul W., Jr.
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McCulloh, Leon R.
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McKelvey, Robert W.
McKenzie, Lionel W.
McKenzie, Ralph N.
McKerihan, Mark D.
McKown, Jon William
McLaughlin, David W.
McLaughlin, Jack E.
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McLeod, Edward B., Jr.
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McMinn, Trevor J.
McNerney, Gerald M.
McNulty, George F.
McOwen, Robert C.
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Meisner, Morris J.
Meister, Erhard V.
Meister, Lyudmila
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Mejia-Hernandez, Isaac
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Mendelsohn, N. S.
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Meyer, Helmut
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Meyer, Jean-Pierre G.
Meyer, Kenneth R.
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Michael, Ernest A.
Michaud, Pierre
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de-Michele, Leonede
Middleton, David
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Mielke, Paul T.
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Mikami, Kentaro
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Miller, Charles F., III
Miller, Curtis P.
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Miller, John G.
Miller, Kenneth S.
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Miller, Patrick D.
Miller, Victor S.
Miller, Willard, Jr.
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Millett, Kenneth C.
Millington, Hugh G.
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Milson, Robert
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Mines, Ray
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Min-Oo, Maung
Miraglio, Anthony C.
Miranda, Rick
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Mitchem, John A.
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Mityagin, Boris
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Miyadera, Isao
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Miyata, Takahisa
Miyazaki, Katura
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Mizumoto, Hisao
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Mocanu, Petru T.
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Moffatt, H. Keith
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Monk, J. Donald
Montgomery, Hugh L.
Montgomery, Peter L.
Moody, Robert V.
Moon, Byung Soo
Moore, Barbara B.
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Moore, Lawrence C., Jr.
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Morain, François
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Moreno, Oscar
Moretz, Marjorie A.
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Morimoto, Akihiko
Morley, Larry J.
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Morris, Peter C.
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Morrison, John A.
Morrison, Tim H.
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Moser, Joseph G.
Moser, William O. J.
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Mosier, Ronald G.
Moskowitz, Samuel E.
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Mount, John A.
Mount, Kenneth R.
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Moy, Allen
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Muhly, Paul S.
Muir, Allan
Müller, Gert H.
Munkholm, Hans J.
Munkres, James R.
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Murai, Nobuyuki
Murakami, Hiroshi
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Murakami, Shingo
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Murphy, Donald P.
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Musson, Ian M.
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Myung, Hyo Chul
Nagahara, Takasi
Nagano, Tadashi
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Nagase, Noriaki
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Nakatsuka, Harunori
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Navarro Sandalinas, Joaquim
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Neggers, Joseph
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Neisendorfer, Joseph
Nelson, David
Nelson, Edward
Nelson, Edward O.
Nelson, Larry D.
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Nencka, Hanna
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Neumann, Peter M.
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Neves, Vitor M. C.
Neveu, Jacques
Neville, Charles W.
Newlander, August, Jr.
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Newman, Morris
Ney, Peter E.
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Nichols, Eugene D.
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Nickel, James A.
Nicol, Charles A.
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Niefield, Susan B.
Nikulin, Viacheslav V.
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Nishiura, Togo
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Nitecki, Zbigniew H.
Nivat, Maurice Paul
Niven, Ivan
Niwano, Eikazu
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Nordgren, Eric A.
Nori, Madhav Vithal
Noriaki, Kamiya
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Novick, Beth A.
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Nussbaum, Roger D.
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Oda, Tadao
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Odom, Earl T., Jr.
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Ogg, Andrew P.
Oguchi, Kunio
Ohm, Jack E.
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Okikiolu, Kate
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Olesen, Victor Jacob
Olimpio Junior, Antonio
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Oliver, Marcel
Oliver, Robert A.
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Olson, Loren D.
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O'Neill, Barrett
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Ono, Takashi
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Orlik, Peter P.
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Orr, Kent
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Osserman, Robert
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Oswald, Urs
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Ozimkoski, Raymond E.
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Palmer, Theodore W.
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Park, Jong An
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Parker, Susan F.
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Parks, Teresa A.
Parmeggiani, Alberto
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Parshall, Brian J.
Paschke, William L.
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Passell, Nicholas
Passerini, Henry J.
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Patrick, David M.
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Patton, L. Raphael
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Pauwels, Eric
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Payne, Lawrence E.
Payton, Robert G.
Pears, Alan R.
Pearson, Stephen C.
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Peck, Paul S.
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Pedersen, Edward A.
Pedersen, Erik Kjaer
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Peiffer, Barry L.
Peixoto, Mauricio M.
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Pennisten, John W.
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Perry, Charles R., Jr.
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Peshkichev, Yuri Afanasievich
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Peters, John E.
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Petersen, Karl E.
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Peterson, Annalisa Marie
Peterson, Charles L.
Peterson, Gary L.
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Petryshyn, W. V.
Petti, Richard
Peyerimhoff, Norbert
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Pfeiffer, Paul E.
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Pham, Tuan Dinh
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Phillips, Ralph S.
Phillips, Richard E.
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Piger, Camille
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Pigozzi, Don L.
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Price, Justin J.
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Rasmussen, Steven
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Ratliff, Louis J., Jr.
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Rebolledo, Rolando A.
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Recillas-Juárez, Felix J.
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Reed, Robert E.
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Reese, Sylvester
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Reilly, Norman Raymond
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Reller, Austin F.
Rempel, Richard S.
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Renggli, Loris G.
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Restrepo, Guillermo
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Reversat, Marc
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Revill, James A.
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Reyes, Ramon
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Rhoads, Gregory S.
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Richmond, Jean B.
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Richter, Horst P.
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Richter, Wayne H.
Richtmyer, Robert D.
Rickart, Charles E.
Rickert, John H.
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Ridley, James N.
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Rietz, Ronald Edgar
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Rigdon, Robert D.
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Rike, Thomas A.
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Rivera Trujillo, Jose A.
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Robbin, Joel W.
Robbins, David P.
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Roberts, Joel L.
Roberts, Joseph B.
Roberts, Leslie G.
Roberts, Lois J.
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Robinson, Daniel A.
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Rosenkrantz, Roger D.
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Rosenthal, Eric S.
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Rossa, Robert F.
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Rossi, Hugo
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Rowe, Niles W.
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Rubinstein, Zalman
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Ruiz, Ceferino
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Runyan, Daniel P.
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Ryan, Peter M.
Ryan, Robert D.
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Schafer, Richard D.
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Schaffner, Stuart Calvin
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Schatz, James R.
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Schechter, Samuel
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Schneider, Todd J.
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Schultens, Jennifer C.
Schumaker, John A.
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Schwartz, Jacob T.
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Schwarz, Binyamin
Schwarz, Fritz
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Scopelli, Alejandro R.
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Seinfeld, Kent
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Serre, Denis A.
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Shalen, Peter B.
Shallit, Jeffrey Outlaw
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Shapiro, Daniel B.
Shapiro, Harold N.
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Shapiro, Victor L.
Sharp, Henry, Jr.
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Shatz, Stephen S.
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Shelley, Ian James
Shelly, Maynard W.
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Shepherdson, John C.
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Sherman, Thomas L.
Shiffman, Bernard
Shiffman, Max
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Shiga, Hiroshige
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Shigeo, Fujisaki
Shimada, Nobuo
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Shimoda, Yasuhiro
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Siegel, Paul H.
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Silberger, Donald Morison
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Silverman, Joseph H.
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Simon, Raúl Alfonso
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Smiley, Leonard
Smillie, John
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Smith, Karen E.
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Smith, Perry B.
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Smith, Spurgeon E.
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Spatz, Ian N.
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Specht, Edward J.
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Spielberg, Stephen E.
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Spruck, Joel
Spruill, Marcus C.
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Staknis, Victor R.
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Stammbach, Urs
Stanley, Lee James
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Starbird, Michael
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Stark, Richard K.
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Steinberg, Maria W.
Steinberg, Robert
Steinby, Magnus
Steincamp, James W.
Steinert, Leon A.
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Stenlund, Mikael Lennart
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Stolz, Stephan A.
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Stone, Emily F.
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Straley, Tina H.
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Strauss, Vladimir A.
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Sturley, Eric A.
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Suita, Nobuyuki
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Suzuki, Michio
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Tamari, Dov
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Tanaka, Katsumi
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Taylor, B. A.
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Taylor, Thomas J.
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Tazawa, Yoshihiko
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Tierney, Myles
Tijerina, Raul M.
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Tischler, David C.
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Titi, Edriss Saleh
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Torri, Damiano
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Tsuji, Kazô
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57	6.8	69	7.6	81	9.6
58	6.8	70	7.7	82	9.8
59	6.9	71	7.8	83	10.0
60	6.9	72	7.9	84	10.2
61	7.0	73	8.1	85	10.5
62	7.0	74	8.2	86	10.8
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Apply to: The Honorary Secretary, Edinburgh Mathematical Society, James Clerk Maxwell Building, King's Buildings, Mayfield Road, Edinburgh, EH9 3JZ, Scotland.

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Address for mail: V. Ulbricht, Institut für Festkörpermechanik, Technische Universität Dresden, D-01062 Dresden, Germany.

Apply to: L. Gaul, Institut A für Mechanik, Universität Stuttgart, Pfaffenwaldring 9, D-70550 Stuttgart, Germany.

Dues: DM 100, payable to G. Alefeld, Institut für Angewandte Mathematik, Universität Karlsruhe, Englerstr. 2, D-76131 Karlsruhe, Germany.

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Apply to: F. H. Goldman, Glasgow Mathematical Association, Department of Mathematics, University of Glasgow, 15 University Gardens, Glasgow G12 8QW, Scotland, e-mail: gma@maths.gla.ac.uk.

Dues: £2.50, payable to Frances Goldman, Glasgow Mathematical Association.

Privileges: *Glasgow Mathematical Journal* available, current price to members £32.

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Apply to: Robert Magnus, Icelandic Mathematical Society, Dunhaga 3, 107-Reykjavik, Iceland, URL: http://www.raunvis.is/is.

Dues: U.S. $10, payable to Magnus M. Haldorsson, at above address.

Privileges: Reduced subscription rate on *Mathematica Scandinavica* and *Nordisk Matematisk Tidskrift* (*Normat*); subscription orders should be sent directly to the journals.

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• Irish Mathematical Society

Address for mail: R. J. Higgs, Department of Mathematics, University College Dublin, Belfield, Dublin 4, Ireland, e-mail: `rhiggs@ollamh.ucd.ie`; URL: http://www.maths.tcd.ie/pub/ims.

Apply to: K. Hutchinson, Treasurer, Irish Mathematical Society, Department of Mathematics, University College Dublin, Belfield, Dublin 4, Ireland.

Dues: U.S. $10, payable to K. Hutchinson, Treasurer, IMS, at above address.

Privileges: Free copy of the *Bulletin of the Irish Mathematical Society* (two times per year), free registration at IMS annual conference (September).

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Dues: Are voluntary but should minimally cover duplication and mailing costs; for reciprocity members (residing outside Hungary) suggested fee is 1/8 of one percent of the member's net income; sponsoring members pay at least U.S. $180 or equivalent per year.

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Address for mail: Union of Czech Math & Phys., Žitná 25, 117 10 Praha 1, Czech Republic, e-mail: `jcmf@math.cas.cz`.

Dues: U.S. $20, payable to Jednota českých matematiků a fyziků.

Privileges: (i) A discount of 20% in the conference fees for conferences, symposia, summer schools, and similar events organized (or coorganized) by the JČMF; (ii) newsletter.

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Apply to: Hilda Draškovičová, Sekretariát JSMF, MFF UK, Mlynská dolina, 842 15 Bratislava, Slovakia.

Dues: U.S. $20, payable to Slovenská sporitel'ňa, Štúrova ul., 800 00 Bratislava, Slovakia, č.u.: 101848-019/0900 UČO: 178705.

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Apply to: Miss S. M. Oakes, London Mathematical Society, 57-58 Russell Square. London WC1B 4HP, United Kingdom, e-mail: `lms@lms.ac.uk`; URL: http://www.lms.ac.uk.

Dues: £8.50, U.S. $17.00, payable to London Mathematical Society. (New members should not send payment until elected.)

Privileges: *LMS Newsletter*; reduced rates for the *Bulletin*, *Journal*, and *Proceedings of the LMS*; *Nonlinearity*; *Journal of Applied Probability*; *Mathematical Proceedings of the Cambridge Philosophical Society*; *Quarterly Journal of Mathematics*; *Glasgow Mathematical Journal*; LMS Lecture Notes; LMS Student Texts; LMS Monographs. (Please write to the LMS for complete details.)

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Dues: NKr. 50 or NKr. 500 for permanent membership, payable to Inger Jansen, Norsk Matematisk Forening.

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Apply to: Karl Sigmund, Universität Wien, Institut für Mathematik, Strudlhofgasse 4, A-1090 Wien, Austria.

Dues: ATS 250, payable to ÖMG (PSK acct. nr. 7823.950), Karlsplatz 13, A-1040 Wien, Austria.

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Privileges: Participation in scientific conferences organized by the Polish Mathematical Society and in its scientific sessions; in addition, members receive one of the following four series of the publication *Annales Societatis Mathematicae Polonae*: *Commentationes Mathematicae* in congress languages, *Wiadomości Matematyczne* (*Mathematical News*) in Polish, *Matematyka Stosowana* (*Applied Mathematics*) in Polish and congress languages, *Dydaktyka Matematyki* (*Didactics of Mathematics*) in Polish.

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Dues: U.S. $30, payable to Salvador Segura Gomis, at the above address.

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Dues: 3500 PTE, payable to Bosco García Archilla, Treasurer, Departamento de Matemáticas, Univ. Autónoma de Madrid, Cantoblanco, 28049 Madrid, Spain.

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Apply to: Secretari de la Societat Catalana de Matemàtiques, Carrer del Carme 47, 08001 Barcelona, Spain, e-mail: scm@iec.es; URL: http://www.iec.es/societat.scm.htm.

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Apply to: Peter Legiša, FMF, Jadranska 19, P.P. 2964, 1000 Ljubljana, Slovenia.

Dues: U.S. $30, payable to SKB banka, (Ljubljana), Acc. No. 429619, Swift Code skbas12x.

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Dues: FIM 80, payable to Aatos Lahtinen, Treasurer, Department of Mathematics, P.O. Box 4, FIN-00014 University of Helsinki, Finland.

Privileges: *Arkhimedes* (six issues per year) and *Eukleides* (newsletter), *Mathematica Scandinavica* at reduced price.

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Dues: 50 SEK., payable to Svenska Matematikersamfundet, Britt-Marie Stocke, Department of Mathematics, University of Umeå, S-901 87 Umeå, Sweden.

Privileges: *Mathematica Scandinavia* and *Nordisk Matematisk Tidskrift* at reduced rate. Newsletter about the activities and meetings of the Society.

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Dues: Voluntary, payable to Union of Bulgarian Mathematicians, Account #185-7808, State Savings Bank/DSK-I/code 421-121-817-001-1, BNB, Sofia City Branch.

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Apply to: Membership Department, Wiskundig Genootschap, University of Utrecht, Postbus 80010, 3508 TA Utrecht, The Netherlands.

Dues: Hfl 55., payable to Amro Bank, Utrecht, The Netherlands, account 45.65.88.167, Penningmeester Wiskundig Genootschap.

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Apply to: Jorge Blanco, Secretario de SUME, Facultad de Ciencias Económicas y de Administración, Av. G. Ramírez 1926, Montevideo, Uruguay.

Dues: Contact Sociedad Uruguaya de Matemática y Estadística for dues information; payable to: Miguel Galmés, Facultad de Ciencias Econónicas y de Administración, Av. G. Ramírez 1926, Montevideo, Uruguay.

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Privileges: *SBMAC Bulletin* and *SBMAC Notices*.

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• Sociedade Paranaense de Matemática*

Apply to: C. Pereira da Silva, Sociedade Paranaense de Matemática, Caixa Postal 1261, 80001-970, Curitiba-PR, Brasil.

Dues: U.S. $12, payable to Sociedade Paranaense de Matemática.

Privileges: *Boletim da Sociedade Paranaense de Matemática* (two issues per year), *Monografias da Sociedade Paranaense de Matemática*.

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• Unión Matemática Argentina

Apply to: Alejandro Neme, IMASL, Ave. Ejercito de los Andes 950, 5700 San Luis, Argentina, e-mail: `uma@unsl.edu.ar`; URL: http://linux0@unsl.edu.ar/uma.

Dues: U.S. $40, payable to Alejandro Neme.

Privileges: Free subscription to *Noticiero UMA* and one of either *Revista de la Unión Matemática Argentina* or *Revista de Educación Matemática*.

Officers: Felipe Zó (President), Jorge Solomin (Vice-President), Alejandro Neme (Treasurer), Hugo Alvarez (Secretary).

Middle East

Iranian Mathematical Society*

Apply to: Rashid Zaare-Nahandi (Secretary of the IMS), P. O. Box 13145-418, Tehran, Iran.

Dues: U.S. $20, Iranian Mathematical Society, P.O. Box 13145-418, Tehran, Iran.

Privileges: *Bulletin of the Iranian Mathematical Society*, *Farhang va Andisheh Reiazi* (a mathematical journal in Persian, if applicable), newsletter (in Persian, if applicable), and reduced rate for participation in the annual Iranian mathematics conferences and other seminars organized by IMS.

Officers: A. Riyazi (President), E. Babolian (Treasurer), R. Zaare-Nahandi (Secretary).

Israel Mathematical Union

Apply to: Shoshana Abramowitz, Secretary, Department of Mathematics, Haifa University, 31905 Haifa, Israel.

Dues: U.S. $15, payable to David Blanc, Treasurer, Department of Mathematics, Haifa University, 31905 Haifa, Israel.

Privileges: Participation in meetings and all other privileges enjoyed by an ordinary member.

Officers: Joseph Zaks (President), David Blanc (Treasurer), Shoshana Abramowitz (Secretary).

Palestine Mathematical Society*

Address for mail: P. O. Box 1862, Ramallah, West Bank, via Israel.

Apply to: Fawzi Yagoub, Department of Mathematics and Computer Science, SUNY College at Fredonia, Fredonia, NY 14063.

Dues: U.S. $30, payable to Fawzi Yagoub, see address above.

Privileges: Free issues of the *PSMS Newsletter*; 50% reduction on all PSMS conference fees; 50% reduction on all PSMS publications.

Officers: Marwan Awartani (President), Tahseen Mughrabi (Vice-President), Abdul-Hamid Aburrub (Treasurer), Haiganoush Preisler (Secretary).

Saudi Association for Mathematical Sciences

Apply to: Fawzi Al-Thukair. President of SAMS, P. O. Box 2455, Riyadh 11451, Saudi Arabia. e-mail: `esmaeljb@ksu.edu.sa`.

Dues: U.S. $30, payable to Saudi Association for Mathematical Sciences, at above address.

Privileges: Reduction in membership fee from U.S. $40 to U.S. $30; proceedings of conferences, symposia, and seminars arranged by the Association.

Officers: Fawzi A. Al-Thukair (President), Mohammed Al-Gwaiz (Vice-President), Abjullah Al-Makoshi (Treasurer), Semir Klob (Secretary).

South Pacific

• Australian Mathematical Society Inc.

Address for mail: Australian Mathematical Society, School of Mathematics, University of Tasmania, GPO Box 252-37, Hobart, Tasmania 7001, Australia, e-mail: `elliott@hilbert.maths.utas.edu.au`; URL: http://www.aust.org.au/.

Apply to: The Administrator, Australian Mathematical Society, Department of Mathematics, Australian National University, Canberra ACT 0200, Australia.

Dues: $Aust 35, payable to the Australian Mathematical Society Inc., c/o The Administrator, at the above address.

Privileges: Free copies of *The Gazette* (five copies in 1997), Reduced prices for *Journal Series A - Pure Mathematics and Statistics* ($A38), *Journal Series B - Applied Mathematics* ($A32), *Bulletin of AustMS* ($A35) and for volumes in *Lecture Series*.

Officers: A. J. van der Poorten (President), W. R. Bloom, J. H. Loxton, and E. O. Tuck (Vice-Presidents), A. Howe (Treasurer), D. Elliott (Secretary).

New Zealand Mathematical Society

Address for mail: NZ Mathematical Society, c/o Dr. Stephen Joe (NZMS Secretary), Department of Mathematics, University of Waikato, Private Bag 3105, Hamilton, New Zealand; tel: +64-7-856-2899, ext. 8363; fax: +64-7-838-4666; e-mail: `stephenj@math.waikato.ac.nz`; URL: http://www.math.waikato.ac.nz/nzms/nzms.html.

Apply to: John A. Shanks, Department of Mathematics and Statistics, University of Otago, P. O. Box 56, Dunedin, New Zealand.

Dues: NZ $16, payable to John A. Shanks, Department of Mathematics and Statistics, University of Otago, P. O. Box 56, Dunedin, New Zealand.

Privileges: *Newsletter of the NZMS* (three per year).

Officers: Rob Goldblatt (President), Douglas Bridges (Vice-President), Mick Roberts (Treasurer), Stephen Joe (Secretary), John Shanks (Membership Secretary).

Mathematics Calendar

The most comprehensive and up-to-date Mathematics Calendar information is available on e-MATH at `http://www.ams.org/mathcal/`.

September 1998

1-9 **Fourth International Workshop on Complex Structures and Vector Fields**, St. Constantine resort (near Varna), Bulgaria. (Sept. 1997, p. 1031)

1-10 **Advanced Course on Dynamical Systems**, Centre de Recerca Matematica, Bellaterra, Spain. (Jun/Jul 1998, p. 751)

2-5 **1998 Conference on Computational Physics (CCP 1998)**, Granada, Spain. (Feb. 1998, p. 295)

*2-4 **Dynamical Systems and Differential Geometry**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.
Organizer: T. Iwai, Graduate School of Engineering, Kyoto Univ., Sakyo-ku, Kyoto 606-8501, Japan.
Information: `http://www.kurims.kyoto-u.ac.jp/workshop-e.html`.

3-4 **Mathematical and Computational Issues in Pattern Formation**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 751)

6-18 **A NATO Advanced Study Institute; Genes, Fossils and Behaviour: An Integrated Approach to Human Evolution**, University of Cambridge, Isaac Newton Institute for Mathematical Sciences, Cambridge, United Kingdom. (Jun/Jul. 1998, p. 751)

7-10 **Undergraduate Mathematics Teaching Conference (UMTC98)**, Sheffield Hallam University, Sheffield, England. (May 1998, p. 640)

7-11 **A Euroconference on Infinite Length Modules**, University of Bielefeld, Bielefeld, Germany. (Apr. 1998, p. 534)

7-12 **International Conference on Partial Differential Equations and Related Topics**, Mission Beach, Queensland, Australia. (Jun/Jul. 1998, p. 751)

7-14 **Voronoi Conference on Analytic Number Theory and Space Tilings**, Kyiv, Ukraine (Jun/Jul. 1998, p. 751)

8-12 **Pattern Formation and Morphogenesis: The Basic Process**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 752)

12-13 **Central Sectional Meeting**, DePaul University, Chicago, IL. (Sept. 1997, p. 1031)

12-14 **Symplectic Geometry and Micro-Local Analysis in honor of Victor Guillemin's 60th Birthday**, Massachusetts Institute of Technology, Cambridge, Massachusetts. (Jun/Jul. 1998, p. 752)

14-17 **Constraint Programming and Large Scale Discrete Optimization**, DIMACS Center, Rutgers University, Piscataway, New Jersey. (Aug. 1998, p. 897)

*14-18 **Integrability: The Seiberg-Witten and Whitham Equations**, Edinburgh, United Kingdom.
Organizing Committee: H. W. Braden (Edinburgh), D. B. Fairlie (Durham), I. Krichever (Columbia), I. A. B. Strachan (Hull), and G. Wilson (I.C. London).
Sponsor: The International Centre for Mathematical Sciences.
Topics: The intention is to bring together mathematicians and mathematical physicists with interests in integrability and its applications. The general objectives are: to discuss the general algebro-geometric and geometric structures underlying integrability and specifically to clarify the appearance of integrable structures in Seiberg-Witten theory; to discuss the Whitham equations and their application in the generalized WKB analysis of (integrable) systems, particularly their appearance in connection with Seiberg-Witten theory; to discuss systems of hydrodynamic type, Frobenius manifolds and algebras; to develop interdisciplinary links and establish new connections between different areas that employ facets of integrability; to enhance collaborative research by bringing together participants from different areas of pure mathemat-

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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`; login and password `e-math`) and use the Lynx option from the main menu.)

ics, applied mathematics and theoretical physics.
Information: ICMS, 14 India Street, Edinburgh EH3 6EZ; tel: (0)131-220-1777; fax: (0)131-220-1053; e-mail: icms@maths.ed.ac.uk. See the Website for updated information and a registration form: http://www.ma.hw.ac.uk/icms/.

14-18 **International Congress on Numerical Methods for Partial Differential Equations**, Marrakech, Morocco. (Jun/Jul. 1998, p. 752)

14-18 **Pattern Formation and Morphogenesis: Model Systems**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 752)

14-18 **Solving Systems of Equations**, Mathematical Sciences Research Institute, Berkeley, California. (May 1998, p. 641)

14-19 **6th International Conference on Evolution Equations and Their Applications in Physical and Life Sciences**, Bad Herrenalb, Germany. (May 1998, p. 641)

14-December 18 **Mathematical Questions in Signal and Image Processing**, Institut Henri Poincaré, Paris, France. (May 1998, p. 641)

15-December 15 **Semester on Dynamical Systems**, Centre de Recerca Matematica, Barcelona, Spain. (Jun/Jul. 1998, p. 753)

*16-18 **Recent Topics on Operator Algebras**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.
Organizer: M. Nagisa, Fac. of Sci., Chiba Univ., Inage-ku, Chiba Pref. 263-0022, Japan.
Information: http://www.kurims.kyoto-u.ac.jp/workshop-e.html.

16-18 **Seventh International Conference on Hydraulic Engineering Software (HYDROSOFT 98)**, Centro di in Como, Italy. (Dec. 1997, p. 1500)

17-20 **The Third Annual Conference on Research in Undergraduate Mathematics Education**, Century Center, South Bend, Indiana. (Feb. 1998, p. 295)

17-29 **Ninth Crimean Autumn Mathematical Symposium on Spectral and Evolutionary Problems**, Crimea, Ukraine. (Mar. 1998, p. 426)

20-25 **Real Analytic and Algebraic Geometry**, Grand Hotel Bellavista, Levico Terme (Trento), Italy. (Jun/Jul. 1998, p. 753)

22-26 **Eighth Meeting on Real Analysis and Measure Theory**, Hotel Panorama, Maiori (Naples), Italy. (Jun/Jul. 1998, p. 753)

24-26 **4th Hellenic European Conference on Computer Mathematics and Its Applications (HERCMA '98)**, Athens, Greece. (Oct. 1997, p. 1158)

25-26 **Developments of Mathematics at the Eve of the Year 2000**, Luxembourg. (Jun/Jul. 1998, p. 753)

26-28 **Interdisciplinary Conference on Waves and Continuation Methods in Biology**, University of Pittsburgh, Pennsylvania. (Apr. 1998, p. 534)

*28-29 **Representation Theory of Finite Groups and Related Topics**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.
Organizer: S. Koshitani, Dept. of Math., Fac. of Sci., Chiba Univ., Inage-ku, Chiba Pref. 263-0022, Japan.
Information: http://www.kurims.kyoto-u.ac.jp/workshop-e.html.

28-30 **International Conference on Ordinal and Symbolic Data Analysis (OSDA98)**, University of Massachusetts, Lincoln Campus Center, Amherst, Massachusetts. (Dec. 1997, p. 1500)

28-October 4 **International Conference "Dynamical Systems: Stability, Control, Optimization (DSSCO'98)"**, Minsk, Belarus. (Oct. 1997, p. 1158)

October 1998

2-4 **Midwest Conference on the History of Mathematics (with a special session on History of Logic)**, Iowa State University, Ames, Iowa. (Feb. 1998, p. 295)

2-3 **Twenty-sixth Annual Mathematics and Statistics Conference**, Miami University, Oxford, Ohio. (Jun/Jul. 1998, p. 753)

4-10 **Clifford Analysis and Its Applications**, Cetraro, Calabria, Italy. (Jun/Jul. 1998, p. 753)

5-7 **Codes and Trees: Algorithmic and Information Theoretic Approaches**, DIMACS Center, Rutgers University, Piscataway, New Jersey. (Jun/Jul. 1998, p. 754)

*5-8 **Research on Complex Dynamical Systems - Where It Is and Where It Is Going**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.
Organizer: M. Kisaka, Fac. of Integrated Arts and Sci., Osaka Prefecrural Univ., Gakuen-cho, Sakai City, Osaka Pref. 599-8231, Japan
Information: http://www.kurims.kyoto-u.ac.jp/workshop-e.html.

5-10 **Fields Institute Workshop on Hydrodynamic Limits**, The Fields Institute for Research in Mathematical Sciences, Toronto, Ontario, Canada. (Feb. 1998, p. 295)

5-10 **Optimal Regularity in Elliptic, Hypoelliptic, and Parabolic Problems**, Grand Hotel Bellavista, Levico Terme (Trento), Italy. (Jun/Jul. 1998, p. 754)

7-11 **International Conference on Operator Theory and Its Applications to Scientific and Industrial Problems**, Winnipeg, Canada. (May 1998, p. 641)

8-9 **Immunology, Cell Signaling, the Physiology of the Immune System and the Dynamics of the Immune Response**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 754)

8-9 **Third International Conference on Mathematical Modelling and Analysis (MMA-98)**, Institute of Mathematics, Riga, Latvia. (May 1998, p. 641)

8-10 **23rd Meeting of the Euro Working Group on Financial Modelling**, Cracow, Poland. (Jun/Jul. 1998, p. 754)

9-10 **AMS Southeastern Sectional Meeting**, Wake Forest University, Winston-Salem, North Carolina. (Sept. 1997, p. 1031)

12-16 **Immune System Modeling & Cell Signaling**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 754)

12-16 **Symbolic Computation in Geometry and Analysis**, Mathematical Sciences Research Institute, Berkeley, California. (Jun/Jul. 1998, p. 755)

12-30 **Third School on Nonlinear Functional Analysis and Applications to Differential Equations**, Trieste, Italy. (Apr. 1998, p. 534)

14-17 **Trends in Mathematical Physics**, University of Tennessee, Knoxville, Tennessee. (Mar. 1998, p. 427)

*15-17 **Mathematical Topics in Biology**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.
Organizer: M. Mimura, Graduate School of Math. Sci., Univ. of Tokyo, Komaba, Meguro-ku, Tokyo 153-0041, Japan.
Information: http://www.kurims.kyoto-u.ac.jp/workshop-e.html.

16-17 **18th Annual Southeastern-Atlantic Regional Conference on Differential Equations**, Auburn University, Auburn, Alabama. (Jun/Jul. 1998, p. 755)

18-20 **Fourth IMACS International Symposium on Iterative Methods in Scientific Computation**, Austin, Texas. (Apr. 1998, p. 534)

18-23 **IEEE Visualization 1998 (Vis98)**, Sheraton Imperial Hotel, Research Triangle Park, North Carolina. (May 1998, p. 642)

*19-21 **Nonlinear Evolution Equations and Applications**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.
Organizer: M. Otani, School of Sci. and Engineering, Waseda Univ., Okubo, Shinjuku-ku, Tokyo 169-0072, Japan.
Information: http://www.kurims.kyoto-u.ac.jp/workshop-e.html.

19-23 **Forging an Appropriate Immune Response as a Problem in Distributed Artificial Intelligence**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 755)

*19-23 **Mutual Understandings Between Analytic Number Theory and Other Number Theories**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.
Organizer: Y. Nakai, Fac. of Education, Yamanashi Univ., Takeda, Kohfu City, Yamanashi Pref. 400-0016, Japan.

Information: http://www.kurims.kyoto-u.ac.jp/workshop-e.html.

20-22 **International Conference on Number Theory and Related Topics**, Yonsei University, Seoul 120-749, Republic of Korea. (Jun/Jul. 1998, p. 755)

22-23 **SIAM Workshop on Mathematical Foundations for Features in CAD, Engineering, and Manufacturing**, Somerset Inn, Troy, Michigan. (Jan. 1998, p. 113)

23-24 **The 20th Midwest Probabilty Colloquium**, Northwestern University, Evanston, Illinois. (May 1998, p. 642)

24-25 **AMS Eastern Sectional Meeting**, Pennsylvania State University, State College, PA. (Sept. 1997, p. 1031)
Information: R. Cascella, rgc@ams.org.

25-28 **Fractal 98, Complexity and Fractals in the Sciences**, Valletta, Malta. (Dec. 1997, p. 1500)

25-29 **Fields Institute Workshop on Monte Carlo Methods**, The Fields Institute for Research in Mathematical Sciences, Toronto, Ontario, Canada. (Feb. 1998, p. 295)

26-28 **2nd International Circuits, Systems and Computers'98 (CSC'98)**, Military Institutions of University Education (MIUE), Hellenic Naval Academy, Terma Hatzikyriakou, 18539, Piraeus, Greece. (Apr. 1998, p. 534)

*26-28 **Mathematical Aspects on Waves of Strong Nonlinearity or Large Degrees of Freedom**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.
Organizer: M. Funakoshi, Dept. of Applied Math. and Phys., Fac. of Eng., Kyoto Univ., Sakyo-ku, Kyoto 606-8501, Japan.
Information: http://www.kurims.kyoto-u.ac.jp/workshop-e.html.

26-30 **Fourth International Conference on Principles and Practice of Constraint Programming (CP98)**, Pisa, Italy. (Jun/Jul. 1998, p. 755)

26-30 **School on Complex Tori, Integrable Systems and Seiberg-Witten Theory**, Grand Hotel Bellavista, Levico Terme (Trento), Italy. (Jun/Jul. 1998, p. 756)

30-November 1 **Midwest Partial Differential Equations Seminar**, University of Illinois at Chicago, Chicago, Illinois. (Aug. 1998, p. 897)

November 1998

2-6 **Complexity of Continuous and Algebraic Mathematics**, Mathematical Sciences Research Institute, Berkeley, California. (Jun/Jul. 1998, p. 756)

2-7 **International Conference on Potential Analysis**, Hammamet, Tunisia. (Mar. 1998, p. 427)

*4-6 **Harmonic Analysis and Nonlinear Partial Differential Equations**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.
Organizer: H. Kozono, Graduate School of Polymathematics, Nagoya Univ., Furo-cho, Chikusa-ku, Nagoya, Aichi Pref. 464-0814, Japan.
Information: http://www.kurims.kyoto-u.ac.jp/workshop-e.html.

8-11 **1998 IEEE Symposium on Foundations of Computer Science (FOCS'98)**, Palo Alto, California. (Jun/Jul. 1998, p. 756)

*9-11 **Preconditioning Techniques in Numerical Computations**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.
Organzier: M. Sugihara, Graduate School of Engineering, Hagoya Univ., Furo-cho, Chikusa-ku, Nagoya, Aichi Pref. 464-0814, Japan.
Information: http://www.kurims.kyoto-u.ac.jp/workshop-e.html.

9-13 **Dynamics and Control of AIDS**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 756)

9-13 **Fields Institute Workshop on Analysis and Simulation of Communication Networks**, Fields Institute, Toronto, Canada. (Aug. 1998, p. 897)

*10-13 **Methods and Applications of Equations of Functions**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.
Organizer: T. Naito, The Univ. of Electro-communications, Chofugaoka, Chofu City, Tokyo 182-0021, Japan.
Information: http://www.kurims.kyoto-u.ac.jp/workshop-e.html.

*11-13 **Decision Theory in Mathematical Modelling**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.
Organizer: Y. Yoshida, Fac. of Economics and Business Administration, Kitakyushu Univ., Kokura minami-ku, Kitakyushu City, Fukuoka Pref. 802-0841, Japan.
Information: http://www.kurims.kyoto-u.ac.jp/workshop-e.html.

14-15 **AMS Western Sectional Meeting**, University of Arizona, Tucson, AZ. (Sept. 1997, p. 1031)
Information: W. Drady, wsd@ams.org.

15-20 **ASME Forum on Parallel Computing Methods**, Anaheim, California. (Jun/Jul. 1998, p. 756)

*16-19 **Theory and Applications of Computer Algebra**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.
Organizer: T. Hilano, Kanagawa Inst. of Tech., Shimo ogino, Atsugi City, Kanagawa Pref. 243-0203, Japan.
Information: http://www.kurims.kyoto-u.ac.jp/workshop-e.html.

*17-19 **First International Conference of Optimization and its Applications**, Mashad, Iran.
Topics: Application of optimization techniques to industrial, agricultural, and commercial problems of the Third World; Optimum control; Optimization in industrial design; Expert systems and AI; New techniques in numerical optimization; Optimization softwares.
Program: The conference program is divided into two parts. The first part contains the presentation of the papers received by the conference and accepted by the organizing committee. In the second part, a night of pure Iranian music and also some tours to historical places such as Khayam's and Ferdowsi's tombs have been arranged. Khayam was a well known Iranian mathematician, and Ferdowsi was a famous Iranian poet.
Registration: Registration fee: $200 U.S.
Information: For further information please contact H. R. Tareghian at taregian@science2.um.ac.ir.

17-19 **Mal'tsev Meeting**, The Institute of Mathematics, Novosibirsk, Russia. (Jun/Jul. 1998, p. 756)

18-20 **DIMACS Workshop on Robust Communication Networks: Interconnection and Survivability**, DIMACS Center, Rutgers University, Piscataway, New Jersey. (Aug. 1998, p. 897)

*18-20 **Mathematical Aspects of Complex Fluids**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.
Organizer: O. Sano, Tokyo Univ. of Agriculture and Tech., Nakamachi, Koganei City, Tokyo 184-0012, Japan.
Information: http://www.kurims.kyoto-u.ac.jp/workshop-e.html.

21-22 **DIMACS Workshops: Reconnecting Two-Year College Faculty to the Mathematical Sciences Enterprise**, DIMACS Center, Rutgers University, Piscataway, New Jersey. (Apr. 1998, p. 534)

23-28 **Conference on Dynamical Systems and Evolutionary Equations, in honor of J. K. Hale**, Instituto Superior Técnico, Lisbon, Portugal. (Aug. 1998, p. 898)

*24-26 **Properties of Ideals on $P\kappa\lambda$**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.
Organizer: Y. Abe, Fac. of Eng., Kanagawa Univ., Kanagawa-ku, Yokohama City, Kanagawa Pref. 221-0802, Japan.
Information: http://www.kurims.kyoto-u.ac.jp/workshop-e.html.

*25-27 **Operator Inequalities and Related Topics**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.
Organizer: H. Nakazato, Fac. of Sci. and Tech., Hirosaki Univ., Bunkyo-cho, Hirosaki City, Aomori Pref. 036-8224, Japan.
Information: http://www.kurims.kyoto-u.ac.jp/workshop-e.html.

27-28 **Short School on Operators on Manifolds with Singularities and Spectral Theory**, Dipartimento di Matematica, Università di Torino, Italy. (Aug. 1998, p. 898)

*30-December 4 **Algebraic Number Theory and Related Topics**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.

Organizer: Y. Ihara, Research Inst. for Math. Sci., Kyoto Univ., Sakyo-ku, Kyoto 606-8502, Japan.

Information: `http://www.kurims.kyoto-u.ac.jp/workshop-e.html`.

30-December 5 **Neural Information Processing Systems: Natural and Synthetic**, Denver, Colorado. (Jun/Jul. 1998, p. 756)

December 1998

*2-4 **Mathematical Economics**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.

Organizer: T. Maruyama, Dept. of Economics, Keio Univ., Mita, Minato-ku, Tokyo 108-0073, Japan.

Information: `http://www.kurims.kyoto-u.ac.jp/workshop-e.html`.

4-5 **NIPS*98 Post Conference Workshops**, Breckenridge, Colorado. (Jun/Jul. 1998, p. 757)

*7-9 **Spectral and Scattering Theory and Related Topics**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.

Organizer: H. Tamura, Fac. of Sci., Ibaragi Univ., Bunkyo, Mito City, Ibaragi Pref. 310-0056, Japan.

Information: `http://www.kurims.kyoto-u.ac.jp/workshop-e.html`.

*7-11 **III International Symposium on Hamiltonian Systems and Celestial Mechanics**, Morelia, Michoacan, Mexico.

Topics: The main topics include: Arnold diffusion, central configurations, singularities in few body problems, billiards, area preserving maps and geometrical mechanics.

Aim: This is an excellent opportunity to gather together people interested in discussing recent advances in research in the field of conservative systems, and related areas.

Invited Speakers: (*Confirmed) H. Cabral* (Universidade Federal de Pernambuco, Brazil), H. Cendra* (Universidad Nacional del Sur Bahia Blanca, Argentina), A. Chenciner (Bureau des Longitudes, France), A. Delshams* (Universidad Politecnica de Catalunya, Spain), A. Jorba* (UB, Spain), J. Koiller* (Universidade Federal de Rio de Janeiro, Brazil), R. de la Llave (Univ. of Texas), J.-P. Marco* (Universite de Paris VI, France), C. McCord* (Univ. of Cincinnati), K. Meyer* (Univ. of Cincinnati), J. P. Ramis* (Universite Paul Sabatier, France), C. Robinson* (Northwestern Univ.), D. Saari* (Northwestern Univ.), D. Schmidt* (Univ. of Cincinnati), S. Wiggins* (Caltech), J. Xia* (Northwestern Univ.).

Presentations: Oral presentations will be for 30 and 45 minutes. All the participants will have the opportunity to present a contribution during a poster session at the meeting. Everybody in the conference is invited to submit a paper to the Proceedings of the Symposium. The contributions will go through the usual referee procedure of any journal and will be edited by World Scientific. There is some room available for those interested in giving a talk. Send title and abstract before September 1 to E. Perez-Chavela, `epc@xanum.uam.mx`.

Organizers: J. Delgado, E. A. Lacomba, J. Llibre, J. Mucino and E. Perez-Chavela.

Information: If you are interested in attending or require more information about Morelia, Mexico, or the conference, please send e-mail to the secretary, P. Seligman `cic@ce.ifisicam.unam.mx`. Further information at our site: `http://oso.uam.mx/jdf/hs98/hamsys98.html`.

*7-11 **Microlocal Analysis and Systems of PDE in the Complex Domain**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.

Organizer: N. Tose, Dept. of Economics, Keio Univ., Mita, Minato-ku, Tokyo 108-0073, Japan.

Information: `http://www.kurims.kyoto-u.ac.jp/workshop-e.html`.

*9-11 **Blowup, Breakdown, and Related Topics in Nonlinear PDEs**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.

Organizer: H. Okamoto, Research Inst. for Math. Sci., Kyoto Univ., Sakyo-ku, Kyoto 606-8502, Japan.

Information: `http://www.kurims.kyoto-u.ac.jp/workshop-e.html`.

13-15 **CMS Winter 1998 Meeting**, Queen's University and Royal Military College, Kingston, Ontario, Canada. (Aug. 1998, p. 898)

*14-16 **Algebraic Combinatorics**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.

Organizer: H. Suzuki, Division of Natural Sci., College of Liberal Arts, International Christian Univ., Ohsawa, Mitaka City, Tokyo 181-0015, Japan.

Information: `http://www.kurims.kyoto-u.ac.jp/workshop-e.html`.

14-18 **First International Conference on Semigroups of Operators, Theory and Applications**, Marriot Hotel, Newport Beach, California. (Feb. 1998, p. 296)

*14-18 **Hyperbolic Spaces and its Related Topics**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.

Organizer: S. Kamiya, Okayama Univ. of Sci., Ridai-cho, Okayama City, Okayama Pref. 700-0005, Japan.

Information: `http://www.kurims.kyoto-u.ac.jp/workshop-e.html`.

16-22 **Symmetry and Perturbation Theory II**, Rome, Italy. (Apr. 1998, p. 534)

19-21 **(ORSI Convention) International Conference on Operations Research and Industry**, Institute of Basic Science, Agra, India. (May 1998, p. 642)

23-25 **The Joint Annual Conference of the Bharat Ganita Parisad and the Jammu Mathematical Society-A symposium on functional analysis and applications**, Department of Mathematics, Lucknow University, Lucknow, India. (Jun/Jul. 1998, p. 757)

January 1999

January-June **The Fields Institute for Research in Mathematical Sciences Program in Probability and Its Applications**, The Fields Institute, Toronto, Ontario, Canada. (Sept. 1997, p. 1031)

4-8 **Cell Adhesion and Motility**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 757)

*7-11 **Singular and Oscillatory Integrals**, University of Wisconsin-Madison, Madison, Wisconsin.

Topics: Harmonic analysis; in particular singular and oscillatory integrals.

Speakers: The list of speakers includes W. Beckner, M. Christ, R. Fefferman, A. Greenleaf, C. Kenig, D. Mueller, K. Okikiolu, D. Phong, C. Sogge, E. M. Stein, G. Weiss, S. Ziesler.

Organizing Committee: A. Carbery (Edinburgh), A. Nagel (Madison), A. Seeger (Madison), J. Wright (New South Wales).

Information: To indicate an interest in attending the conference, to register or to receive future announcements, send e-mail to `soi@math.wisc.edu`. For further information see the Website `http://conley.math.wisc.edu/~seeger/soi1.html`.

8-9 **Nonlinear Differential Equations: A Meeting Honoring Professor Alan Lazer on the Occasion of his 60th Birthday**, The University of Miami, Coral Gables, Florida. (Apr. 1998, p. 535)

8-12 **Twenty-third Holiday Symposium: Algebraic Structures For Logic**, New Mexico State University, Las Cruces, New Mexico. (May 1998, p. 642)

11-14 **Workshop on Coding and Cryptography**, Cercle militaire St. Augustin, Paris, France. (Aug. 1998, p. 898)

13-16 **Joint Mathematics Meeting**, San Antonio Convention Center, San Antonio, Texas. (Sept. 1997, p. 1031)

15-16 **ASL Winter Meeting (in conjunction with AMS meeting)**, San Antonio, Texas. (May 1998, p. 642)

17-19 **Tenth Annual ACM-SIAM Symposium on Discrete Algorithms (SODA'99)**, Omni Inner Harbor Hotel, Baltimore, Maryland. (Jun/Jul. 1998, p. 758)

* 18-20 **Coherent Vatical Structures - Their Roles in Turbulence Dynamics**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.
Organizer: S. Kida, National Inst. for Fusion Sci., Oroshi-cho, Toki City, Gifu Pref. 509-5202, Japan.
Information: `http://www.kurims.kyoto-u.ac.jp/workshop-e.html`.

19-23 **Introductory Workshop in Random Matrix Models and their Applications**, Mathematical Sciences Research Institute, Berkeley, California. (Jun/Jul. 1998, p. 758)

25-29 **Computational Modeling in Biological Fluid Dynamics**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 758)

* 25-29 **Researches on Automorphic Forms and L-functions**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.
Organizer: S.-I. Mizumoto, Fac. of Sci., Tokyo Inst. of Tech., Oh-okayama, Meguro-ku, Tokyo 152-0033, Japan.
Information: `http://www.kurims.kyoto-u.ac.jp/workshop-e.html`.

26-30 **Fields Institute Workshop on Probability in Finance**, Fields Institute, Toronto, Canada. (Aug. 1998, p. 898)

February 1999

* 1-4 **Singularity Theory and Differential Equations**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.
Organizer: T. Fukui, Fac. of Sci., Saitama Univ., Shimo-ohkubo, Urawa City, Saitama Pref. 338-0825, Japan.
Information: `http://www.kurims.kyoto-u.ac.jp/workshop-e.html`.

7-11 **35th Australasian Applied Mathematics Conference**, Mollymook Golf Club, Ulladulla, New South Wales. (Dec. 1997, p. 1500)

8-12 **Membrane Transport and Renal Physiology**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 758)

13 **Hormones**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 758)

15-19 **Endocrinology: Mechanism of Hormone Secretion and Control**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 758)

22-26 **Random Matrices, Statistical Mechanics, and Integrable Systems**, Mathematical Sciences Research Institute, Berkeley, California. (Jun/Jul. 1998, p. 758)

March 1999

* 1-4 **M/SET, International Conference on Mathematics/Science Education & Technology**, San Antonio, Texas.
Information: `http://www.aace.org/conf/Default.htm`.

* 3-5 **Theory and Applications of Realtime Computation**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan.
Organizer: N. Yonezaki, Graduate School of Information Sci. and Eng., Tokyo Inst. of Tech., Oh-okayama, Meguro-ku, Tokyo 152-0033, Japan.
Information: `http://www.kurims.kyoto-u.ac.jp/workshop-e.html`.

5 **Audition**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 758)

7-13 **Dirac Operators, Index Theorems and Numerical Invariants of Manifolds**, Greifswald University, Germany, Island of Usedom. (Jun/Jul. 1998, p. 759)

* 7-14 **Eighth International Conference on Geometry**, Nahsholim, Israel.
Topics: Foundations of geometry, geometric algebra, discrete and combinatorial geometry, convexity. Special section: Geometry and school.
Information: R. Artzy, e-mail: `rartzy@s2.haifa.ac.il` or J. Zaks, e-mail: `jzaks@s2.haifa.ac.il`, Dept. of Mathematics, Univ. of Haifa, 31905 Haifa, Israel.

8-12 **Audition**, University of Minnesota, Minneapolis, Minnesota.

12-13 **AMS Southeastern Section Meeting**, University of Florida, Gainesville, Florida. (Jun/Jul. 1998, p. 759)

16-20 **1999 UAB-GIT International Conference on Differential Equations and Mathematical Physics**, University of Alabama at Birmingham, Birmingham, Alabama. (Jun/Jul. 1998, p. 759)

18-21 **AMS Central Sectional Meeting**, University of Illinois-Urbana, Urbana, Illinois. (Aug. 1997, p. 846)

20-23 **ASL Annual Meeting**, San Diego, California. (May 1998, p. 642)

22-24 **Ninth SIAM Conference on Parallel Processing for Scientific Computing**, Adam's Mark San Antonio-Riverwalk Hotel, San Antonio, Texas. (Jun/Jul. 1998, p. 759)

* 24-26 **DIMACS Workshop on Mobile Networks and Computing**, DIMACS Center, Rutgers University, Piscataway, New Jersey.
Organizers: B. R. Badrinath (Dept. of CS, Rutgers Univ.), F. Hsu (Dept. of CIS, Fordham Univ.), P. Pardalos (Univ. of Florida), and S. Rajasekaran (Univ. of Florida).
Aim: The new challenges in designing software systems for mobile networks include location and mobility management, channel allocation, power conservation, among some others. This workshop is aimed at bringing together researchers from academia as well as the industry who are working on various aspects of mobile computing.
Topics: Topics will include sensor networks, smart spaces, field computing, channel allocation, etc.
Local Arrangements: P. Pravato, DIMACS Center, `pravato@dimacs.rutgers.edu`, tel: 732-445-5929.
Information: WWW: `http://dimacs.rutger edu/Workshops/Mobile/index.html`. Contact `raj@cise.ufl.edu`.

24-27 **Fifth SIAM Conference on Mathematical and Computational Issues in the Geosciences**, Adam's Mark San Antonio-Riverwalk Hotel, San Antonio, Texas. (Jun/Jul 1998, p. 759)

25-26 **Third International Multidisciplinary Congress in Quality and Reliability**, Paris, France. (Aug. 1998, p. 899)

April 1999

7-9 **Fourth International Conference on Typed Lambda Calculi and Applications (TLCA'99)**, l'Aquila, Italy. (Jun/Jul. 1998, p. 759)

10-11 **AMS Western Sectional Meeting**, University of Nevada, Las Vegas, NV. (Apr. 1997, p. 481)
Information: W. Drady, `wsd@ams.org`.

12-15 **Nonlinear Evolution Equations and Wave Phenomena: Computation and Theory**, Athens, Georgia. (Apr. 1998, p. 535)

* 17-18 **Riviere-Fabes Symposium on Analysis and PDE**, University of Minnesota, Minneapolis, Minnesota.
Organizers: M. Jodeit, W. Littman, W. M. Ni.
Main Speakers: J. Bourgain, C. Kenig.
Information: School of Mathematics, University of Minnesota, 206 Church Street S.E., 127 Vincent Hall, Minneapolis, MN 55455; tel: 612-625-5591, `jodeit@math.umn.edu`, or Web page: `http://www.math.umn.edu/`.

17-19 **Weekend Algebra Conference**, University of Southern Mississippi, Hattiesburg, Mississippi. (Jan. 1998, p. 113)

19-23 **Local Interaction and Global Phenomena in Vegetation and Other Systems**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 759)

24-25 **AMS Eastern Sectional Meeting**, State University of New York, Buffalo, NY. (Apr. 1997, p. 481)
Information: R. Cascella, `rgc@ams.org`.

May 1999

10-12 **Sixth SIAM Conference on Optimization**, Radisson Atlanta Hotel, Atlanta, Georgia. (Jun/Jul. 1998, p. 760)

12-15 **1999 SIAM Annual Meeting**, Radisson Atlanta Hotel, Atlanta, Georgia. (Jun/Jul. 1998, p. 760)

13-14 **Introduction to Epidemiology and Immunology**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 760)

* 14-16 **BLMS'99, Joint meeting of the London Mathematical Society and the Belgian**

Mathematical Society, Université Libre de Bruxelles, Brussels, Belgium.
Scientific Program: There will be four plenary lectures (on Saturday and Sunday morning) and four parallel sessions of eight 40-minute lectures (on Friday and Saturday afternoon).
Sessions and Organizers: Algebraic geometry and mathematical logic: J. Denef (K. U. Leuven), W. A. Hodges (Queen Mary and Westfield College, London) and C. Michaux (U.M.H., Mons). Combinatorics and finite geometries: P. Cameron (Queen Mary and Westfield College, London) and J. Thas (U. Gent). Differential geometry and mathematical physics: N. J. Hitchin (Oxford) and L. Lemaire (U.L. Bruxelles). Stochastic mathematics: M. Hallin (U.L. Bruxelles), W. S. Kendall (Warwick), and N. Veraverbeke (L.U.C., Diepenbeek).
Local Organizing Committee: L. Lemaire, J. Leroy, M. Parker, Campus Plaine ULB., Boulevard du Triomphe, C. P. 218/01, B-1050 Bruxelles; e-mail: `leroy@ulb.ac.be`; tel: 32-2-650-58-45; fax: 32-2-650-58-67.
Information: A second announcement with further details about the program will be sent sometime in October 1998. To receive this announcement, send a request to: J. Leroy, Campus Plaine ULB, C. P. 218/01, Boulevard du Triomphe, B-1050 Brussels, e-mail: `leroy@ulb.ac.be`; tel: 32-2-650-58-45; fax: 32-2-650-58-67.

17-21 **Mathematical Approaches for Emerging and Reemerging Infectious Diseases**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 760)

24-28 **Fifth SIAM Conference on Applications of Dynamical Systems**, Snowbird Ski and Summer Resort, Snowbird, Utah. (Jun/Jul. 1998, p. 760)

26-28 **Crystallographic Groups and their Generalizations II**, K. U. Leuven (Campus Kortrijk), Kortrijk, Belgium. (Aug. 1998, p. 899)

*26-29 **Third International Conference on Dynamic Systems and Applications**, Atlanta, Georgia.
General Topics: Theoretical and numerical methods in the areas of differential equations, integral equations, discrete analogs of these equations, and applications of these equations to various sciences and engineering.
Contributed Papers: Authors of contributed papers are requested to submit, before February 15, 1999, an abstract containing the topic of talk, a summary of talk (not exceeding half typed page), full address of each author, along with telephone and fax numbers, and e-mail addresses.
Deadlines: Abstract of contributed paper: February 15, 1999; Camera-ready paper for proceedings: August 30, 1999.
Registration: Pre-registration by March 30, 1999 (U.S. $125.00, students: U.S. $100.00); Registration after March 31, 1999: U.S. $150.00, students: U.S. $125.00. Registration includes copy of the abstracts, conference proceedings, and coffee & snack. A banquet will be held May 27, 1999; cost: U.S. $30.
Proceedings: Publication in the conference proceedings of the papers submitted to conference is subject to submitting the paper before the deadline, acceptance of the paper, and registration of one of the authors of the article. Publication of the proceedings is expected to be summer 2000.
Accommodation: Selected motels in downtown Atlanta, and Morehouse dormitory (details in the second announcement).
Information: Conference address: M. Sambandham, ICDSA, Department of Mathematics, Morehouse College, Atlanta, GA 30314; tel: 404-215-2614, fax: 770-451-0453; e-mail: `icdsa@yahoo.com`; `http://www.dynamicpublishers.com/`. To receive the second announcement send your name and address before December 1, 1998.

*31-June 4 **Turku Symposium on Number Theory in Memory of Kustaa Inkeri**, University of Turku, Finland.
Focus: This conference is dedicated to the memory of Kustaa Inkeri (1908-1997), professor of mathematics at the Univ. of Turku, 1950-1972 and the founder of the number theoretic research tradition in Finland. The subject of the conference will be number theory in a broad sense with applications.
Topics: An essential part of the program will consist of survey lectures on topics of general and actual interest. In addition, all participants are invited to give talks. These may be of a more specialized nature, concerning areas such as algebraic number theory, analytic number theory, Diophantine approximations and transcendence, Diophantine problems, elementary number theory, applied, algorithmic and computational number theory.
Invited participants: The following number theorists have already agreed to participate and give invited talks: P. Bundschuh (Cologne), G. Frey (Essen), M. N. Huxley (Cardiff), A. Ivic (Beograd), Y. Motohashi (Tokyo), W. Narkiewicz (Wroclaw), A. van der Poorten (Sydney), P. Ribenboim (Kingston).
Fees: The registration fee will be FIM 300 if it is paid before January 31, 1999; otherwise it is FIM 400.
Organizers: M. Jutila, T. Metsaenkylae.
Pre-Registration: Everybody interested in the second announcement (to be sent in Fall 1998), and possibly in giving a talk, is requested to pre-register by October 31, 1998.
Information: For more information and for a pre-registration form, see the Web page `http://www.utu.fi/ml/matlts/symp/`, or contact either of the organizers, address: Department of Mathematics, University of Turku, FIN-20014, Turku, Finland; e-mail: `matti.jutila@utu.fi` or `taumets@utu.fi`.

June 1999

7-11 **From Individual to Aggregration: Modeling Animal Grouping**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 760)

7-11 **Random Matrices and Their Applications: Quantum Chaos, GUE Conjecture for Zeros of Zeta Functions, Combinatorics, and All That**, Mathematical Sciences Research Institute, Berkeley, California. (Jun/Jul. 1998, p. 760)

*7-11 **Second IMACS Conference on Monte Carlo Methods**, Varna, Bulgaria.
Aim: The purpose of the seminar is to provide a forum for the presentation of recent advances in the analysis, implementation, and applications of Monte Carlo simulation techniques and, in particular, to stimulate the exchange of information between specialists in these areas.
Topics: The topics should cover both theoretical developments (random numbers, quasi-MC methods, numerical MC methods, statistical analysis, variance reduction, perturbation techniques, MC error analysis) and application fields (particle transport, reliability analysis, quantum mechanics, statistical physics, stimulation of random processes and fields).
Information: `http://copern.acad.bg/mcm99/dbase2.htmlor` send e-mail to: `imacs99@copern.acad.bg`.

*13-17 **Conference on The Mathematics of Public-Key Cryptography**, The Fields Institute, Toronto, Ontario, Canada.
Organizing Committee: A. Odlyzko (AT&T, Florham Park), G. Walsh (Univ. of Ottawa), H. Williams (Certicom Corporation, Mississauga).
Scope: In recent years there has been an enormous growth in the implementation of public-key cryptography, both in government and in industry. Many developers are currently providing information security Technology based on the concept of public-key cryptography. The level of security provided by this cryptography depends on the difficulty of certain mathematical problems, specifically integer factorization and the computation of discrete logarithms in finite abelian groups. Although there has been an increase in the amount of research devoted to this topic, it is the purpose of this conference to promote further research in order to increase our understanding of the level of security provided by these cryptosystems. Efficient implementation of public-key systems is another important aspect of this research area.
Topics: The content of the meeting is intended to include most areas of computational number theory, but with an underlying common thread toward furthering the knowledge of the connections to the mathematics of public-key cryptography.
Invited Speakers: E. Bach (Univ. of Wisconsin), J. Buchmann (Technische Universitdt Darmstadt), D. Coppersmith (IBM Research), G. Frey (Universitat Gesamthochschule Essen), N. Koblitz (Univ. of Washington), A. Lenstra (Citibank, Parsippany), A. Menezes (Univ. of Waterloo), F. Morain (Ecole Poly-

technique, LIX), H. Niederreiter (Austrian Academy of Sciences), C. Pomerance (Univ. of Georgia), H. te Riele (Centrum voor Wiskunde en Informatica), O. Schirokauer (Oberlin College), C. P. Schnorr (Universitdt Frankfurt), V. Shoup (IBM Zurich Research Laboratory), A. Stein (Univ. of Manitoba), P. Van Oorschot (Entrust Technologies), S. Vanstone (Certicom Corporation, Mississauga).

Call for Papers: There will be room for 20-minute contributed talks. Extended abstracts of proposed talks should reach the general chair, G. Walsh, gwalsh@jeanne.mathstat.uottawa.ca by January 15, 1999.

Funding: There will likely be some funding available to cover local expenses for those who are eligible to apply. This is meant primarily for graduate students, postdocs, and participants without access to travel funds otherwise.

Sponsor: Certicom Corporation, Communications Security Establishment, Entrust Technologies, The Fields Institute for Research in Mathematical Sciences, and RSA Data Security.

Information: Please contact the Institute at: The Fields Institute, 222 College Street, Toronto, Ontario M5T 3J1, Canada; tel: 416-348-9710; fax: 416-348-9385; e-mail: publickey@fields.utoronto.ca; Website: http://www.fields.utoronto.ca.

17-20 **Mathematics in Physics and Computer Science (Cooperation project between scientists from the CIS and Germany)**, Technische Universitaet Berlin, Germany. (Aug. 1998, p. 899)

*25-30 **Intermediate questions of Model Theory and Universal Algebra**, Novosibirsk State Technical University & Math. Institute of Siberian branch of Academy of Russia, Novosibirsk, Russia.

Organizers: V. A. Gorbunov, E. A. Palutin, A. G. Pinus, K. N. Ponomaryov.

Topics: Universal algebra, model theory, group and fields theories.

Information: e-mail: algebra@nstu.nsk.su.

*29-July 3 **Theory and Mathematics in Biology and Medicine (TMBM99)**, Vrije Universiteit, Amsterdam, The Netherlands

Aim: The international conference on Theory and Mathematics in Biology and Medicine 1999 aims to stimulate collaboration between mathematicians and bioscientists and to act as the main forum for the exchange of recent research results and new perspectives in the fields of Theoretical Biology and Medicine. This is the 4th of the official meetings, taking place every 3 years under auspices of the European Society for Mathematical and Theoretical Biology (ESMTB). In addition, it will be joint with the annual meeting of the Society for Mathematical Biology (SMB). The Netherlands Society for Theoretical Biology is responsible for the local organization. Through these links, this will be the first World Congress devoted to a rapidly growing, interdisciplinary domain of science where experimental biology and medicine, biochemistry, mathematics, computational science, physics and various fields of technology all come together.

Program: The conference will cover the theory and mathematics from all disciplines within Biology and Medicine, including immunology, epidemiology, evolution, ecology, molecular biology, cell signalling, tumor growth and treatment, morphogenesis, pattern formation, metabolic modeling, protein folding, neuromodeling, computational biology, cardiovascular modeling, and biomechanics. In addition, special sessions will be organized around focused topics that are particularly new or rapidly gaining importance. Participants are strongly encouraged to forward suggestions regarding the scientific program to: tmbm99@bio.vu.nl. Please mail suggestions as soon as possible, but no later than August 15, 1998.

Scientific Committee: Z. Agur, W. Alt, A. Goldbeter, L. Gross, M. Gyllenberg, R. Heinrich, A. Herz, P. Hogeweg, Y. Iwasa, V. Krivan, Y. Kuznetsov, A. Perelson, A. Pugliese, C. Sander, A. Stevens.

Organizing Committee: A. de Roos, F. van den Bosch, P. Doucet, O. Diekmann, P. Haccou, H. Heesterbeek, L. Hemerik, J. Kaandorp, C. de Kovel, M. Kretzschmar, B. Kooi, M. Luger, J. van Pelt, H. Westerhoff.

Information: For more information please visit the following web-site: http://www.bio.vu.nl/tmbm99, or contact the Conference Service of the Vrije Universiteit Amsterdam, VU Conference Service, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands; Phone: +31-(0)20-4445790, Fax: +31-(0)20-4445825; e-mail: vu_conference@dienst.vu.nl.

July 1999

*2-10 **The 1999 Federated Logic Conference (FLoC '99)**, Trento, Italy.

Focus: In 1996, as part of its Special Year on Logic and Algorithms, DIMACS hosted the first Federated Logic Conference (FLoC). It was modeled after the successful Federated Computer Research Conference (FCRC) and brought together synergetic conferences that apply logic to computer science. This is the second Federated Logic Conference (FLoC '99) and is hosted by ITC-IRST.

Conference Participation: The following conferences will participate in FLoC: Conference on Automated Deduction (CADE), Conference on Computer-Aided Verification (CAV), IEEE Symposium on Logic in Computer Science (LICS), and Conference on Rewriting Techniques and Applications (RTA). LICS and RTA will be held in parallel during the first four days of FLoC. CADE and CAV will be held during the last four days. Preconference workshops will be held on June 29-July 1, midconference workshops and excursions will be held on July 6, and postconference workshops will be held on July 11-12. Plenary events involving all the conferences are planned. Submissions must be directed to the individual conferences. Parallel submissions are not allowed: a paper may not be submitted to more than one of the participating conferences. Calls for papers and call for workshop proposals will be issued in the near future.

Information: Additional information regarding the participating meetings will be posted on the FLoC Web page later this spring— http://www.cs.bell-labs.com/~libkin/floc99/.

Steering Committee: A. Asperti (RTA), F. Giunchiglia (conference chair), L. Libkin (publicity chair), E. Moggi (LICS) S. R. della Rocca (LICS), J. Sifakis (CAV), P. Traverso (CADE), M. Y. Vardi (chair).

5-9 **The Fourth International Congress on Industrial and Applied Mathematics**, Edinburgh, Scotland. (Dec. 1997, p. 1500)

12-17 **Journees Arithmetiques 1999**, Rome, Italy. (May 1998, p. 642)

7-17 **Emerging Applications of Dynamical Systems**, University of Minnesota, Minneapolis, Minnesota. (Mar. 1998, p. 427)

*25-August 7 **The 14th International Conference on Banach Algebras**, Pomona College, Claremont, California.

Focus: This series of conferences on the general theory of Banach algebras and related areas of mathematics began at UCLA in 1974 and has continued, with the most recent conferences having been in Newcastle, England, in 1995, and Blaubeuren, Germany, in 1997. The title of the 14th international conference will be: "Banach Algebras and Operators on Banach Spaces".

Program: There will be approximately 50 talks, each 30 or 60 minutes long, on Monday through Friday of both weeks of the conference. There will also be several hours each afternoon for informal interaction among participants.

Organizing Committee: W. G. Bade (U.C. Berkeley), P. C. Curtis (U.C.L.A.), H. G. Dales (Univ. of Leeds), S. Grabiner (Pomona College), M. Thomas (California State Univ., Bakersfield).

Information: If you are interested in attending the conference, please contact S. Grabiner (at SGRABINER@POMONA.EDU) or M. Thomas (at BA99@CS.CSUBAK.EDU). Further information can also be found on our Web site http://www.cs.csubak.edu/~ba99/.

*26-30 **ENUMATH 99 - Third European Conference on Numerical Mathematics and Advanced Applications**, University of Jyvaskyla, Jyvaskyla, Finland.

Program Committee: F. Brezzi (Italy), M. Feistauer (Czech Republic), R. Glowinski (USA/France), R. Jeltsch (Switzerland), Yu. Kuznetsov (USA/Russia), J. Periaux (France), R. Rannacher (Germany).

Scientific Committee: O. Axelsson (Netherlands), H. G. Bock (Germany), C. Canuto (Italy), M. Griebel (Germany), C. Johnson (Sweden), G. Kobelkov (Russia), U. Langer

(Austria), P. Le Tallec (France), K. W. Morton (UK), P. Neittaanmaki (Finland), O. Pironneau (France), D. Talay (France), W. Wendland (Germany).

Local Organizing Committee: T. Karkkainen, P. Neittaanmaki, T. Rossi, P. Tarvainen, T. Tiihonen.

Aim: The ENUMATH conferences were established in 1995 in order to provide a forum for discussion on recent aspects of numerical mathematics. They seek to convene leading experts and young scientists with special emphasis on contributions from Europe. Recent results and new trends in the analysis of numerical algorithms as well as their application to challenging scientific and industrial problems will be discussed. Apart from theoretical aspects, a major part of the conference will be devoted to numerical methods for interdisciplinary applications.

Program: The program of the conference will consist of about 10 invited lectures; about 10 minisymposia on specific topics; contributed papers (oral presentation); a poster session.

Second Announcement: The second announcement and call for papers with information about invited speakers, planned minisymposia, submission of contributions, registration fee and social programme, etc. will be sent out in October 1998.

Information: Contact E. Laiho-Logren, Secretary ENUMATH 99, Department of Mathematics, Univ. of Jyvaskyla, P.O. Box 35, FIN-40351 Jyvaskyla, Finland; tel: +358-14-602732; fax: +358-14-602731/+358-14-602771; e-mail: enumath99@math.jyu.fi. Up-to-date information about the ENUMATH 99 Conference is available at: http://www.math.jyu.fi/enumath.

August 1999

*August–December **MSRI Program in Galois Groups and Fundamental Groups**, Mathematical Sciences Research Institute, Berkeley, California.

Focus: This program brings together two areas of mathematics that each concern symmetry—symmetry in algebra, in the case of Galois theory; and symmetry in geometry, in the case of fundamental groups. In each of these two situations, mathematical objects can be studied by examining the forms that their symmetries can take. This MSRI program will consider how these two situations can interact, so that algebra can be used in the service of geometry, and vice versa, in order to study problems that would otherwise be intractable.

Organizing Committee: E. Bayer, M. Fried, D. Harbater, Y. Ihara, B. H. Matzat, M. Raynaud, J. Thompson.

Information: For more details and information on how to apply, see http://www.msri.org.

*August–May 2000 **MSRI Program in Noncommutative Algebra**, Mathematical Sciences Research Institute, Berkeley, California.

Focus: A striking change in noncommutative algebra over the last decade has been the emphasis on the study of concrete examples—frequently those that have arisen in neighboring areas—rather than on the abstract theory. This has led to significant and unexpected interactions both within algebra and between algebra and other areas. The program will be based on these developments and interactions, concentrating on: noncommutative algebraic geometry, Hopf algebras, algebraic aspects of representation theory and quantum groups, Lie and Jordan algebras, combinatorial methods and computation in algebra, and classical ring theory, including finite and infinite dimensional rings and polynomial identity rings. The program will promote interactions among researchers in these overlapping areas.

Program Committee: M. Artin, S. Montgomery, C. Procesi, L. Small, T. Stafford, E. Zelmanov.

Information: For information on how to apply, see http://www.msri.org.

2–13 **IMA Summer Program: IMA Workshop on Codes, Systems and Graphical Models**, University of Minnesota, Minneapolis, Minnesota. (Jun/Jul. 1998, p. 760)

9–14 **Gyorgy Alexits Memorial Conference**, Budapest, Hungary. (Jun/Jul. 1998, p. 760)

19–21 **20th Anniversary of Boundary Elements Conference (BEM 20)**, University of Central Florida, Orlando, Florida. (Mar. 1998, p. 427)

23–27 **International Conference on Topology and its Applications**, Kanagawa University, Yokohama, Japan. (Aug. 1998, p. 899)

September 1999

*1–3 **First International Conference on the Integration of Dynamics, Monitoring and Control (DYMAC 99)**, Manchester, United Kingdom.

Topics: Integrating dynamics, condition monitoring and control for the twenty-first century. Dynamics: Linear and nonlinear dynamics; noise; vibro-acoustics; dynamic testing and identification; smart structures. Control: advanced control; model predictive control; intelligent control; active control of noise and vibration; process control; adaptive control. Condition monitoring: condition based maintenance; fault diagnosis; fault detection; risk assessment; structural health monitoring. Integration and supporting technology: smart sensors; fieldbus; metrology; advanced signal processing; neural networks; multivariate statistics; data compression and fusion; optimisation; system identification.

Call for Papers: Authors are invited to submit an abstract (400–800 words) by January 15, 1999, to: A. Starr, Conference Secretary, DYMAC'99, Manchester School of Engineering, The University of Manchester, Oxford Road, Manchester M13 9PL, UK; tel: (+44) 161-275-4302; fax: (+44) 161-275-4346; e-mail: andrew.starr@man.ac.uk; Web: http://www.eng.man.ac.uk/mech/dymac99.htm.

14–16 **ElectrIMACS—Conference on Electrical Machines, Converters and Systems**, Lisbon, Portugal. (Apr. 1998, p. 535)

October 1999

2–3 **AMS Eastern Sectional Meeting**, Providence College, Rhode Island. (Sept. 1997, p. 1031)

Information: R. Cascella, e-mail: rgc@ams.org.

8–10 **AMS Central Sectional Meeting**, University of Texas, Austin. (Sept. 1997, p. 1031)

Information: W. Drady, e-mail: wsd@ams.org.

January 2000

19–22 **Joint Mathematics Meeting**, Sheraton Washington Hotel & Omni Shoreham Hotel, Washington, District of Columbia. (Sept. 1997, p. 1031)

March 2000

*6–17 **Homogenization and Effective Media Theories**, Mathematical Sciences Research Institute, Berkeley, California.

Focus: This workshop will focus on the development of models for composite materials, and their treatment by mathematical and computational methods. Composite materials have clearly become a very central area of study in mechanics and computational mechanics, and the last 15-20 years have also seen an ever-increasing use of highly sophisticated mathematical tools.

Organizing Committee: M. Vogelius (chair), I. Babuska, B. Kohn, M. Luskin, and S. Torquato.

Information: For more information, visit http://www.msri.org.

*20–31 **Superconvergence in Finite Element Methods**, Mathematical Sciences Research Institute, Berkeley, California.

Focus: Superconvergent points are special points at which we can guarantee that the error is of higher order, r+p for some positive p (often, p=1). In principle, one could talk about superconvergence in a particular problem, but most work is aimed at broad classes of problems. Typically one looks for conditions on the finite element mesh that will, together with smoothness assumptions on the partial differential equation, guarantee the existence of superconvergent points. If one knows enough such points one may use them to construct, in a local fashion, an approximation which is better everywhere, a so called patch recovery. This better approximation may then play the role of the "exact" solution and comparing it with the original approximation then furnishes an a posteriori estimate of the error in the original approximation.

The problem of a priori identifying superconvergent points is part of the broader problem area of higher order recovery techniques (or postprocessing), and also of the area of a posteriori error estimation.

As is common in applied mathematics, the theories cover only a portion of problems and methods of use and interest. E.g., little is known about superconvergence in mixed finite element methods, and some of the general theories do not apply at the boundary of the underlying domain; this is unfortunate since, in many calculations, quantities on the boundary are of main interest.

At the workshop, there will be a mix of senior and junior researchers interested in the theoretical and practical aspects of superconvergence and related fields. It is hoped that fundamental practical and theoretical problems can be identified and stock taken of appropriate tools for attacking them.

Organizers: I. Babuska, R. Lazarov, L. Wahlbin.

Information: For more information, visit http://www.msri.org.

April 2000

*17-28 **Elastic Shells: Modeling, Anaslysis and Numerics**, Mathematical Sciences Research Institute, Berkeley, California.

Focus: Elastic shells are thin curved solid bodies which resist deformation owing to both the material of which they are composed and to their shape. They are extremely important in structural mechanics and engineering because a well-designed shell can sustain large loads with remarkably little material. For this reason, shells are a favored structural element in both natural and man-made constructions. The way a shell responds to external and internal forces and displacements is determined by a complex coupling of the mechanical properties of the material and the shell's geometry. Beginning in the late nineteenth century, and especially during the past few decades, there have been intense efforts to derive an accurate mathematical theory of shells. Such a theory is essential to the accurate prediction of shell behavior and to the design of shells optimally suited to an application.

Organizers: D. N. Arnold (Penn State), I. Babuska (Austin), F. Brezzi (Pavia), P. Ciarlet (Paris), and J. Pitkaranta (Helsinki).

Information: For more information, visit http://www.msri.org.

7-9 **AMS Central Sectional Meeting**, University of Notre Dame, Notre Dame, Indiana. (Sept. 1997, p. 1031)

Information: W. Drady, e-mail: wsd@ams.org.

June 2000

12-15 **Integral Methods in Science and Engineering (IMSE2000)**, Banff Conference Centre, Banff, Alberta, Canada. (Oct. 1997, p. 1158)

July 2000

19-26 **The Third World Congress of Nonlinear Analysts (WCNA-2000)**, Catania, Italy. (Feb. 1998, p. 296)

August 2000

*August-December **MSRI Program in Algorithmic Number Theory**, Mathematical Sciences Research Institute, Berkeley, California.

Focus: Number theory has always been intertwined with computation, and over the last 20 years the influx of new ideas, concerns, and techniques has continued unabated. Its interconnections with cryptography, arithmetic algebraic geometry and theoretical complexity, make algorithmic number theory an ideal MSRI topic at this time. Specific areas of active interest are elliptic curves, factoring, lattice basis reduction, discrete logarithms, higher genus curves, and finite fields. There are tensions here: between explicit computations and asymptotic questions of complexity; between elementary and advanced methods; between practical considerations and, in the case of cryptography, abstract notions of "security". These tensions provide a rich source of inspiration and will encourage interaction between disparate groups. These programs will be sequenced as above in overlapping segments.

Program Committee: J. Buhler, H. Lenstra.

Information: For more details, visit http://www.msri.org.

*August-May **MSRI Program in Operator Algebras**, Mathematical Sciences Research Institute, Berkeley, California.

Focus: Since the 1984-85 MSRI program in operator algebras, developments have continued at a rapid pace, and interactions with other fields such as elementary particle physics and quantum groups continue to grow.

Topics: These topics will be emphasized: noncommutative geometry; simple C^* algebras; noncommutative dynamical systems; subfactors; quantization; algebraic quantum field theory; free probability theory; operator spaces. These programs will be sequenced as above in overlapping segments.

Program Committee: A. Connes, E. G. Effros, U. Haagerup, M. A. Rieffel (co-chair), D. Voiculescu (co-chair).

Information: For more details, visit http://www.msri.org.

7-12 **Nevanlinna Colloquium**, University of Helsinki, Helsinki, Finland. (May 1998, p. 642)

January 2001

*January-May **MSRI Program in Spectral Invariants—Analytic and Geometric Aspects**, Mathematical Sciences Research Institute, Berkeley, California.

Focus: The past few decades have witnessed many new developments, centered around the study of new spectral invariants and their application to problems in conformal geometry, classification of 4-manifolds, index theory and other topics. This program will bring together people working on different aspects of the various problems in these areas, to appraise the current status of development, to encourage interactions among these different points of view, and to assess future directions.

Program Committee: S.-Y. A. Chang, R. Mazzeo.

Information: For more details, visit http://www.msri.org.

10-13 **Joint Mathematics Meeting**, New Orleans Marriott & ITT Sheraton New Orleans Hotel, New Orleans, Louisiana. (Sept. 1997, p. 1031)

March 2001

16-18 **AMS Southeastern Sectional Meeting**, University of South Carolina, Columbia, South Carolina. (Jan. 1998, p. 113)

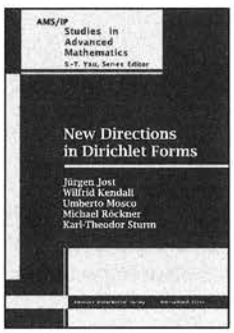
October 2001

13-14 **AMS Eastern Sectional Meeting**, Williams College, Williamstown, Massachusetts. (Sept. 1997, p. 1031)

Information: R. Cascella, e-mail: rgc@ams.org.

New Publications Offered by the AMS

Algebra and Algebraic Geometry



New Directions in Dirichlet Forms

Jürgen Jost, *Max Planck Institute for Mathematics, Leipzig, Germany*, **Wilfrid Kendall**, *University of Warwick, Coventry, England*, **Umberto Mosco**, *University of Rome "La Sapienza", Italy*, **Michael Röckner**, *University of Bielefeld, Germany*, and **Karl-Theodor Sturm**, *University of Bonn, Germany*

The theory of Dirichlet forms brings together methods and insights from the calculus of variations, stochastic analysis, partial differential and difference equations, potential theory, Riemannian geometry and more. This book features contributions by leading experts and provides up-to-date, authoritative accounts on exciting developments in the field and on new research perspectives. Topics covered include the following: stochastic analysis on configuration spaces, specifically a mathematically rigorous approach to the stochastic dynamics of Gibbs measures and infinite interacting particle systems; subelliptic PDE, homogenization, and fractals; geometric aspects of Dirichlet forms on metric spaces and function theory on such spaces; generalized harmonic maps as nonlinear analogues of Dirichlet forms, with an emphasis on non-locally compact situations; and a stochastic approach based on Brownian motion to harmonic maps and their regularity.

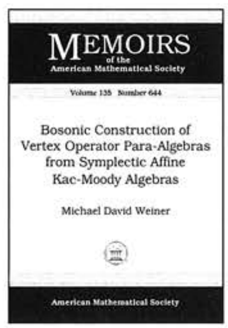
Various new connections between the topics are featured, and it is demonstrated that the theory of Dirichlet forms provides the proper framework for exploring these connections.

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

Contents: **J. Jost**, Nonlinear Dirichlet forms; **W. S. Kendall**, From stochastic parallel transport to harmonic maps; **U. Mosco**, Dirichlet forms and self-similarity; **M. Röckner**, Stochastic analysis on configuration spaces: Basic ideas and recent results; **K.-T. Sturm**, The geometric aspect of Dirichlet forms.

AMS/IP Studies in Advanced Mathematics, Volume 8

September 1998, 277 pages, Hardcover, ISBN 0-8218-1061-8, LC 98-25202, 1991 *Mathematics Subject Classification*: 31C25; 35J20, 58E20, 47H20, 60J35, **All AMS members $39**, List $49, Order code AMSIP/8N



Bosonic Construction of Vertex Operator Para-Algebras from Symplectic Affine Kac-Moody Algebras

Michael David Weiner, *Pennsylvania State University, Altoona*

Inspired by mathematical structures found by theoretical physicists and by the desire to understand the "monstrous moonshine" of the monster group, Borcherds, Frenkel, Lepowsky, and Meurman introduced the definition of vertex operator algebra (VOA). An important part of the theory of VOAs concerns their modules and intertwining operators between modules. Feingold, Frenkel, and Ries defined a structure, called a vertex operator para-algebra (VOPA), where a VOA, its modules and their intertwining operators are unified.

In this work, for each $n \geq 1$, the author uses the bosonic construction (from a Weyl algebra) of four level $-1/2$ irreducible representations of the symplectic affine Kac-Moody Lie algebra $C_n^{(1)}$. They define intertwining operators so that the direct sum of the four modules forms a VOPA. This work includes the bosonic analog of the fermionic construction of a vertex operator superalgebra from the four level 1 irreducible modules of type $D_n^{(1)}$ given by Feingold, Frenkel, and Ries. While they get only a VOPA when $n = 4$ using classical triality, the techniques in this work apply to any $n \geq 1$.

Contents: Introduction; Bosonic construction of symplectic affine Kac-Moody algebras; Bosonic construction of symplectic vertex operator algebras and modules; Bosonic construction of vertex operator para-algebras; Appendix; Bibliography.

Memoirs of the American Mathematical Society, Volume 135, Number 644

Continued

September 1998, 106 pages, Softcover, ISBN 0-8218-0866-4, LC 98-26523, 1991 *Mathematics Subject Classification*: 17B69; 81R10, 81T40, **Individual member $24**, List $40, Institutional member $32, Order code MEMO/135/644N

Basic Almost-Poised Hypergeometric Series

Chu Wenchang, *Dalian University of Technology, People's Republic of China*

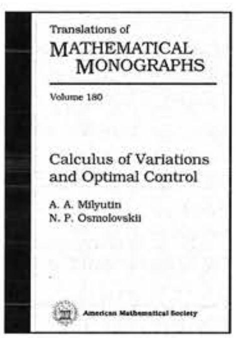
This work is dedicated to extensive research on basic almost-poised hypergeometric series. Approximately 200 formulas are established. Their applications to bilateral series, q-Clausen formulae, and Rogers-Ramanujan identities are provided.

Contents: Introduction; Basic almost poised series; The q-Whipple transformations; Bilateral almost-poised evaluations; The Rogers-Ramanujan identities; The q-Clausen-Orr-formulae; Appendix: Mathematica program.

Memoirs of the American Mathematical Society, Volume 135, Number 642

September 1998, 99 pages, Softcover, ISBN 0-8218-0811-7, LC 98-25203, 1991 *Mathematics Subject Classification*: 33C20, 33D20; 05A19, 05A30, **Individual member $23**, List $39, Institutional member $31, Order code MEMO/135/642N

Analysis



Calculus of Variations and Optimal Control

A. A. Milyutin, *Russian Academy of Sciences, Moscow*, and **N. P. Osmolovskii**, *Moscow State Civil Engineeering University, Russia*

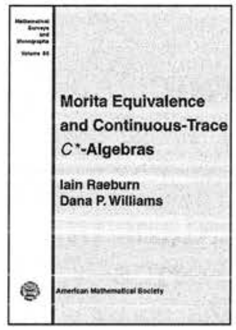
The theory of a Pontryagin minimum is developed for problems in the calculus of variations. The application of the notion of a Pontryagin minimum to the calculus of variations is a distinctive feature of this book. A new theory of quadratic conditions for a Pontryagin minimum, which covers broken extremals, is developed, and corresponding sufficient conditions for a strong minimum are obtained. Some classical theorems of the calculus of variations are generalized.

This text will also be of interest to those working in applications.

Contents: *First order conditions:* First order conditions; Theory of a weak minimum for the problem on a fixed time interval; Theory of the maximum principle; Extremals and the Hamiltonian of a control system; Hamilton-Jacobi equation and field theory; Transformations of problems and invariance of extremals; *Quadratic conditions:* Quadratic conditions and conjugate points for broken extremals; Quadratic conditions for a Pontryagin minimum and sufficient conditions for a strong minimum: Proofs; Quadratic conditions in the general problem of the calculus of variations and related optimal control problems; Investigation of extremals by quadratic conditions: Examples; Bibliography.

Translations of Mathematical Monographs, Volume 180

October 1998, 372 pages, Hardcover, ISBN 0-8218-0753-6, LC 98-29674, 1991 *Mathematics Subject Classification*: 49-02, 49K15, **Individual member $77**, List $129, Institutional member $103, Order code MMONO/180N



Morita Equivalence and Continuous-Trace C^*-Algebras

Iain Raeburn, *University of Newcastle, NSW, Australia*, and **Dana P. Williams**, *Dartmouth College, Hanover, NH*

In this text, the authors give a modern treatment of the classification of continuous-trace C^*-algebras up to Morita equivalence. This includes a detailed discussion of Morita equivalence of C^*-algebras, a review of the necessary sheaf cohomology, and an introduction to recent developments in the area.

The book is accessible to students who are beginning research in operator algebras after a standard one-term course in C^*-algebras. The authors have included introductions to necessary but nonstandard background. Thus they have developed the general theory of Morita equivalence from the Hilbert module, discussed the spectrum and primitive ideal space of a C^*-algebra including many examples, and presented the necessary facts on tensor products of C^*-algebras starting from scratch. Motivational material and comments designed to place the theory in a more general context are included.

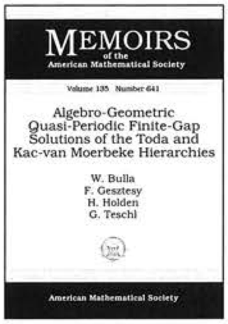
The text is self-contained and would be suitable for an advanced graduate or an independent study course.

Contents: The algebra of compact operators; Hilbert C^*-modules; Morita equivalence; Sheaves, cohomology, and bundles; Continuous-trace C^*-algebras; Applications; Epilogue: The Brauer group and group actions; The spectrum; Tensor products of C^*-algebras; The imprimitivity theorem; Miscellany; Index; Bibliography.

Mathematical Surveys and Monographs, Volume 60

September 1998, 327 pages, Hardcover, ISBN 0-8218-0860-5, LC 98-25838, 1991 *Mathematics Subject Classification*: 46L05; 46L35, 46L40, 43A65, **Individual member $39**, List $65, Institutional member $52, Order code SURV/60N

Differential Equations



Algebro-Geometric Quasi-Periodic Finite-Gap Solutions of the Toda and Kac-van Moerbeke Hierarchies

W. Bulla, *Graz Technical University, Austria*, **F. Gesztesy**, *University of Missouri, Columbia*, **H. Holden**, *Norwegian University of Science and Technology, Trondheim*, and **G. Teschl**, *Institut für Reine und Angewandte Mathematik, Aachen, Germany*

In this work, the authors provide a self-contained discussion of all real-valued quasi-periodic finite-gap solutions of the Toda and Kac-van Moerbeke hierarchies of completely integrable evolution equations. The approach utilizes algebro-geometric methods, factorization techniques for finite difference expressions, as well as Miura-type transformations. Detailed spectral theoretic properties of Lax pairs and theta function representations of the solutions are derived.

Features:

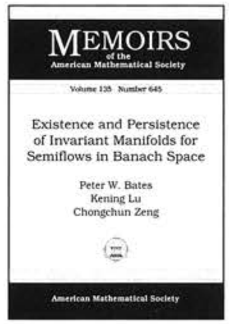
- Simple and unified treatment of the topic.
- Self-contained development.
- Novel results for the Kac-van Moerbeke hierarchy and its algebro-geometric solutions.

Contents: Introduction; The Toda hierarchy, recursion relations, and hyperelliptic curves; The stationary Baker-Akhiezer function; Spectral theory for finite-gap Jacobi operators; Quasi-periodic finite-gap solutions of the stationary Toda hierarchy; Quasi-periodic finite-gap solutions of the Toda hierarchy and the time-dependent Baker-Akhiezer function; The Kac-van Moerbeke hierarchy and its relation to the Toda hierarchy; Spectral theory for finite-gap Dirac-type difference operators; Quasi-periodic finite-gap solutions of the Kac-van Moerbeke hierarchy; Hyperelliptic curves of the Toda-type and theta functions; Periodic Jacobi operators; Examples, $g - 0, 1$; Acknowledgments; Bibliography.

Memoirs of the American Mathematical Society, Volume 135, Number 641

September 1998, 79 pages, Softcover, ISBN 0-8218-0808-7, LC 98-25199, 1991 *Mathematics Subject Classification*: 39A70, 35Q58; 39A12, 35Q51, **Individual member $23**, List $38, Institutional member $30, Order code MEMO/135/641N

Geometry and Topology



Existence and Persistence of Invariant Manifolds for Semiflows in Banach Space

Peter W. Bates and **Kening Lu**, *Brigham Young University, Provo, UT*, and **Chongchun Zeng**, *New York University, Courant Institute, NY*

Since the early 1970s, mathematicians have tried to extend the work of N. Fenichel and of M. Hirsch, C. Pugh and M. Shub to give conditions under which invariant manifolds for semiflows persist under perturbation of the semiflow. This work provides natural conditions and establishes the desired theorem. The technique is geometric in nature, and in addition to rigorous proofs, an informal outline of the approach is given with useful illustrations.

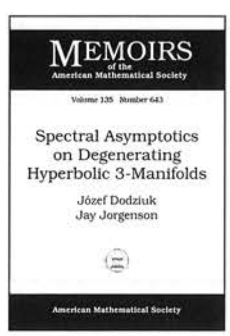
Features:

- Important theoretical tools for working with infinite-dimensional dynamical systems, such as PDEs.
- Previously unpublished results.
- New ideas regarding invariant manifolds.

Contents: Introduction; Notation and preliminaries; Statements of theorems; Local coordinate systems; Cone lemmas; Center-unstable manifold; Center-stable manifold; Smoothness of center-stable manifold; Smoothness of center-unstable manifold; Persistence of invariant manifold; Persistence of normal hyperbolicity; Invariant manifolds for perturbed semiflow; References.

Memoirs of the American Mathematical Society, Volume 135, Number 645

September 1998, 129 pages, Softcover, ISBN 0-8218-0868-0, LC 98-25200, 1991 *Mathematics Subject Classification*: 58F15; 58F35, 58G30, 58G35, 34C35, 58F30, **Individual member $25**, List $41, Institutional member $33, Order code MEMO/135/645N



Spectral Asymptotics on Degenerating Hyperbolic 3-Manifolds

Józef Dodziuk, *City University of New York*, and **Jay Jorgenson**, *Oklahoma State University, Stillwater*

In this volume, the authors study asymptotics of the geometry and spectral theory of degenerating sequences of finite volume hyperbolic manifolds of three dimensions. Thurston's hyperbolic surgery theorem asserts the existence of non-trivial sequences of finite volume hyperbolic three manifolds which converge to a three manifold with additional cusps. In the geometric aspect of their study, the authors use the convergence of hyperbolic metrics on the thick parts of the manifolds under consideration to investigate convergence of tubes in the manifolds of the sequence to cusps of the limiting manifold.

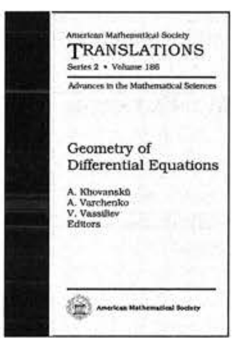
In the spectral theory aspect of the work, they prove convergence of heat kernels. They then define a regularized heat trace associated to *any* finite volume, complete, hyperbolic three manifold, and study its asymptotic behavior through degeneration. As an application of the analysis of the regularized heat trace, they study asymptotic behavior of the spectral zeta function, determinant of the Laplacian, Selberg zeta function, and spectral counting functions through degeneration.

The authors' methods are an adaptation to three dimensions of the earlier work of Jorgenson and Lundelius who investigated the asymptotic behavior of spectral functions on degenerating families of finite area hyperbolic Riemann surfaces.

Contents: Introduction; Review of hyperbolic geometry; Convergence of heat kernels; Infinite cylinder estimates; Heat kernels and regularized heat traces; Degenerating heat traces; Poisson kernel estimates; Analysis of trace integrals; Convergence of regularized heat traces; Long time asymptotics; Spectral zeta functions; Selberg zeta functions; Hurwitz-type zeta functions; Asymptotics of spectral measures; Eigenvalue counting problems; Convergence of spectral projections; Bibliography.

Memoirs of the American Mathematical Society, Volume 135, Number 643

September 1998, 75 pages, Softcover, ISBN 0-8218-0837-0, LC 98-26524, 1991 *Mathematics Subject Classification*: 58G11, 58G25, 11F72, 57N10; 57M50, 35K05, 58G26, **Individual member $23**, List $39, Institutional member $31, Order code MEMO/135/643N



Geometry of Differential Equations

A. Khovanskiĭ, *Russian Academy of Sciences, Moscow*, **A. Varchenko**, *University of North Carolina, Chapel Hill*, and **V. Vassiliev**, *Moscow, Russia*, Editors

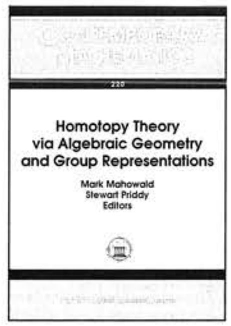
This volume contains articles written by V. I. Arnold's colleagues on the occasion of his 60th birthday. The articles are mostly devoted to various aspects of geometry of differential equations and relations to global analysis and Hamiltonian mechanics.

This text will also be of interest to those working in algebra and algebraic geometry.

Contents: **H. Cendra**, **D. D. Holm**, **J. E. Marsden**, and **T. S. Ratiu**, Lagrangian reduction, the Euler-Poincaré equations, and semidirect products; **Y. Eliashberg** and **M. Gromov**, Lagrangian intersection theory: Finite-dimensional approach; **A. Gabrielov** and **A. Khovanskii**, Multiplicity of a Noetherian intersection; **Yu. I. Manin**, Sixth Painlevé equation, universal elliptic curve, and mirror of $\mathbf{P}^2$; **Ya. G. Sinai**, Convex hulls of random processes; **O. Viro**, Mutual position of hypersurfaces in projective space; **A. Weinstein** and **P. Xu**, Hochschild cohomology and characteristic classes for star-products.

American Mathematical Society Translations—Series 2 (*Advances in the Mathematical Sciences*), Volume 186

August 1998, 194 pages, Hardcover, ISBN 0-8218-1094-4, LC 91-640741, 1991 *Mathematics Subject Classification*: 58Fxx; 14-XX, 32-XX, 70-XX, **Individual member $53**, List $89, Institutional member $71, Order code TRANS2/186N



Homotopy Theory via Algebraic Geometry and Group Representations

Mark Mahowald and **Stewart Priddy**, *Northwestern University, Evanston, IL*, Editors

The academic year 1996–97 was designated as a special year in Algebraic Topology at Northwestern University (Evanston, IL). In addition to guest lecturers and special courses, an international conference was held entitled "Current trends in algebraic topology with applications to algebraic geometry and physics". The series of plenary lectures included in this volume indicate the great breadth of the conference and the lively interaction that took place among various areas of mathematics. Original research papers were submitted, and all submissions were refereed to the usual journal standards.

Features:

- A paper prepared by C. Rezk on the Hopkins-Miller theorem.
- A set of problems presented at a special problem session held at the conference.

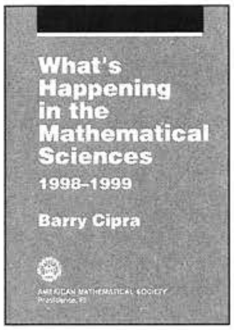
This text will also be of interest to those working in algebra and algebraic geometry.

Contents: **A. Adem**, Buildings, group extensions and the cohomology of congruence subgroups; **A. Baker**, Hecke algebras acting on elliptic cohomology; **R. R. Bruner**, Some root invariants and Steenrod operations in $\mathrm{Ext}_A(F_2, F_2)$; **F. R. Cohen** and **U. Tillmann**, Toward homology operations for mapping class groups; **O. Cornea**, Spanier-Whitehead duality and critical points; **P. Goerss**, Comparing completions of a space at a prime; **V. Gorbounov** and **P. Symonds**, Toward the homotopy groups of the higher real K-theory EO_2; **D. H. Gottlieb**, Skew symmetric bundle maps; **W.-H. Lin** and **M. Mahowald**, The Adams spectral sequence for Minami's theorem; **J. Martino** and **S. Priddy**, Applications of the Minami-Webb formula to splitting classifying spaces; **J. P. May**, Brave new worlds in stable homotopy theory; **R. J. Milgram** and **C. Overton**, The stable splitting of $B_{M_{12}}$ and related groups; **N. Minami**, On the Kervaire invariant problem; **J. Morava**, Schur Q-functions and a Kontsevich-Witten genus; **D. Juan-Pineda**, Stable splittings of classifying spaces of amalgams of finite groups; **D. C. Ravenel**, What we still don't know about loop spaces of spheres; **N. Ray**, A topological calculus for formal power series; **C. Rezk**, Notes on the Hopkins-Miller theorem; **H. Sadofsky** and **W. S. Wilson**, Commutative Morava homology Hopf algebras; Northwestern 1997 algebraic topology conference–Problems.

Contemporary Mathematics, Volume 220

September 1998, 379 pages, Softcover, ISBN 0-8218-0805-2, LC 98-27238, 1991 *Mathematics Subject Classification*: 55Pxx, 55Nxx, 55Qxx, 20Cxx; 55S10, 20J06, **Individual member $44**, List $74, Institutional member $59,Order code CONM/220N

General and Interdisciplinary



What's Happening in the Mathematical Sciences, 1998–1999

Barry Cipra

Praise for volumes 1, 2 and 3 of *What's Happening*

Stylish format ... largely accessible to laymen ... This publication is one of the snappier examples of a growing genre from scientific societies seeking to increase public understanding of their work and its societal value.

—Science & Government Report

Another choice of new exciting developments in mathematics. These volumes really deserve a large audience, students as well as researchers will be fascinated by the insights and overviews presented.

—Zentralblatt für Mathematik

The topics chosen and the lively writing fill a notorious gap—to make the ideas, concepts and beauty of mathematics more visible for the general public ... well-illustrated ... Congratulations to Barry Cipra.

—Zentralblatt für Mathematik

This volume is fourth in the much-acclaimed AMS series *What's Happening in the Mathematical Sciences*. The lively style and in-depth coverage of some of the most important "happenings" in mathematics today make this publication a delightful and intriguing read accessible to a wide audience. High school students, professors, researchers, engineers, statisticians, computer scientists—anyone with an interest in mathematics—will find captivating material in this book. As the 20th century draws to a close, *What's Happening* presents the state of modern mathematics and its worldwide significance in a timely and enduring fashion.

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October 1998, approximately 120 pages, Softcover, ISBN 0-8218-0766-8, 1991 *Mathematics Subject Classification*: 00A06, List $14, Order code HAPPENING/4N

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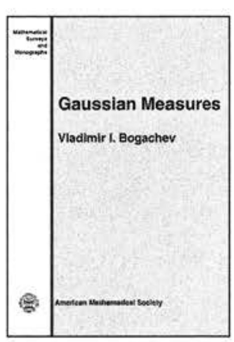

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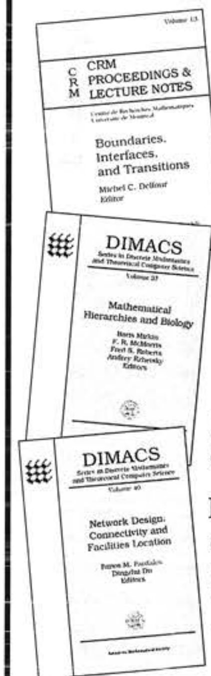

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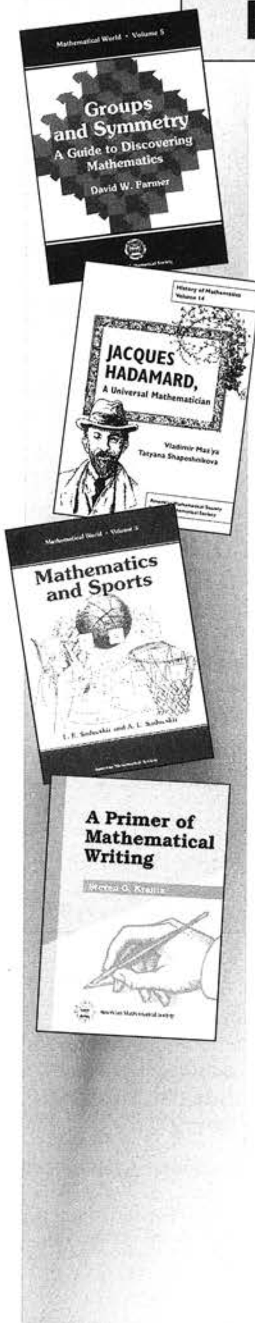

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Positions available, items for sale, services available, and more

CALIFORNIA

UNIVERSITY OF CALIFORNIA, DAVIS
Regular Faculty Positions in Mathematics

The UC Davis Department of Mathematics invites applications for four positions at either the assistant (tenure-track) or associate professor (tenured) level in the following areas: (1) analysis/partial differential equations, (2) geometry/topology, and (3) applied mathematics, effective July 1, 1999.

Appointments will be made commensurate with qualifications. Minimum qualifications 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 service. Candidates for the associate professor position must have demonstrated outstanding attainment in research and teaching.

The application deadline is October 15, 1998, or until positions are filled. To initiate the application process, request an application package by sending an e-mail message to `forms@math.ucdavis.edu` or by writing to:

Chair of Search Committee
Department of Mathematics
University of California
Davis, California 95616-8633

The University of California, Davis, is an Affirmative Action/Equal Opportunity Employer with a strong institutional commitment to the achievement of diversity among its faculty and staff.

For more information regarding the position or institution: `http://math.ucdavis.edu`.

ILLINOIS

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
Department of Mathematics
Postdoctoral Positions
J. L. Doob Research Assistant Professor

The Department of Mathematics of the University of Illinois at Urbana-Champaign is soliciting applications for postdoctoral positions. Two appointments will be made starting August 21, 1999; 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 $40,000 per year.

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 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 December 1, 1998. 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.

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
Department of Mathematics
Tenured Position

Applications are invited for one or more full-time tenured faculty positions to commence August 21, 1999. Those faculty will be expected to pursue an outstanding research program and teach graduate students as well as undergraduate students. The department will consider applicants in all fields of mathematics, but we intend to show preference in applied mathematics, partial differential equations and global analysis, number theory, algebraic geometry, combinatorics, computational mathematics, and probability theory. Salary and teaching load are competitive.

Applicants are expected to have a Ph.D. and a documented record of leadership in

---

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 1998 rate is $100 per inch or fraction thereof on a single column (one-inch minimum), calculated from top of headline. Any fractional text of 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.

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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: October issue–July 21, 1998; November issue–August 20, 1998; December issue–September 18, 1998; January issue–October 26, 1998; February issue–November 12, 1998; March issue–December 21, 1998.

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 `classads@ams.org`. AMS location for express delivery packages is 201 Charles Street, Providence, Rhode Island 02904. Advertisers will be billed upon publication.

research as well as of excellence in teaching. They should send a curriculum vitae, a list of publications, a few selected reprints or preprints, and the names and addresses of three references to the address below. The department will solicit letters for the finalists for the tenured positions.

Philippe Tondeur, Chair
Department of Mathematics
University of Illinois
at Urbana-Champaign
1409 West Green Street
Urbana IL 61801
tel. (217) 333-3352
e-mail: `tenure@math.uiuc.edu`

We anticipate an ongoing search, but will begin considering applications and conducting interviews on October 5, 1998. 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.

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, 1999, at the tenure-track (assistant professor) level. Those faculty will be expected to pursue a vigorous research program and 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, partial differential equations and global analysis, number theory, algebraic geometry, combinatorics, computational mathematics, and probability 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.

Philippe Tondeur, Chair
Department of Mathematics
University of Illinois
at Urbana-Champaign
1409 West Green Street
Urbana, IL 61801
tel. (217) 333-3352
e-mail: `search@math.uiuc.edu`

For fullest consideration, all materials, including letters of reference, should be received by December 1, 1998; 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
Faculty Position in Actuarial Science

Applications are invited for a full-time faculty position in actuarial science to commence August 21, 1999 or 2000, rank depending on qualifications. The person selected will be expected to teach graduate and advanced undergraduate students and to pursue professional activity through research and professional committee work. He or she should also have the potential to assume direction of the Actuarial Program after several years. This involves increased responsibilities in advising and placing students, maintaining relations with our alumni and with insurance companies and consulting firms, and raising funds to enhance the operation of the program. Salary and teaching load are competitive.

Applicants for a tenured position are expected to be Fellows of either the Society of Actuaries or the Casualty Actuarial Society, with a documented record of leadership in the actuarial field. A Ph.D. is desirable. Applications for a tenure-track position should be associates of one of the professional societies, should have completed the Ph.D. (or equivalent) by the time the appointment begins, and should present evidence of excellence in teaching. Preference will be given to candidates with outstanding credentials in actuarial science from academia or business and a strong commitment to teaching.

All applicants should send a letter of application with a curriculum vitae and publication list, plus the names and addresses of three references to:

Philippe Tondeur, Chair
Department of Mathematics
University of Illinois
at Urbana-Champaign
1409 West Green Street
Urbana, IL 61801
tel. (217) 333-3352
e-mail: `search@math.uiuc.edu`

All applications received by December 1, 1998, will receive full consideration. We will review later applications until the search is closed. Applications from women and minority candidates are especially encouraged. The University of Illinois is an Affirmative Action/Equal Opportunity Employer.

ILLINOIS WESLEYAN UNIVERSITY

The Department of Mathematics and Computer Science at Illinois Wesleyan University invites applications for a full-time, tenure-track position in computer science to begin August 1999. Candidates must have a Ph.D. in computer science or a closely related field. The position is open to all areas of specialization in CS; however, preference may be given to those who could teach courses in network theory and design, software engineering, simulation, or theory of computation in addition to the core CS curriculum.

Illinois Wesleyan is a highly selective undergraduate liberal arts university of 1,900 students located in Bloomington, Illinois, a community of about 100,000. The Department of Mathematics and Computer Science is located in the new Center for Natural Science Learning and Research. This $25 million facility is equipped with over ninety Sun SPARC stations for student and faculty use. For additional information on the computer science curriculum and facilities see `http://www.iwu.edu/~cs/`.

Send a letter of application and résumé, and have three letters of reference sent under separate cover, to: Dr. Melvyn Jeter, Chair, Department of Mathematics and Computer Science, Illinois Wesleyan University, P.O. Box 2900, Bloomington, IL 61702-2900.

IWU is an Equal Opportunity Employer. Applications will be reviewed beginning November 2, 1998. Preference may be given to those completed by this date. Acceptance and review of applications will continue until the position is filled. Interviews for this position may be held at the Joint AMS-MAA Mathematics Meetings in San Antonio, Texas (January 1999).

ILLINOIS WESLEYAN UNIVERSITY

The Department of Mathematics and Computer Science at Illinois Wesleyan University invites applications for a full-time, tenure-track position jointly in both mathematics and computer science to begin August 1999. Candidates must have a Ph.D. in computer science or mathematics and possess considerable expertise in both areas. The position is open to all areas of specialization in mathematics and CS.

Illinois Wesleyan is a highly selective undergraduate liberal arts university of 1,900 students located in Bloomington, Illinois, a community of about 100,000. The Department of Mathematics and Computer Science is located in the new Center for Natural Science Learning and Research. This $25 million facility is equipped with over ninety Sun SPARC stations for student and faculty use. For additional information on the computer science curriculum and facilities see `http://www.iwu.edu/~cs/`. Send letter of application, AMS cover sheet, and résumé, and three letters of reference under separate cover, to: Dr. Melvyn Jeter, Chair, Department of Mathematics and Computer Science, Illinois Wesleyan University, P.O. Box 2900, Bloomington, IL 61702-2900.

Illinois Wesleyan University is an Equal Opportunity Employer. Applications will be reviewed beginning January 31, 1999. Preference may be given to those completed by this date. Preliminary interviews for this position will be held at the Joint Mathematics Meetings in San Antonio, Texas (January 1999). Review of applications will continue until the position is filled.

MARYLAND

UNIVERSITY OF MARYLAND AT 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 applicants whose primary interest is in one of the following categories: (1) algebra, number theory, and algebraic geometry; (2) applied and computational harmonic analysis; (3) probability and statistics, with an emphasis on applications, including applications to financial mathematics.

Candidates at all levels will be considered. Priority will be given to applications received by November 1, 1998. Appointments will commence in fall 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 three letters of recommendation to:

The Hiring Committee
Department of Mathematics
University of Maryland
College Park, Maryland 20742

MICHIGAN

Actuarial Assistant

Job requires M.S. in Actuarial Sciences and 3 months experience as an actuarial assistant. Duties: assisting with establishing reserves on a quarterly basis; preparation of reports by summarizing data to meet financial regulations; and preparation of reports for internal operations. 40 hrs/wk.; $39,500/yr.; 8 a.m. to 4:30 p.m.; qualified applicants should send résumés to: 7310 Woodward Ave., 4th floor, Detroit, MI 48202. Ref. No. 39097. Employer paid ad. AA/EOE.

NEVADA

THE UNIVERSITY OF NEVADA, RENO

Applications are invited for two tenure-track assistant professorships beginning fall 1999. Position 1: Differential Geometry. Position 2: Statistics. Minimum qualifications: Ph.D. in a mathematical science, evidence of strong potential for significant research, and documented excellence in teaching. Academic-year salary dependent on experience and qualifications. For detailed position announcements and information about our department, including research interests of the faculty, see `http://www.unr.edu/math/`. Send curriculum vitae and at least three letters of recommendation to: Search Committee (specify either Geometry or Statistics), Department of Mathematics/084, University of Nevada, Reno, NV 89557. (At least one reference letter must address teaching experience.) Please include the Academic Employment in Mathematics Application Cover Sheet. Review of applications will begin on December 1, 1998. To receive full consideration, applications must be completed by then. AA/EEO

NEW YORK

UNIVERSITY AT BUFFALO STATE UNIVERSITY OF NEW YORK

The Department of Mathematics anticipates the appointment of a tenure-track assistant professor beginning September 1, 1999. The salary will be competitive. We seek applicants in applied mathematics who have excellent research accomplishments/potential and a strong commitment to teaching.

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 at Buffalo, SUNY
Diefendorf Hall, Rm. 106
3435 Main Street, Bldg. 20
Buffalo, New York 14214-3093

No electronic applications will be accepted.

The deadline for applications is **November 1, 1998.** 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, color, handicap, national origin, race, religion, sex, marital, or veteran status.

OKLAHOMA

SAXON PUBLISHERS, INC.
Secondary Mathematics Assistant Editor

One-year assignment (with possible opportunity of renewal in one-year increments). Saxon Publishers, Inc., a K-12 textbook publisher, is seeking an assistant secondary math editor to assist senior editor in revising 2nd-year algebra text. Candidate must be willing to relocate and work on site. Qualifications: Excellent writing and editing skills, solid mathematics background as evidenced by graduate studies and advanced degree. Preferred: Familiarity with the Saxon pedagogy, classroom experience with secondary students teaching high school-level math, editing experience in the publishing industry. Salary commensurate with experience. Please send résumé and salary requirements to Human Resources, Saxon Publishers, Inc., 1320 W. Lindsey, Norman, OK 73069.

RHODE ISLAND

BROWN UNIVERSITY

One professorship at the associate professor level with tenure, to begin July 1, 1999. Preference to be given to applicants with research interests consonant with those of the present members of the department. We are especially looking for candidates in the general area of analysis, but exceptional candidates in all fields will be seriously considered. Candidates should have a distinguished research record and a strong commitment to undergraduate and graduate teaching. Qualified individuals are invited to send a vita and at least five letters of recommendation to Senior Search Committee, Department of Mathematics, Box 1917, Brown University, Providence, Rhode Island 02912. Applications must be received by November 9, 1998, in order to receive consideration. E-mail inquiries can be addressed to `srsearch@math.brown.edu`. Brown University is an Equal Opportunity/Affirmative Action Employer and encourages applications from women and minorities.

WISCONSIN

UNIVERSITY OF WISCONSIN - MADISON

The Department of Mathematics invites applications for one or more positions to begin August 23, 1999, at either the assistant professor (tenure-track) or associate professor (tenured) level. Applications are invited in all areas of mathematics. Among the department's priorities are partial differential equations, and real and harmonic analysis. Candidates should exhibit evidence of outstanding research potential, normally including significant contributions beyond the doctoral dissertation. A strong commitment to excellence in instruction is also expected. Additional departmental information is available on our WWW site, `http://www.math.wisc.edu/`.

Applicants should send a completed AMS Standard Cover Sheet, a curriculum vitae that includes a publication list, and brief descriptions of research and teaching to:

Hiring Committee
Dept. of Mathematics, Van Vleck Hall
University of Wisconsin-Madison
480 Lincoln Drive
Madison, WI 53706-1388

Applicants should also arrange to have sent to the above address three or four letters of recommendation, at least one of which addresses the applicant's teaching experiences and capabilities. Completed applications received by November 15, 1998, will be assured full consideration. Additional letters will be solicited by the department for candidates who are finalists for a tenured position.

The University of Wisconsin is an Affirmative Action/Equal Opportunity Employer and encourages applications from women and minorities. Unless confidentiality is requested in writing, information regarding the applicants must be released upon request. Finalists cannot be guaranteed confidentiality.

UNITED KINGDOM

ALL SOULS COLLEGE, OXFORD
Senior Research Fellowships

All Souls College intends to elect two Senior Research Fellows with effect from 1 October 1999 (or an agreed later date). One Fellowship will be in law, and one in mathematics or the theoretical life sciences (both subjects broadly conceived). The Fellowships are open to women and men.

The College regards a Senior Research Fellowship as being of comparable academic standing to an Oxford University professorship, and applicants are expected to have a correspondingly distinguished record of achievement in research.

Senior Research Fellowships are normally held until retirement age (subject to renewal by the College every seven years and the requirements of the Education Reform Act, 1988).

Further particulars, including details of emoluments and terms of appointment, application forms, and copies of a memorandum for referees may be obtained from the Warden's Secretary, All Souls College, Oxford OX1 4AL. Applications, on the application form, should reach the warden no later than Friday, 18 September 1998 (the envelope containing the application to be marked "Senior Research Fellowship"). Applicants are asked to ensure that references from not more than three referees also reach the warden by Friday, 18 September 1998.

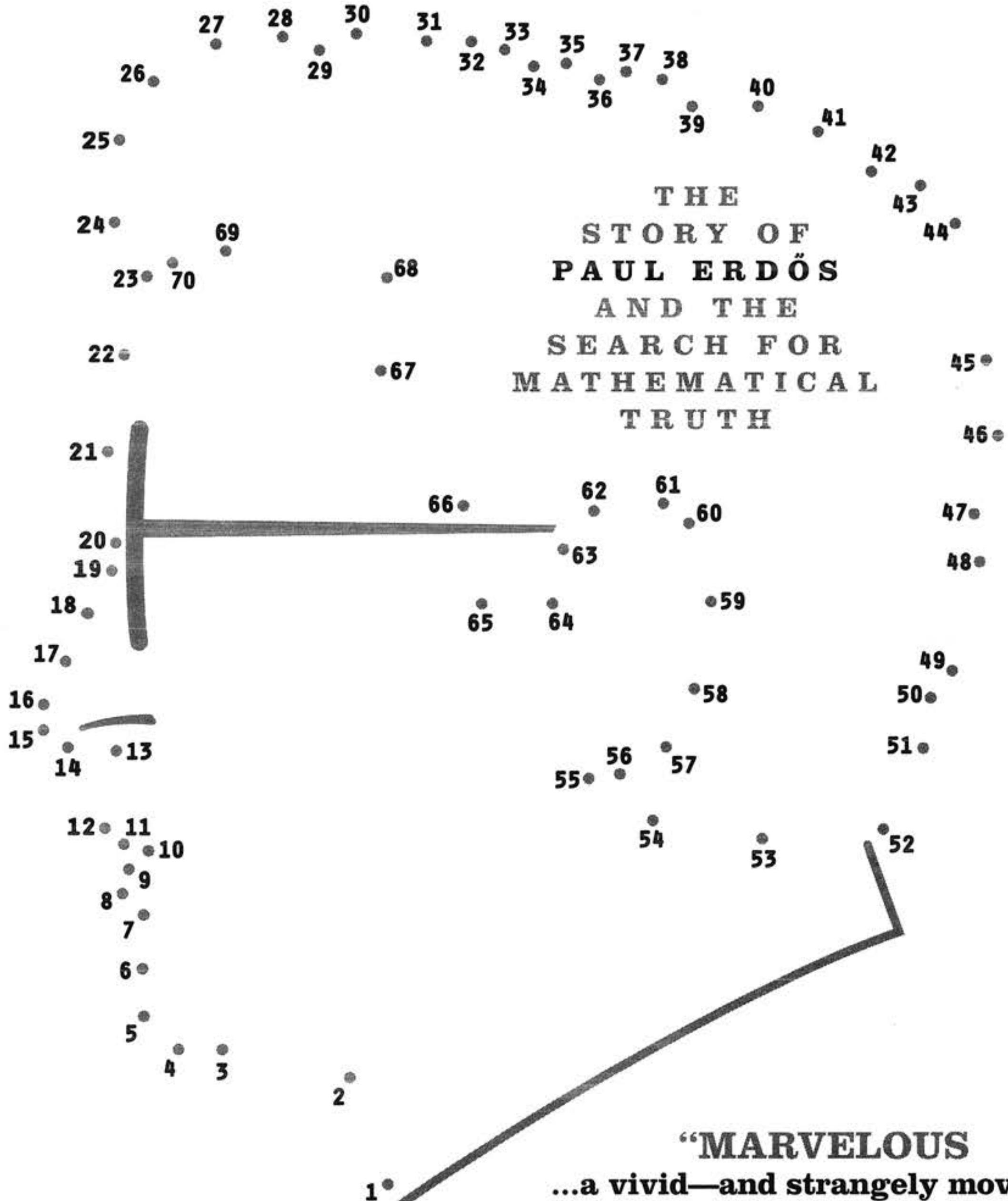
PUBLICATIONS WANTED

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`.

A FASCINATING BIOGRAPHY OF THE MOST BRILLIANT —AND ECCENTRIC—MATHEMATICIAN OF OUR TIME

The Man Who Loved Only Numbers



THE STORY OF **PAUL ERDŐS** AND THE SEARCH FOR MATHEMATICAL TRUTH

"MARVELOUS
...a vivid—and strangely moving—portrait of this singular creature, one that brings out not only Erdös' genius and his oddness, but his warmth and sense of fun, the joyfulness of his strange life."—OLIVER SACKS

Written by
Paul Hoffman,
Publisher of Encyclopedia Britannica

AT BOOKSTORES NOW FROM
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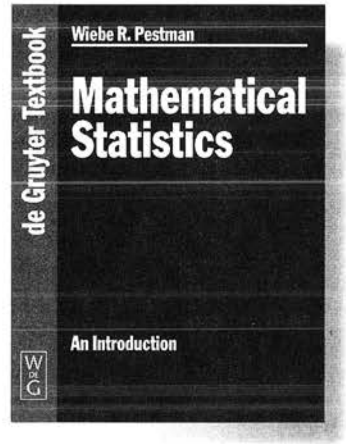
de Gruyter Textbook

Wiebe R. Pestman

Mathematical Statistics
An Introduction

1998. xi + 545 pages
Hardcover $79.95 3-11-015357-2. Paper $39.95 3-11-015356-4



This book provides a first introduction to mathematical statistics. The text originated from a series of lectures given at the University of Nijmegen (Holland) and is intended for students who already have some basic mathematical background.

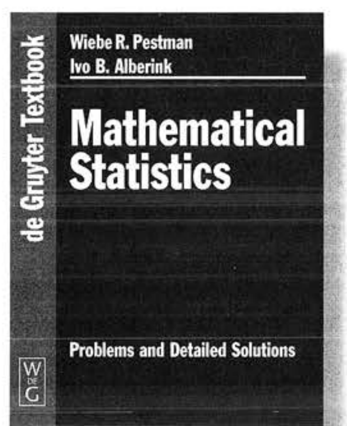
The text covers compulsory fundamental topics like estimation theory, sufficiency, hypothesis testing, analysis of variance, and non-parametric methods. There are also introductory sections about the Kolmogorov-Smirnov test, von Mises differentiation, influence functions, robustness, metrics on sets of distribution functions, smoothing techniques, bootstrap methods, and density estimation. The final chapter of the book contains a first course in vectorial statistics and multiple regression analysis.

As a rule, theorems are proved in a mathematically rigorous way. Many examples and exercises are included. There is a companion volume, in which completely worked through solutions to all exercises can be found. Both books are very suitable for self instruction.

Wiebe R. Pestman and Ivo B. Alberink

Mathematical Statistics
Problems and Detailed Solutions

1998. ix + 325 pages
Hardcover $79.95 3-11-015359-9. Paper $39.95 3-11-015358-0



This book contains some 325 problems in mathematical statistics, varying in difficulty, together with their solutions. The book is primarily intended as a solutions manual to the textbook **Mathematical Statistics – An Introduction**, which also includes the problems.

As a set, the two books are very suitable for self instruction. The solutions manual is nevertheless as self-contained as is reasonably possible. For example, in the beginning of every chapter a summary is given of the topics covered by the corresponding chapter in the textbook. The text can be used by mathematicians and natural science and economics students who have mastered the topics of a first-year course in calculus and linear algebra.

Walter de Gruyter
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AMERICAN MATHEMATICAL SOCIETY

Mathematical Physics

Perspectives on Quantization

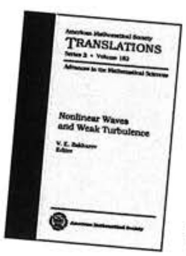
Lewis A. Coburn, *State University of New York at Buffalo*, and
Marc A. Rieffel, *University of California, Berkeley*, Editors

This book presents the proceedings of a 1996 Joint Summer Research Conference sponsored by AMS-IMS-SIAM on "Quantization" held at Mount Holyoke College (Northampton, MA). The purpose of the conference was to bring together researchers focusing on various mathematical aspects of quantization.

In the early work of Weyl and von Neumann at the beginning of the quantum era, the setting for this enterprise was operators on Hilbert space. This setting has been expanded, especially over the past decade, to involve C^*-algebras—noncommutative differential geometry and noncommutative harmonic analysis—as well as more general algebras and infinite-dimensional manifolds. The applications now include quantum field theory, notable conformal and topological field theories related to quantization of moduli spaces, and constructive quantum field theory of supersymmetric models and condensed matter physics (the fractional quantum Hall effect in particular).

The spectrum of research interests which significantly intersects the topic of quantization is unusually broad, including, for example, pseudodifferential analysis, the representation theory of Lie groups and algebras (including infinite-dimensional ones), operator algebras and algebraic deformation theory. The papers in this collection originated with talks by the authors at the conference and represent a strong cross-section of the interests described above.

Contemporary Mathematics, Volume 214; 1998; 195 pages; Softcover; ISBN 0-8218-0684-X; List $39; Individual member $23; Order code CONM/214NA



Nonlinear Waves and Weak Turbulence

V. E. Zakharov, *Landau Institute for Theoretical Physics, Moscow, Russia*, Editor

This book is a collection of papers on dynamical and statistical theory of nonlinear wave propagation in dispersive conservative media. Emphasis is on waves on the surface of an ideal fluid and on Rossby waves in the atmosphere. Although the book deals mainly with weakly nonlinear waves, it is more than simply a description of standard perturbation techniques. The goal is to show that the theory of weakly interacting waves is naturally related to such areas of mathematics as Diophantine equations, differential geometry of waves, Poincaré normal forms and the inverse scattering method.

American Mathematical Society Translations—Series 2, (*Advances in the Mathematical Sciences*), Volume 182; 1998; 197 pages; Hardcover; ISBN 0-8218-4113-0; List $89; Individual member $53; Order code TRANS2/182NA

AMS
AMERICAN MATHEMATICAL SOCIETY

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.

MATHEMATICAL SCIENCES RESEARCH INSTITUTE

DEPUTY DIRECTOR

The Mathematical Sciences Research Institute (MSRI), in Berkeley, seeks a Deputy Director to serve for two to three years beginning in August 1999.

MSRI is an independent nonprofit corporation founded in 1981 by the mathematics departments of several leading American universities. It is located on top of a hill overlooking the University of California at Berkeley and the San Francisco Bay. Its purpose is to further research in the mathematical sciences through major programs of a semester or a year, through workshops, and through postdoctoral training. It also contributes to the encouragement of diversity in the research population, to connections of mathematics with other sciences, and to programs of outreach to the public. MSRI attracts over 1000 Mathematical Scientists to its programs each year, with an average of about 20 postdocs and 60 more senior mathematicians in residence at any time.

The Deputy Director works with the Director on all phases of Institute activity, and helps to formulate Institute policy. He or she has responsibility for administration of present and future programs, including recruiting/hiring postdocs and other members; works on special projects such as journalist-in-residence; works with the Scientific Advisory Council in choosing future programs and members; is ex officio member of the Board of Trustees, and helps coordinate its work, as well as that of the Human Resources Advisory Committee and the Committee of Academic Sponsors (currently 34 universities around the country).

The Deputy Director must be a mathematical scientist with an established research record, substantial administrative experience, and a broad understanding of mathematical culture.

Applications are welcome until November 15, 1998. For more information see our web page **http://www.msri.org**, or contact

Search Committee
MSRI, 1000 Centennial Drive
Berkeley CA 94720-5070.

International Congress of Chinese Mathematicians
Beijing, China
December 12 - 16, 1998

With the cooperation of many mathematicians and institutions, the Morningside Center of Mathematics, Acad. Sinica, is hosting the 1st International Congress of Chinese Mathematicians (ICCM). It will be held in Beijing during the period of December 12 - December 16, 1998. The 1st ICCM is financially supported by Mr. Ronnie Chan and Mr. Gerald Chan. The generous donation of the Chan brothers is also instrumental to the formation of the Morningside Center in Beijing.

Mathematical Program

The conference will consist of plenary addresses, 45-minute addresses, and poster sessions.

Honorary Chairs of ICCM: Shiing-Shen Chern (UC Berkeley) and Buqing Su (Fudan).

Scientific Committee: Shing-Tung Yau (Chair), Tony Chan, Shiu-Yuen Cheng, Charles Chui, Ming-Chang Kang, Ngaiming Mok, Duong H. Phong, Jian-Shu Li, Daqian Li, Fanghua Lin, Tai-Ping Liu, McKenzie Wang, Yuan Wang, Lan Wen, Roderick Wong, Stephen Yau, and Jing Yu.

Plenary Speakers: Ching-Li Chai* (U. Penn), Shui-Nee Chow (Georgia Tech.), Fan Chung (U. Penn), John Coates (Cambridge), Ron Graham (AT&T Bell Lab), Jiaxing Hong* (Fudan), Tom Hou (Caltech), Masaki Kashiwara* (Kyoto Institute), Peter Lax* (Courant), Jun Li (Stanford), Peter Li (UC Irvine), Bong Lian (Brandeis), Chang-Shou Lin (National Chung-Cheng), Zhiming Ma (Acad. Sinica, Beijing), Daniel Stroock (MIT), Gang Tian (MIT), Jeff Zhihong Xia (Northwestern), Zhouping Xin (Courant), Horng-Tzer Yau (Courant), Shouwu Zhang (Columbia University). (*: To be confirmed.)

Morningside Medals and Morningside Lectures

In conjunction to the ICCM, there will also be activities related to the Morningside Center, with distinguished guests such as J.P. Bourguignon, F. Browder, D. Eisenbud, G. Faltings, P. Griffiths, A. Jaffe, J.L. Lions, J. Palis, and M. Taylor. The Morningside Lectures in Mathematics and Mathematical Economics will be delivered.

Another event is the award ceremony of the Morningside Medals in the People's Great Hall of China during the opening of ICCM. The Morningside Medals were established, through the Morningside Center of Mathematics, to encourage outstanding young mathematicians of Chinese descent in their pursuit of mathematical truth. Up to two gold medals, carrying a cash award of 200,000 Yuan (approximately USD25,000), and four silver medals, carrying a cash award 50,000 Yuan, will be awarded. Medalists are selected by a panel of internationally renowned mathematicians. The recipients will only be announced during the award ceremony, and the Medals will only be awarded to those that are present.

Social Events

There will be a banquet and a concert on the opening night in the People's Great Hall. A half-day tour of Beijing is also arranged for the participants.

Registration and Support

All participants are required to register. The registration fee of USD100 includes working lunches, the banquet, the concert, and a copy of the Proceedings of ICCM 98. Limited funds will be available for the reimbursement of local expenses for graduate students and new Ph.D's (within last 3 years). Participants without research grants can also apply for a waiver for registration fee. Applications for both local support and fee waiver (email preferred) should be sent to the address below with the deadline of September 30, 1998.

For further and updated information on the meeting, please consult the ICCM homepage at: **http://www.math.tamu.edu/~huai-dong.cao/iccm** or send email to **iccm@math.tamu.edu** Alternatively you may write directly to: ICCM, Mathematics Department, Texas A&M University, College Station, TX 77843, USA

AMERICAN MATHEMATICAL SOCIETY

Application for Membership 1998

(January–December)

Date . . . . 19 . . . .

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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City ***State*** ***Country***

Date of Birth . . . .
Day ***Month*** ***Year***

If formerly a member of AMS, please indicate dates . . . .

Check here if you are now a member of either MAA ☐ or SIAM ☐

Degrees, with institutions and dates . . . .

. . . .

. . . .

Present position . . . .

Firm or institution . . . .

. . . .
City ***State*** ***Zip/Country***

Primary Fields of Interest (choose five from the list at right)

. . . .

Secondary Fields of Interest (choose from the list at right)

. . . .

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Address for all mail

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Signature

Prepayment Methods and Mailing Addresses

All prices quoted in U.S. dollars.
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For Foreign Bank Transfers: American Mathematical Society, State Street Bank and Trust Company, 225 Franklin St., ABA #011000028, Account #0128-262-3, Boston, MA 02110.

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Fields of Interest

If you wish to be on the mailing lists to receive information about publications in fields of mathematics in which you have an interest, please consult the list of major headings below. These categories will be added to your computer record so that you will be informed of new publications or special sales in the fields you have indicated.

EME	Education/Mathematics Education
00	General
01	History and biography
03	Mathematical logic and foundations
04	Set theory
05	Combinatorics
06	Order, lattices, ordered algebraic structures
08	General algebraic systems
11	Number theory
12	Field theory and polynomials
13	Commutative rings and algebras
14	Algebraic geometry
15	Linear and multilinear algebra; matrix theory
16	Associative rings and algebras
17	Nonassociative rings and algebras
18	Category theory, homological algebra
19	*K*-theory
20	Group theory and generalizations
22	Topological groups, Lie groups
26	Real functions
28	Measure and integration
30	Functions of a complex variable
31	Potential theory
32	Several complex variables and analytic spaces
33	Special functions
34	Ordinary differential equations
35	Partial differential equations
39	Finite differences and functional equations
40	Sequences, series, summability
41	Approximations and expansions
42	Fourier analysis
43	Abstract harmonic analysis
44	Integral transforms, operational calculus
45	Integral equations
46	Functional analysis
47	Operator theory
49	Calculus of variations and optimal control; optimization
51	Geometry
52	Convex and discrete geometry
53	Differential geometry
54	General topology
55	Algebraic topology
57	Manifolds and cell complexes
58	Global analysis, analysis on manifolds
60	Probability theory and stochastic processes
62	Statistics
65	Numerical analysis
68	Computer science
70	Mechanics of particles and systems
73	Mechanics of solids
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

Membership Categories

Please read the following to determine what membership category you are eligible for, and then indicate below the category for which you are applying.

*For **ordinary members** whose annual professional income is below $45,000, the dues are $96; for those whose annual professional income is $45,000 or more, the dues are $128.*

*The **CMS cooperative rate** applies to ordinary members of the AMS who are also members of the Canadian Mathematical Society and reside outside of the U.S. For members whose annual professional income is $45,000 or less, the dues are $82; for those whose annual professional income is above $45,000, the dues are $109.*

*For a **joint family membership,** one member pays ordinary dues, based on his or her income; the other pays ordinary dues based on his or her income, less $20. (Only the member paying full dues will receive the* Notices *and the* Bulletin *as a privilege of membership, but both members will be accorded all other privileges of membership.)*

*Minimum dues for **contributing members** are $192. The amount paid which exceeds the higher ordinary dues level and is purely voluntary may be treated as a charitable contribution.*

*For either **students** or **unemployed individuals,** dues are $32, and annual verification is required.*

*The annual dues for **reciprocity members** who reside outside the U.S. and Canada are $64. To be eligible for this classification, members must belong to one of those foreign societies with which the AMS has established a reciprocity agreement, and annual verification is required. Reciprocity members who reside in the U.S. or Canada must pay ordinary member dues ($96 or $128).*

*The annual dues for **category-S members,** those who reside in developing countries, are $16. Members can chose only one privilege journal. Please indicate your choice below.*

*Members can purchase a **multi-year membership** by prepaying their current dues rate for either two, three, four or five years. This option is not available to category-S, unemployed, or student members.*

1998 Dues Schedule (January through December)

Ordinary member . . . . ☐ $96 ☐ $128

CMS cooperative rate . . . . ☐ $82 ☐ $109

Joint family member (full rate) . . . . ☐ $96 ☐ $128

Joint family member (reduced rate) . . . . ☐ $76 ☐ $108

Contributing member (minimum $192) . . . . ☐

Student member (please verify)[1] . . . . ☐ $32

Unemployed member (please verify)[2] . . . . ☐ $32

Reciprocity member (please verify)[3] . . . . ☐ $64 ☐ $96 ☐ $128

Category-S member[4] . . . . ☐ $16

Multi-year membership . . . . $ . . . . for . . . . years

[1] ***Student Verification*** (sign below)

I am a full-time student at . . . .

. . . . *currently working toward a degree.*

[2] ***Unemployed Verification*** (sign below) *I am currently unemployed and actively seeking employment.*

[3] ***Reciprocity Membership Verification*** (sign below) *I am currently a member of the society indicated on the right and am therefore eligible for reciprocity membership.*

. . . .

Signature

[4] ☐ *send* **NOTICES** ☐ *send* **BULLETIN**

Reciprocating Societies

- ☐ Allahabad Mathematical Society
- ☐ Australian Mathematical Society
- ☐ Azerbaijan Mathematical Society
- ☐ Balkan Society of Geometers
- ☐ Berliner Mathematische Gessellschaft e.V.
- ☐ Calcutta Mathematical Society
- ☐ Croatian Mathematical Society
- ☐ Cyprus Mathematical Society
- ☐ Dansk Matematisk Forening
- ☐ Deutsche Mathematiker-Vereinigung e.V.
- ☐ Edinburgh Mathematical Society
- ☐ Egyptian Mathematical Society
- ☐ Gesellschaft für Angewandte Mathematik und Mechanik
- ☐ Glasgow Mathematical Association
- ☐ Hellenic Mathematical Society
- ☐ Icelandic Mathematical Society
- ☐ Indian Mathematical Society
- ☐ Iranian Mathematical Society
- ☐ Irish Mathematical Society
- ☐ Israel Mathematical Union
- ☐ János Bolyai Mathematical Society
- ☐ The Korean Mathematical Society
- ☐ London Mathematical Society
- ☐ Malaysian Mathematical Society
- ☐ Mathematical Society of Japan
- ☐ Mathematical Society of Serbia
- ☐ Mathematical Society of the Philippines
- ☐ Mathematical Society of the Republic of China
- ☐ Mongolian Mathematical Society
- ☐ Nepal Mathematical Society
- ☐ New Zealand Mathematical Society
- ☐ Nigerian Mathematical Society
- ☐ Norsk Matematisk Forening
- ☐ Österreichische Mathematische Gesellschaft
- ☐ Palestine Society for Mathematical Sciences
- ☐ Polskie Towarzystwo Matematyczne
- ☐ Punjab Mathematical Society
- ☐ Ramanujan Mathematical Society
- ☐ Real Sociedad Matemática Española
- ☐ Saudi Association for Mathematical Sciences
- ☐ Sociedad Colombiana de Matemáticas
- ☐ Sociedad Española de Matemática Aplicada
- ☐ Sociedad de Matemática de Chile
- ☐ Sociedad Matemática de la Republica Dominicana
- ☐ Sociedad Matemática Mexicana
- ☐ Sociedad Uruguaya de Matemática y Estadística
- ☐ Sociedade Brasileira Matemática
- ☐ Sociedade Brasileira de Matemática Aplicada e Computacional
- ☐ Sociedade Paranaense de Matemática
- ☐ Sociedade Portuguesa de Matemática
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- ☐ Société Mathématique de France
- ☐ Société Mathématique Suisse
- ☐ Society of Associations of Mathematicians & Computer Science of Macedonia
- ☐ Society of Mathematicians, Physicists, and Astronomers of Slovenia
- ☐ South African Mathematical Society
- ☐ Southeast Asian Mathematical Society
- ☐ Suomen Matemaattinen Yhdistys
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- ☐ Wiskundig Genootschap

AMERICAN MATHEMATICAL SOCIETY

Wavelets, Multiwavelets, and Their Applications

Akram Aldroubi, *Vanderbilt University, Nashville, TN*, and **EnBing Lin**, *University of Toledo, OH*, Editors

This volume contains refereed research articles on the active area of wavelets and multiwavelets. The book draws upon work presented by experts in the field during the special session on "Wavelets, Multiwavelets and Their Applications" at the Joint Mathematics Meetings in San Diego (January 1997).

Wavelets were implicit in mathematics, physics, signal or image processing, and numerical analysis long before they were given the status of a unified scientific field in the late 1980s. They continue to be one of the few subjects that have attracted considerable interest from the mathematical community as well as from other diverse disciplines where they have had promising applications. The topic is in full evolution, with many active research efforts emerging from the fruitful interaction of various mathematical subjects and other scientific disciplines.

Contemporary Mathematics, Volume 216; 1998; 175 pages; Softcover; ISBN 0-8218-0793-5; List $49; Individual member $29; Order code CONM/216NA

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NATIONAL UNIVERSITY OF SINGAPORE

Founded 1905

DEPARTMENT OF COMPUTATIONAL SCIENCE
FACULTY APPOINTMENTS
http://www.cz3.nus.sg:8100/

The Department of Computational Science offers interdisciplinary programmes in Computational Chemistry, Computational Mathematics, Computational Physics and Computational Biology. There is currently a small core of faculty members and several postdoctoral research fellows in the Department. Faculty members from other departments in the Faculty of Science also contribute to the teaching and research in the department.

Major research areas in the Department include computational statistical and condensed matter physics, nonlinear dynamics and complex systems, scientific visualization, neural computing, computational quantum chemistry and molecular modelling, computational fluid dynamics, geometric modelling, wavelet analysis and applications, signal and image processing. There are strong links between the Department and other national research centres. Ties with other academic institutions and research centres overseas are maintained and the Department is fast gaining international recognition.

Applications are invited for **faculty appointments** at all levels in any of the following areas:

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- **Computational Biology**
- **Computational Condensed Matter and Statistical Physics**
- **Computational Fluid Dynamics**
- **Geometric Modelling**
- **Neural Computing**
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- **Computational Chemistry (molecular modelling, computer-aided drug design)**
- **Scientific Visualization**
- **Symbolic Computing**

Visiting appointments will also be considered.

Gross annual emoluments range as follows: (US $1.00 = S$1.59, approximate)

Lecturer	S$ 58,840	to	74,800
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In addition, a 13th month Annual Allowance (of one month's salary) and an Annual Variable Component (of normally 2 months' salary) may be payable at year end, under the flexible wage system, to staff on normal contracts. The commencing salary will depend on the candidate's qualifications, experience and the level of appointment offered.

Leave and medical benefits will be provided. Depending on the type of contract offered, other benefits may include: provident fund benefits or an end-of-contract gratuity, a settling-in allowance, subsidised housing, education allowance for up to three children subject to a maximum of S$16,425 per annum per child, passage assistance and baggage allowance for the transportation of personal effects to Singapore. Staff members may undertake consultation work, subject to the approval of the University, and retain consultation fees up to a maximum of 60% of their gross annual emoluments in a calendar year.

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10 Kent Ridge Crescent
Singapore 119260
Fax: (65)774-6756
e-mail: cscsec@leonis.nus.edu.sg

*Applications should be submitted by **30 September 1998**.*
Only shortlisted candidates will be notified.

CMS Winter 1998 Meeting

Queen's University and Royal Military College, Kingston, Ontario, December 13-15, 1998

The Canadian Mathematical Society, Queen's University and the Royal Military College cordially invite researchers, educators and students to the 1998 Winter Meeting of the Canadian Mathematical Society. The scientific programme will take place at the Holiday Inn and the Howard Johnson Confederation Place Hotel, Kingston, Ontario, from Sunday, December 13 to Tuesday, December 15, 1998.

PLENARY SPEAKERS: Miklos Csörgo (Carleton), **Henri Darmon** (McGill), **Z. Füredi** (University of Illinois at Urbana/Inst. Hungarian Acad. Sci.), **Donal O'Shea** (Mt. Holyoke College).

PRIZE AND PUBLIC LECTURES: The **Coxeter-James Lecture** will be given by **Henri Darmon**, McGill University. **H.S.M. Coxeter**, University of Toronto, will deliver a public lecture.

SYMPOSIA:

Algebraic Geometry (Org: **P. Milman,** University of Toronto); Donal O'Shea (Mt. Holyoke College), Fedya Bogomolov (NYU Courant Institute), Askold Khovanskii (Univ. of Toronto), Jenia Shustin (Tel-Aviv Univ.), Yosef Yomdin (Weizmann Institute).

Discrete Geometry (Org: **Robert Erdahl,** Queen's University, **Marjorie Senechal**, Smith College, and **Walter Whiteley**, York University). Speakers to be announced.

Education Session - Identifying and Overcoming Barriers to Teaching and Learning Mathematics at University (Org: **Morris Orzech** and **Grace Orzech,** Queen's University); Donal O'Shea (Mt. Holyoke College) - plenary, Ed Barbeau (University of Toronto), Bernard Hodgson (Université Laval), Tom Rishel (Cornell University), Martha Siegel (Towson University), Morris Orzech (Queen's University).

Extremal Combinatorics (Org: **D. de Caen**, Queen's University); Zoltan Füredi (University of Illinois at Urbana and Math. Inst. Hungarian Acad. Sci.) - plenary, Richard Anstee (UBC), Jason Brown (Dalhousie), Ralph Faudree (Memphis), Jerrold Griggs (South Carolina), Penny Haxell (Waterloo), David Fisher (Colorado), Felix Lazebnik (Delaware), Laszlo Székely (South Carolina), Bing Zhou (Trent).

Number Theory (Org: **Ram Murty and Noriko Yui**, Queen's University); This session has recieved additional funding from the Centre de recherches mathématiques. Henri Darmon (McGill) - plenary and Coxeter-James Lecturer, Chantal David (Concordia), Jacek W. Fabrykowski (Manitoba), C. Greither (Laval), E. Goren (McGill), Hershy Kisilevsky (Concordia), Manfred Kolster (McMaster), A. Ledet (Queen's), Claude Levesque (Laval), Kumar Murty (Toronto), W. Nowak (Australia), Vladimir Platonov (Waterloo), Daniel Roy (Ottawa), Gary Walsh (Ottawa), Hugh Williams (Manitoba), Kenneth Williams (Carleton).

Operator Algebras (Org: **James Mingo**, Queen's University); Ken Davidson (Waterloo), George Elliott (Toronto), Thierry Giordano (Ottawa), Andu Nica (Waterloo).

Probability Theory (Org: **Miklos Csörgo,** Carleton University); This session has received additional funding from The Fields Institute. There will be thirty-three invited 1/2-hour speakers, which are to be announced. Miklos Csörgo (Carleton) - plenary.

Topology (Org: **Eddy Campbell,** Queen's University); This session will include talks on the following: ***Differential Geometry and Global Analysis*** (Org: **Muang Min-Oo** and **McKenzie Wang,** McMaster University); ***Homotopy Theory*** (Org: **Lisa Langsetmo,** University of Ottawa and **Jim Shank,** Queen's University); ***Set Theoretic Topology*** (Org: **Juris Steprans** and **Steve Watson,** York University); ***Symplectic/Low Dimensional Topology*** (Org: **Steve Boyer,** UQAM), **Jacques Hurtubise,** McGill, CRM and **François Lalonde,** UQAM, CRM). Speakers to be announced.

Universal Algebra and Multiple-Value Logic (Org: **L. Haddad,** Royal Military College); Speakers to be announced.

Graduate Student Seminar (Org: **David Gregory,** Queen's University); A special session is being organized for graduate students. Anyone interested in participating in the organization of this programme should contact the Meeting Director at the following address: **md-w98@cms.math.ca**

Contributed Papers: Contributed papers of 15 minutes duration are invited and **graduate students are particularly urged to participate.** For an abstract to be eligible, the abstract must be received **before September 31, 1998.** The abstract must be accompanied by its contributor's registration form and appropriate fees.

Submission of Abstracts: The CMS publishes abstracts for all scheduled talks. Titles for Plenary Speakers, Prize Lecturers and Invited Special Session Speakers for the scientific and education programme will appear in the

November issue of the *CMS Notes*. Titles for Contributed Papers will appear in the **December** issue of the *CMS Notes*. All abstracts will be published in the meeting directory and will be available on the Canadian Mathematical Electronics Services (Camel).

Plenary Speakers, Prize Lecturers and Invited Special Session Speakers for the scientific and education programme: These speakers are asked to submit their abstracts to the CMS as instructed by their organizers by September 31, 1998.

Contributed Papers: Those submitting contributed papers may submit their abstracts electronically, following instructions given below, or by using the standard CMS form available from the CMS office in Ottawa or in the **September** issue of the *CMS Notes*. Abstracts should be sent to the Abstracts Coordinator, CMS Executive Office, 577 King Edward, P.O. Box 450, Station A, Ottawa, Ontario CANADA K1N 6N5, **so as to arrive by September 31, 1998.**

Electronic submission of abstracts: This service is available only to those who use the TEX typesetting system. Files should include the speaker's name, affiliation, complete address, title of talk and the abstract itself. Files may be sent by e-mail to the Abstracts Coordinator at: **abstracts@cms.math.ca** *Please note the appropriate deadline given above for the submission of your abstract. Please note that we cannot accept abstracts sent by FAX.*

SOCIAL EVENTS: Social events include a cash-bar reception on Saturday evening, during evening registration, a delegates' luncheon on Sunday, December 13 (the cost of this luncheon is included in most registration categories).

REGISTRATION: Forms are available from the CMS Executive Office, 577 King Edward, Suite 109, PO Box 450, Station A, Ottawa, Ontario, CANADA K1N 6N5 Tel: 613-562-5702, FAX: 613-565-1539, e-mail: meetings@cms.math.ca. Registration fees are given in Canadian dollars. Speakers should contact their organizers for special speaker rates. **Electronic preregistration** is available on our Camel site at http://camel.math.ca/Events/winter98/. This site also has the latest information on the meetings.

	Before Nov. 15	After Nov. 15
CMS/AMS/MAA members with grants	$260	$340
CMS/AMS/MAA members without grants	130	170
Non-members with grants	390	505
Non-members without grants	195	255
One-day fee	130	170
Teachers/students/postdocs/retired/unemployed	95	125
Sunday night Banquet	45	45

ACCOMMODATION: It is recommended that those attending the conference book early to avoid disappointment. Blocks of rooms have been reserved at three different facilities and will be held until the dates given below. Reservations not in by that date will be on a request only, space available basis. Attendees should make their own reservations. Please mention that you are participating in the CMS Winter Meeting. The conference rate is extended up to two days pre and post convention.

Holiday Inn Kingston - Waterfront
One Princess Street
Kingston, Ontario
CANADA K7L 1A1
Check-in: 2:00 pm, Check-out: 11:00 am
Reservation Deadline: **November 10, 1998**
Rate: $60.00 single/double occupancy
Applicable taxes: 12% (including 7% GST)
Phone: (613) 549-8400
Reservations Fax: (613) 549-2014
Toll-free reservations: 1-800 HOLIDAY
Reservations Manager: Anna-Marie de Vos

Howard Johnson Confederation Place Hotel
237 Ontario Street
Kingston, Ontario
CANADA K7L 2Z4
Check-in: 2:00 pm, Check-out: 11:00 am
Reservation Deadline: **November 13, 1998**
Rate: $55.00 single/double occupancy
Applicable taxes: 12% (including 7% GST)
Phone: (613) 549-6300
Fax: (613) 549-1508
Toll-free reservations: 1-888-825-4656

Ramada Plaza Hotel Harbourfront Kingston
1 Johnson Street
Kingston, Ontario
CANADA K7L 5H7
Check-in: 3:00 pm, Check-out: 11:00 am
Reservation Deadline: **November 14, 1998**
Rate: $79.00 single/double occupancy
Applicable taxes: 12% (including 7% GST)
Phone: (613) 549-8100
Fax: (613) 547-3241
Toll-free reservations: 1-888-548-6726
Note: The rooms have been held under the group block number 5649. Mention this number when making a reservation.

ACKNOWLEDGEMENTS: The Meeting Committee wishes to extend its thanks to the members of the Department of Mathematics and Statistics at Queen's University and the members of the Department of Mathematics and Computer Science of the Royal Military College, for their support.

MEETING COMMITTEE: *Meeting Directors*: Tony Geramita (Queen's) and David Wehlau (RMC), *Local Arrangements Committee*: Fady Alajaji (Queen's) and Leo Jonker (Queen's), *Algebraic Geometry*: P. Milman (Toronto), *Discrete Geometry*: Robert Erdahl (Queen's), Marjorie Senechal (Smith College), Walter Whiteley (York), *Education: Teaching and Learning Mathematics at University*: Morris Orzech and Grace Orzech (Queen's), *Extremal Combinatorics*: D. de Caen (Queen's), *Number Theory*: Ram Murty and Noriku Yui (Queen's), *Operator Algebras*: James Mingo (Queen's), *Probability Theory*: Miklos Csörgo (Carleton), *Topology*: Eddy Campbell (Queen's), *Universal Algebra and Multiple-Valued Logic* and *Contributed Papers*: L. Haddad (RMC), *Graduate Student Session*: David Gregory (Queen's), *Other members*: Monique Bouchard (CMS) — Ex-officio, Jean Fugere (RMC), Graham Wright (CMS) — Ex-officio.

Meetings & Conferences of the AMS

PROGRAM ALERT: 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. What this means is that most meeting programs will appear in the *Notices* *after* the meeting takes place. However, complete meeting programs will be available on e-MATH about two to three weeks after the abstract deadline. ***Remember***, e-MATH is your most comprehensive source for up-to-date meeting information. See `http://www.ams.org/meetings/`.

Chicago, Illinois

DePaul University-Chicago

September 12-13, 1998

Meeting #935

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: June 1998
Program issue of *Notices*: November 1998
Issue of *Abstracts*: Volume 19, Issue 3

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

Invited Addresses

Vitaly Bergelson, Ohio State University, *Number theory, combinatorics and ergodic theorems along polynomials.*

Sheldon Katz, Oklahoma State University, *The mathematics and physics of mirror symmetry.*

Ralf Spatzier, University of Michigan, *Rigidity phenomena in geometry and dynamics.*

Vladimir Voevodsky, Northwestern University, *Motivic homotopy type?*

Special Sessions

Algebraic Coding, **William C. Huffman**, Loyola University of Chicago, and **Vera S. Pless**, University of Illinois at Chicago.

Algebraic Combinatorics: Association Schemes and Related Topics, **Sung Yell Song**, Iowa State University.

Algebraic Geometry and Mirror Symmetry, **Ezra Getzler** and **Mikhail Kapranov**, Northwestern University, and **Sheldon Katz**, Oklahoma State University.

Commutative Algebra, **Irena V. Peeva**, Massachusetts Institute of Technology, and **Michael Stillman**, Cornell University.

Complex Dynamics, **Shmuel Friedland**, University of Illinois at Chicago.

Complexity of Geometric Structures on Manifolds, **Melvin G. Rothenberg** and **Shmuel A. Weinberger**, University of Chicago.

Ergodic Theory and Topological Dynamics, **Roger L. Jones**, DePaul University, and **Randall McCutcheon**, Wesleyan College.

Fourier Analysis, **Marshall Ash**, DePaul University, and **Mark A. Pinsky**, Northwestern University.

K-Theory and Motivic Cohomology, **Kevin Knudson**, Northwestern University, and **Mark Walker**, University of Nebraska-Lincoln.

Nonlinear Partial Differential Equations, **Gui-Qiang Chen** and **Konstantina Trivisa**, Northwestern University.

Number Theory, **Jeremy T Teitelbaum** and **Yuri T.schinkel**, University of Illinois at Chicago.

Orthogonal Polynomial Series, Summability and Conjugates, **Calixto P. Calderon**, University of Illinois at Chicago, and **Luis A. Caffarelli**, University of Texas at Austin.

Rigidity in Geometry and Dynamics, **Steven E. Hurder**, University of Illinois at Chicago, and **Ralf J. Spatzier**, University of Michigan.

Stochastic Analysis, **Richard B. Sowers**, University of Illinois-Urbana, and **Elton P. Hsu**, Northwestern University.

Topics in Mathematics and Curriculum Reform, **Richard J. Maher**, Loyola University Chicago.

Winston-Salem, North Carolina

Wake Forest University

October 9–10, 1998

Meeting #936

Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: August 1998
Program issue of *Notices*: December 1998
Issue of *Abstracts*: Volume 19, Issue 3

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: August 18, 1998

Invited Addresses

David F. Anderson, University of Tennessee, *Unique and nonunique factorization in integral domains.*

Idris Assani, University of Carolina, Chapel Hill, *A.e. multiple recurrence and Wiener Wintner dynamical systems.*

Marcy Barge, Montana State University, *Structure of attractors.*

Roger Temam, Indiana University, *Some mathematical problems related to the equations of the atmosphere and the oceans.*

Special Sessions

Abelian Groups and Modules (Code: AMS SS B1), **Ulrich Albrecht**, Auburn University.

Boundary Value Problems (Code: AMS SS K1), **John V. Baxley** and **Stephen B. Robinson**, Wake Forest University.

Combinatorics and Graph Theory (Code: AMS SS A1), **Bruce Landman**, University of North Carolina.

Commutative Ring Theory (Code: AMS SS E1), **David F. Anderson**, University of Tennessee, Knoxville, and **Evan Houston**, University of North Carolina, Charlotte.

Ergodic Theory (Code: AMS SS F1), **Idris Assani**, University of North Carolina, Chapel Hill.

Modern Methods in Set Theory and General Topology (Code: AMS SS H1), **Winfried Just** and **Paul Szeptycki**, Ohio University.

Noncommutatuve Algebra (Code: AMS SS C1), **Ellen Kirkman** and **James Kuzmanovich**, Wake Forest University.

Operator Theory and Holomorphic Spaces (Code: AMS SS L1), **Tavan T. Trent** and **Zhijian Wu**, University of Alabama.

Recent Results on the Topology of Three-Manifolds (Code: AMS SS D1), **Hugh Nelson Howards**, Wake Forest University.

Spectral Theory of Differential Equations and Applications (Code: AMS SS G1), **Dominic Clemence** and **Alexandra Kurepa**, North Carolina A&T University.

Topology in Dynamics (Code: AMS SS J1), **Marcy Barge**, Montana State University-Bozeman, and **Krystyna M. Kuperberg**, Auburn University.

State College, Pennsylvania

Pennsylvania State University

October 24–25, 1998

Meeting #937

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: August 1998
Program issue of *Notices*: January 1999
Issue of *Abstracts*: Volume 19, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: September 1, 1998

Invited Addresses

Jeffrey Adams, University of Maryland, College Park, *Title to be announced.*

Nigel D. Higson, Pennsylvania State University, *Title to be announced.*

Tasso J. Kaper, Boston University, *Title to be announced.*

Kate Okikiolu, University of California, San Diego and MIT, *Title to be announced.*

Special Sessions

Automorphic Forms and Arithmetic Geometry (Code: AMS SS H1), **Kevin L. James**, and **Wen-Ching Winnie Li**, Pennsylvania State University.

C-Algebraic Methods in Geometry and Topology* (Code: AMS SS B1), **Nigel D. Higson**, Pennsylvania State University, and **Erik Guentner** and **John D. Trout Jr.**, Dartmouth College.

Least Squares and Total Least Squares (Code: AMS SS G1), **Jesse L. Barlow**, Pennsylvania State University.

Mathematical Modeling of Inhomogeneous Materials: Homogenizaton and Related Topics (Code: AMS SS D1), **Leonid Berlyand**, Pennsylvania State University, and **Karl Voss**, Yale University.

Metric Topology (Code: AMS SS F1), **Steve Armentrout**, **Joseph Borzelino**, **Hossein Movahedi-Lankarani**, and **Robert Wells**, Pennsylvania State University.

Modeling of Phase Transitions of Partially Ordered Physical Systems (Code: AMS SS C1), **Maria-Carme T. Calderer**, Pennsylvania State University.

Operator Algebras and Noncommutative Geometry (Code: AMS SS K1), **Victor Nistor**, **Paul F. Baum**, and **Adrian Ocneanu**, Pennsylvania State University.

Partitions and q-Series (Code: AMS SS A1), **George E. Andrews**, **Ken Ono**, and **Scott D. Ahlgren**, Pennsylvania State University.

Set Theory (Code: AMS SS J1), **Thomas Jech**, Pennsylvania State University.

Symplectic Geometry and Quantization (Code: AMS SS E1), **Jean-Luc Brylinski**, **Ranee Brylinski**, **Boris Tsygan**, and **Ping Xu**, Pennsylvania State University.

Tucson, Arizona

University of Arizona-Tucson

November 14–15, 1998

Meeting #938

Western Section
Associate secretary: Robert M. Fossum/Bernard Russo
Announcement issue of *Notices*: September 1998
Program issue of *Notices*: To be announced
Issue of *Abstracts*: Volume 19, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: September 23, 1998

Invited Addresses

Alexandru Buium, University of New Mexico, *Differential algebraic geometry and derivatives of integers.*

Hans Koch, University of Texas at Austin, *Title to be announced.*

Mark Lewis, University of Utah, *Title to be announced.*

Jiang-Hua Lu, University of Arizona, *Title to be announced.*

Special Sessions

Arithmetic Algebraic Geometry (Code: AMS SS H1), **Douglas Ulmer**, University of Arizona.

Classical and Quantum Mechanical Lattice Spin Systems (Code: AMS SS E1), **Tom Kennedy**, University of Arizona.

Conditionally Positive Definite Functions and Interpolation Schemes (Code: AMS SS G1), **Donald Myers**, University of Arizona.

Dynamical Systems (Code: AMS SS F1), **Marek Rychlik** and **Maciej P. Wojtkowski**, University of Arizona.

Filaments, Interfaces and Patterns (Code: AMS SS I1), **Nicholas Ercolani** and **Jerry Moloney**, University of Arizona.

Geometry and Lie Groups (Code: AMS SS B1), **Samuel R. Evens** and **Jiang-Hua Lu**, University of Arizona.

Groups and Computation (Code: AMS SS A1), **Robert Beals**, University of Arizona.

Integrable Systems and Random Matrix Theory (Code: AMS SS K1), **K. T-R McLaughlin**, University of Arizona, and **Craig A. Tracy**, University of California, Davis.

Mathematics and Biology (Code: AMS SS D1), **Jim Cushing** and **Shandelle M. Henson**, University of Arizona.

Spectral Geometry and Its Applications (Code: AMS SS C1), **Xianzhe Dai**, University of Southern California, and **Leonid Friedlander**, University of Arizona.

Striking the Balance:Theory, Technique, and Applications in Lower Division Mathematics Courses (Code: AMS SS J1), **Joseph Watkins**, University of Arizona.

Accommodations

Participants should make their own arrangements directly with the hotel of their choice and state that they will be attending the American Mathematical Society meeting. The AMS is not responsible for rate changes or for the quality of the accommodations.

Embassy Suites Hotel, 535 E. Broadway, Tucson, AZ; 520-745-2700 or 800-362-2779; $90/single or double, $100/triples, $110 quads.

Marriott University Park, 880 E. Second St., Tucson, AZ; 520-792-4100 or 800-228-9290; $92/single or double (2 ppl/1bed), double with 2 beds is $102, $112/triples, and $122/quads; walking distance to meeting.

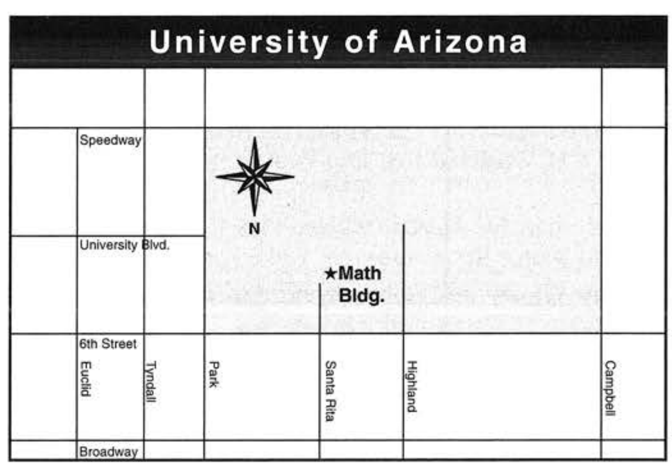
Plaza Hotel, 1900 E. Speedway, Tucson, AZ; 520-327-7341 or 800-843-8052; $59/single and $69/double; walking distance to meeting.

Food Service

There are a number of restaurants adjacent to the campus. A list of restaurants will be available at the registration desk.

Local Information

Please visit the Web site maintained by the Department of Mathematics at `www.math.arizona.edu/` and the University of Arizona Web site `www.arizona.edu`.



Other Activities

AMS Book Sale: Examine the newest titles from AMS! Most books will be available at a special 50% discount offered only at meetings. Complimentary coffee will be served, courtesy of AMS Membership Services.

Parking

Parking is available at no charge on Saturday and Sunday in Zone 1 parking as well as the parking garages.

Registration and Meeting Information

The registration desk will be located in the lobby of the Mathematics Building, and will be open 8:00 a.m. to 5:00 p.m. on Saturday, and 8:00 a.m. to noon on Sunday. Talks will take place in the following buildings: Bio Sciences West, Physics & Atmospheric Sciences (PAS), Shantz, and Mathematics.

Registration fees: (payable on-site only) $30/AMS members; $45/nonmembers; $10/emeritus members, students, or unemployed mathematicians. Fees are payable by cash, check, VISA, MasterCard, Discover, or American Express.

Travel

By Air: The Tucson International Airport is served by most major airlines. Service to the University of Arizona campus is provided by Stagecoach Shuttle at a cost of $12 for one person, $15 for two people, and $18 for three or more people. Taxi fare is approximately $16.

Driving: Take the Speedway exit from the I-10 freeway and proceed east approximately 2.5 miles to Euclid Avenue. Turn right (south) and continue to 6th Street; take a left (east) to Santa Rita (approximately 4 blocks); make a left (north) on Santa Rita and the Math Building will be directly ahead.

Weather

Temperatures vary from 78°F to 50°F at the beginning of the month to 68°F to 42°F towards the end of the month. For up-to-date weather information visit `http://nimbo.wrh.noss.gov/Tucson/twc.html`.

San Antonio, Texas

Henry B. Gonzales Convention Center

January 13–16, 1999

Meeting #939

Joint Mathematics Meetings, including the 105th Annual Meeting of the AMS, 82nd Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL).

Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: October 1998
Program issue of *Notices*: January 1998
Issue of *Abstracts*: Volume 20, Issue 1

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: August 6, 1998
For abstracts: October 1, 1998
For summaries of papers to MAA organizers: September 4, 1998

Joint Invited Addresses

Jennifer Tour Chayes, Microsoft, *Title to be announced* (AMS-MAA Invited Address).

Joan Feigenbaum, AT&T Bell Laboratories, *Department Head, Algorithms & Distributed Data* (AMS-MAA Invited Address).

Joint Special Sessions

Geometry in Dynamics (Code: AMS SS F1), **Krystyna Kuperberg**, Auburn University.

Mathematics and Education Reform (Code: AMS SS M1), **William H. Barker**, Bowdoin College, **Jerry L. Bona**, University of Texas at Austin, **Naomi Fisher**, University of Illinois at Chicago, and **Kenneth C. Millett**, University of California Santa Barbara.

Model Theory and Its Applications (Code: AMS SS S1), **Anand Pillay**, MSRI and University of Illinois, Urbana.

Research in Mathematics by Undergraduates (Code: AMS SS E1), **John E. Meier** and **Leonard A. VanWyk**, Lafayette College.

The History of Mathematics (Code: AMS SS L1), **Karen H. Parshall**, University of Virginia, and **Victor J. Katz**, University of the District of Columbia.

AMS Invited Addresses

Ronald L. Graham, AT&T Labs, *Title to be announced* (AMS Retiring Presidential Address).

Helmut Hofer, New York University-Courant Institute, *Title to be announced* (AMS Colloquium Lectures).

Nancy J. Kopell, Boston University, *Title to be announced* (AMS Josiah Willard Gibbs Lecture).

Sorin Popa, University of California Los Angeles, *Title to be announced.*

Chuu-Lian Terng, Northeastern University, *Title to be announced.*

Alan D. Weinstein, University of California, Berkeley, *Midpoints.*

AMS Special Sessions

Banach Spaces of Holomorphic Functions and Operators on These Spaces (Code: AMS SS D1), **Benjamin A. Lotto**, Vassar College, and **Pamela B. Gorkin**, Bucknell University.

Bergman Spaces and Related Topics (Code: AMS SS B1), **Peter L. Duren**, University of Michigan, Ann Arbor, and **Michael Stessin**, SUNY at Albany.

Combinatorial Topology (Code: AMS SS K1), **Laura M. Anderson** and **Jonathan P. McCammond**, Texas A&M University.

Commutative Algebra (Code: AMS SS G1), **Scott Thomas Chapman**, Trinity University.

Commutative Algebra and Algebraic Geometry (Code: AMS SS J1), **Roger A. Wiegand**, University of Nebraska and Purdue University, and **Susan Elaine Morey**, Southwest Texas State University.

Computational Algebraic Geometry for Curves and Surfaces (Code: AMS SS R1), **Mika K. Seppala**, Florida State University, and **Emil J. Volcheck**, National Security Agency.

Development of Electronic Communications in Mathematics (Code: AMS SS N1), **Alfonso Castro**, University of North Texas, and **Rafael De La Llave**, University of Texas at Austin.

Discrete Models and Difference Equations (Code: AMS SS T1), **Saber Elaydi**, Trinity University, and **Gerry Ladas**, University of Rhode Island.

Dynamical, Spectral, and Arithmetic Zeta-Functions (Code: AMS SS H1), **Michel L. Lapidus**, University of California, Riverside, and **Machiel van Frankenhuysen**, Institut des Hautes Études Scientifiques.

Hamiltonian Mechanics: Applications to Celestial Mechanics and Chemistry (Code: AMS SS Y1), **Michael K. Rudnev**, The University of Texas at Austin, and **Stephen R. Wiggins**, California Institute of Technology.

Mathematics Education and Mistaken Philosophies of Mathematics (Code: AMS SS U1), **Saunders Mac Lane**, University of Chicago, and **Richard A. Askey**, University of Wisconsin-Madison.

Operator Algebras and Applications (Code: AMS SS P1), **Allan P. Donsig**, University of Nebraska-Lincoln, and **Nik Weaver**, Washington University.

Probabilistic Combinatorics (Code: AMS SS C1), **Béla Bollobás**, University of Memphis.

Recent Developments in Differential Geometry (Code: AMS SS V1), **Huai-Dong Cao** and **Jian Zhou**, Texas A&M University.

Several Complex Variables (Code: AMS SS A1), **Emil J. Straube** and **Harold P. Boas**, Texas A&M University.

Singularities in Algebraic and Analytic Geometry (Code: AMS SS X1), **Caroline G. Grant**, U.S. Naval Academy, and **Ruth I. Michler**, University of North Texas.

The Functional and Harmonic Analysis of Wavelets (Code: AMS SS Q1), **Lawrence W. Baggett**, University of Colorado, and **David R. Larson**, Texas A&M University.

The Mathematics of the Navier-Stokes Equations (Code: AMS SS W1), **Peter A. Perry** and **Zhong-Wei Shen**, University of Kentucky.

Gainesville, Florida

University of Florida

March 12-13, 1999

Meeting #940

Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses

Alexander N. Dranishnikov, University of Florida, *Title to be announced.*

Gregory F. Lawler, Duke University, *Title to be announced.*

Michael P. Loss, Georgia Institute of Technology, *Title to be announced.*

John G. Thompson, University of Florida, *Title to be announced.*

Special Sessions

Algebraic and Geometric Combinatorics (Code: AMS SS P1), **Andrew J. Vince** and **Neil L. White**, University of Florida.

Analytical Problems in Mathematical Physics (Code: AMS SS M1), **Eric A. Carlen**, Georgia Institute of Technology, and **Laszlo Erdos**, Courant Institute, NYU.

Computability Theory (Code: AMS SS G1), **Douglas Cenzer**, University of Florida, **Geoffrey Louis LaForte**, University of West Florida, and **Rick L. Smith**, University of Florida.

Continuum Theory and Dynamical Systems (Code: AMS SS A1), **Philip Boyland** and **Beverly Brechner**, University of Florida, and **John Mayer**, University of Alabama at Birmingham.

Finite Groups and Their Representations (Code: AMS SS D1), **Alexandre Turull**, University of Florida.

Galois Theory (Code: AMS SS E1), **J. G. Thompson** and **H. Voelklein**, University of Florida.

Geometric Topology (Code: AMS SS H1), **James E. Keesling** and **Alexander N. Dranishnikov**, University of Florida.

Geometry of Interacting Particles, Random Walks, and Brownian Motion (Code: AMS SS N1), **Irene Hueter**, University of Florida, and **Gregory F. Lawler**, Duke University.

Groups and Geometries (Code: AMS SS F1), **Chat Ho** and **Peter Sin**, University of Florida.

Linear Operator Theory (Code: AMS SS J1), **Leiba Rodman**, College of William & Mary, and **Scott A. McCullough**, University of Florida.

Markov Processes and Potential Theory (Code: AMS SS C1), **Joe Glover** and **Murali Rao**, University of Florida.

Partial Differential Equations and Applications (Code: AMS SS K1), **Gang Bao** and **Yun-mei Chen**, University of Florida.

Probability on Algebraic Structures (Code: AMS SS Q1), **Gregory M. Budzban** and **Philip Feinsilver**, Southern Illinois University at Carbondale, and **Arunava Mukherjea**, University of South Florida.

Structure and Representation Theory of Lattice-Ordered Groups and f-Rings (Code: AMS SS L1), **Jorge Martinez**, University of Florida.

The Erdős Legacy and Connections to Florida (Code: AMS SS B1), **Krishnaswami Alladi** and **Jean Larson**, University of Florida.

Urbana, Illinois

University of Illinois, Urbana-Champaign

March 18–21, 1999

Meeting #941

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses

Alexander Beilinson, MIT, *Title to be announced.*

Alexandra Bellow, Northwestern University, *Title to be announced.*

Igor Krichever, Columbia University, *Title to be announced.*

Steven Rallis, Ohio State University, *Title to be announced.*

Trevor Wooley, University of Michigan, *Title to be announced.*

Special Sessions

Algebraic K-Theory (and the 5th Annual Great Lakes K-Theory Conference (Code: AMS SS H1), **Daniel Grayson**, University of Illinois-Urbana.

Combinatorial Designs (Code: AMS SS M1), **Ilene H. Morgan**, University of Missouri-Rolla, and **Walter D. Wallis**, Southern Illinois University-Carbondale.

Diophantine Equations, Inequalities and Related Arithmetic Problems (Code: AMS SS F1), **Michael Bennett**, University of Illinois-Urbana, and **Trevor Wooley**, University of Michigan.

Elementary and Analytic Number Theory (Code: AMS SS E1), **Harold G. Diamond** and **A. J. Hildebrand**, University of Illinois-Urbana.

Galois Representations (Code: AMS SS C1), **Nigel Boston**, University of Illinois-Urbana, and **Michael Larsen**, University of Missouri.

Graph Theory (Code: AMS SS G1), **Douglas B. West**, University of Illinois-Urbana.

Holomorphic Vector Bundles and Complex Geometry (Code: AMS SS L1), **Maarten Bergvelt**, **Steven Bradlow**, and **John P. D'Angelo**, University of Illinois-Urbana, and **Lawrence Ein**, University of Illinois-Chicago.

Integrable Equations (Code: AMS SS I1), **Igor Krichever**, Columbia University, and **Kirill Vaninsky**, Kansas State University.

Martingales and Analysis (Code: AMS SS D1), **Joseph Max Rosenblatt**, **Renming Song**, and **Richard B. Sowers**, University of Illinois-Urbana.

Nonstandard Analysis (Code: AMS SS B1), **C. Ward Henson** and **Peter Loeb**, University of Illinois-Urbana.

Operator Spaces and Their Applications (Code: AMS SS J1), **Gilles Pisier**, Texas A&M, and **Zhong-Jin Ruan**, University of Illinois-Urbana.

Recent Progress in Elementary Geometry (Code: AMS SS A1), **John E. Wetzel**, University of Illinois-Urbana, and **Clark Kimberling**, University of Evansville.

Symplectic Geometry and Topology (Code: AMS SS K1), **Eugene M. Lerman** and **Susan Tolman**, University of Illinois-Urbana.

Las Vegas, Nevada

University of Nevada-Las Vegas

April 10–11, 1999

Meeting #942

Western Section
Associate secretary: Bernard Russo
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Special Sessions

Analysis and Geometry (Code: AMS SS I1), **Peter Li** and **Song-Ying Li**, University of California, Irvine.

Combinatorial Theory (Code: AMS SS G1), **Kequan Ding**, University of Illinois-Urbana, **Peter Shiue**, University of Las Vegas, Nevada, and **Yeong-Nan Yeh**, Academia Sinica.

Control and Dynamics of Partial Differential Equations (Code: AMS SS A1), **Zhonghai Ding**, University of Nevada-Las Vegas.

Diophantine Problems (Code: AMS SS J1), **Arthur Baragar**, University of Nevada-Las Vegas, and **Michael Bennett**, University of Illinois.

Geometric Group Theory (Code: AMS SS H1), **Eric M. Freden**, Southern Utah University, and **Eric Lewis Swenson**, Brigham Young University.

Graph Theory (Code: AMS SS B1), **Hung-Lin Fu**, University of National Chiao-Tung University-Taiwan, **Chris A. Rodger**, Auburn University, and **Michelle Schultz**, University of Nevada-Las Vegas.

Nonlinear PDEs - Methods and Applications (Code: AMS SS C1), **David Costa**, University of Nevada-Las Vegas.

Number Theory (Code: AMS SS F1), **Gennady Bachman**, University of Nevada-Las Vegas, **Richard A. Mollin**, University of Calgary, and **Peter J. Shiue**, University of Nevada-Las Vegas.

Numerical Analysis and Computational Mathematics (Code: AMS SS E1), **Jun Zhang**, University of Minnesota and University of Kentucky, and **Jennifer Zhao**, University of Michigan, Dearborn.

Set Theory (Code: AMS SS D1), **Douglas Burke** and **Derrick DuBose**, University Nevada-Las Vegas.

Buffalo, New York

State University of New York at Buffalo

April 24–25, 1999

Meeting #943

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses

Michele M. Audin, University of Louis Pasteur, *Title to be announced.*

Russel Caflisch, University of California, Los Angeles, *Title to be announced.*

Jeff Smith, Purdue University, *Title to be announced.*

Alexander Voronov, MIT, *Title to be announced.*

Gregg J. Zuckerman, Yale University, *Title to be announced.*

Special Sessions

Combinatorics and Graph Theory (Code: AMS SS C1), **Harris Kwong**, SUNY College at Fredonia.

Knot and 3-Manifolds (Code: AMS SS E1), **Thang T.Q. Le**, State University of New York at Buffalo, **William W. Menasco**, SUNY at Buffalo, and **Morwen B. Thistlethwaite**, University of Tennessee.

Mathematical Physics (Code: AMS SS D1), **Jonathan Dimock**, SUNY at Buffalo.

Representations of Lie Algebras (Code: AMS SS F1), **Duncan J. Melville**, Saint Lawrence University.

Smooth Categories in Geometry and Mechanics (Code: AMS SS A1), **F. William Lawvere**, SUNY at Buffalo.

Thin Films: Solid and Liquid (Code: AMS SS B1), **E. Bruce Pitman**, SUNY at Buffalo, and **Brian Spencer**, SUNY at Buffalo.

Denton, Texas

University of North Texas

May 19–22, 1999

Meeting #944

Fourth International Joint Meeting of the AMS and the Sociedad Matemática Mexicana (SMM).
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: January 1999
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Melbourne, Australia

Melbourne, Australia

July 12–16, 1999

Meeting #945

First International Joint Meeting of the American Mathematical Society and the Australian Mathematical Society
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses

Jennifer Chayes, Microsoft, *Title to be announced.*

Michael Eastwood, University of Adelaide, *Title to be announced.*

Vaughan Jones, University of California, Berkeley, *Title to be announced.*

Hyam Rubinstein, Melbourne University, *Title to be announced.*

Richard M. Schoen, Stanford University, *Title to be announced.*

Neil Trudinger, Australian National University, *Title to be announced.*

Special Sessions

Discrete Groups (Code: AMS SS H1), **Marston Conder**, **Gaven Martin**, and **Eamonn O'Brien**, University of Auckland.

Fluid Dynamics (Code: AMS SS C1), **Susan Friedlander**, Northwestern University, and **Roger H.J Grimshaw**, Monash University.

Geometric Themes in Group Theory (Code: AMS SS A1), **Gustav I. Lehrer**, University of Sydney, **Cheryl E. Praeger**, University of Western Australia, and **Stephen D. Smith**, University of Illinois at Chicago.

Low Dimensional Topology (Code: AMS SS D1), **William H. Jaco**, Oklahoma State University, and **Hyam Rubinstein**, Melbourne University.

Mathematical Physics: Many Body Systems (Code: AMS SS B1), **Alan L. Carey**, University of Adelaide, **Paul A. Pearce**, University of Melbourne, and **Mary Beth Ruskai**, University of Massachusetts, Lowell.

Mathematics Learning Centers (Code: AMS SS G1), **Judith Baxter**, University of Illinois, Chicago, **Jackie Nicholas**, University of Sidney, and **Jeanne Wald**, Michigan State University.

Moduli Spaces of Riemann Surfaces, Mapping Class Groups and Invariants of 3-manifolds (Code: AMS SS F1), **Ezra Getzler**, Northwestern University, and **Richard Hain**, Duke University.

Probability Theory and Its Applications (Code: AMS SS E1), **Timothy Brown**, University of Melbourne, **Phil Pollett**, University of Queensland, and **Ruth J. Williams**, University of California, San Diego.

Providence, Rhode Island

Providence College

October 2–3, 1999

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: January 6, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Special Sessions

Algebraic and Geometric Combinatorics (Code: AMS SS A1), **Vesselin N. Gasharov**, Cornell University, and **Ira M. Gessel**, Brandeis University.

Austin, Texas

University of Texas-Austin

October 8–10, 1999

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: January 6, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses

Mikhail Kapranov, Northwestern University, *Title to be announced.*

John Roe, Oxford University and Pennsylvania State University, *Title to be announced.*

Catherine Sulem, University of Toronto, *Title to be announced.*

Tatiana Toro, University of Washington, *Title to be announced.*

Special Sessions

The Development of Topology in the Americas (Code: AMS SS A1), **Cameron Gordon**, University of Texas, Austin, and **Ioan Mackenzie James**, University of Oxford.

Washington, District of Columbia

Marriott Wardman Park Hotel and Omni Shoreham Hotel

January 19–22, 2000

Joint Mathematics Meetings, including the 106th Annual Meeting of the AMS, 83rd Meeting of the Mathematical Association of America (MAA), with minisymposia and other special events contributed by the Society for Industrial and Applied Mathematics (SIAM), and the annual meetings of

the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM).
Associate secretary: Robert M. Fossum
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 20, 1999
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

Lowell, Massachusetts

University of Massachusetts, Lowell

April 1–2, 2000

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: July 1, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Notre Dame, Indiana

University of Notre Dame

April 7–9, 2000

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: July 7, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Odense, Denmark

Odense University

June 12–15, 2000

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 issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Toronto, Ontario Canada

University of Toronto

September 22–24, 2000

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

New York, New York

Columbia University

November 3–5, 2000

Southeastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: February 3, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

New Orleans, Louisiana

New Orleans Marriott and ITT Sheraton New Orleans Hotel

January 10–13, 2001

Joint Mathematics Meetings, including the 107th Annual Meeting of the AMS, 84th Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM).
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: 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: Robert J. Daverman
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: June 15, 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

Southeastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: July 28, 2000
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 issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: January 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: Robert J. Daverman
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: 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

Mathematical Sciences Employment Register

Henry B. Gonzales Convention Center, San Antonio, Texas

January 13, 14, and 15, 1999

1999 Employment Register Schedule

Wednesday, January 13, 7:30 a.m. Distribution of Employment Register material for on-site registrants and participants registered in advance who did not receive materials by mail.

9:00 a.m. Short (optional) orientation session.

9:30 a.m.–4:00 p.m. Submission of all interview request forms for both Thursday and Friday interviews. Those who do not submit interview request sheets by 4:00 p.m. will be unable to participate in the scheduled Employment Register on Thursday and Friday.

10 a.m.–5 p.m. Interview Center open.

N.B.— No regular Employment Register interviews are scheduled on Wednesday.

Thursday, January 14, 7:00 a.m.–8:15 a.m. Distribution of interview schedules for both Thursday and Friday.

8:15 a.m.–4:40 p.m. Scheduled interviews.

8:15 a.m.–7:30 p.m. Interview Center open.

Friday, January 15, 8:15 a.m.–4:40 p.m. Scheduled interviews.

8:15 a.m.–7:30 p.m. Interview Center open.

Saturday, January 16, 9:00 a.m.–12 noon. Interview Center open.

All participants in the 1999 scheduled Employment Register must submit their Interview Request/Availability Forms between 9:30 a.m. and 4:00 p.m. on Wednesday or they will not be included when the interview scheduling program runs Wednesday night. Should unexpected delays occur while travelling, contact the Employment Register Desk by telephone at 401-455-4107 before 4:00 p.m. EST on Wednesday, January 13.

Overview of the Employment Register

The Mathematical Sciences Employment Register, held annually at the Joint Mathematics Meetings in January, provides opportunities for mathematical scientists seeking professional employment to meet employers who have positions to be filled.

The Employment Register has grown in recent years to house two services: the scheduled employment register tables and the self-scheduled Interview Center. Use of the Register by employers has gone up. At the 1998 Employment Register, 86 employers and 394 applicants participated, giving an overall applicant to employer ratio of 4.6:1. The number of interviews for each applicant is just over three interviews in the scheduled program and just under four interviews in the Interview Center, for an average total of seven interviews. Each employer conducts approximately 30–40 interviews.

This year, one additional option is available for employers: the use of an "Information Booth" table in the center of the Employment Register where employers can distribute information and speak with walk-up candidates about open positions.

The Mathematical Sciences Employment Register is sponsored by the American Mathematical Society, the Mathematical Association of America, and the Society for Industrial and Applied Mathematics; it is managed by members of the AMS staff under the general guidance of the AMS-MAA-SIAM Committee on Employment Opportunities.

Employers: Choose one or more of these tables:
- *traditional Employment Register scheduling system*
- *Interview Center table*
- *centrally located Information Booth*

The **Interview Center** allows any employer to reserve a table in an area adjacent to the Employment Register. You will arrange your own schedule and interviews, either in advance or on site using the Employment Register Message Center. If you have never used the Employment Register before, you might want to try conducting your interviews at this convenient location. Since you will be setting your own schedule, you have complete control over whom you see, for how long, and when you will be interviewing. The Center will be open longer hours: Wednesday, 10:00 a.m.–5:00 p.m.; Thursday and Friday, 8:00 a.m.–7:30 p.m.; and Saturday, 9:00 a.m.–12 noon. The fee for use of this area is the same as the normal employer fee. You will be mailed in advance the *Winter List of Applicants* containing information about the candidates present at the Employment Register.

How to Register for the Interview Center

Register for the Joint Meetings and pay the employer fee by November 9. Indicate on the Meetings Registration Form that you are using the Interview Center. Also, submit an Employer Form (found at www.ams.org/emp-reg/employer.html). Call 800-321-4267, ext. 4105, or e-mail emp-info@ams.org with any questions.

How to Use the Interview Center

If you are scheduling interviews in advance, tell applicants to find the table with your institution name in the Employment Register Interview Center (not the regular table area). You can schedule any time from 10 a.m.–5 p.m. Wednesday, 8 a.m.–7:30 p.m. Thursday and Friday, and 9:00 a.m.–12 noon Saturday. To schedule interviews yourself after arriving in San Antonio, leave messages for Employment Register applicants in the Employment Register Message Center. Paper forms will be provided to help you leave messages. You will be provided with a box in the Employer Message Center where applicants can leave items for you.

How to Use the Regular Scheduling System at the Employment Register

Employers will choose on Wednesday, January 13, which of the eight sessions to participate in. Submit your availability/interview request forms by 4:00 p.m. Wednesday. You may ask to be scheduled with ten applicants per day. You are virtually assured of those requests being filled by the scheduling algorithm, provided the applicants are present. The rest of your interviews will be with applicants who ask to see you. Employers should be specific about job requirements on the Employer Form to avoid interviews with inappropriate candidates.

Schedules are distributed on Thursday morning for both Thursday and Friday interviews. The schedule allows fifteen-minute interviews, with five minutes between for note taking. One or more interviewers for the same position(s) may interview at the table separately, together, or in shifts.

Employers should bring school catalogs, corporate reports, or more lengthy job descriptions to the Employment Register Desk early on Wednesday for perusal by applicants prior to interviews.

New Information Booths for Informal Discussions

Some employers need to distribute information about open positions during the Joint Meetings and are willing to speak with walk-up applicants in an informal way. The Information Booth tables, located in the center of the Employment Register, provide a perfect setting for this. Normal table fees are charged. Keep in mind, however, only a table and chairs will be provided. No shipping or receiving services, no electrical connections, and no sales of any kind are allowed. Those requiring such services should utilize Joint Meetings exhibit space.

Registering for More Than One Type of Table

Employers can reserve and pay for two tables at the first and second table rates and indicate that they are of different types. Please specify this on the registration form as well as the Employer Form. Interview Request Forms must be turned in on Wednesday by 4:00 p.m. for those who will be using the scheduling system for any portion of their time.

Employers: How to Register

The fee for all employers to register in advance is $200 for the first table and $50 for each additional table. On-site registration fees (any registrations after 12/18/98) are $250 for the first table and $75 for each additional table. Employers must also register for the Joint Meetings and pay the appropriate Joint Meetings fee. Joint Meetings registration forms are available in the back of this issue or on e-MATH in the Meetings section (http://www.ams.org/amsmtgs/2031_registration.html).

Employer Forms are available in the back of this issue or electronically on e-MATH, and they can also be submitted electronically. The URL is http://www.ams.org/emp-reg/. The Employer Form and registration form must be received by November 9, 1998. Call the Employment Register staff with any deadline problems at 800-321-4267, ext. 4105, or emp-info@ams.org. Please indicate on each form which type or types of tables you plan to use. A "second table" fee should be paid for any additional type of table.

It is the policy of some institutions to pay directly for employer fees. If a payment of this type is made separately from the submission of the advance registration materials, it is important that the institution's fiscal department include the name of the department and interviewer with their payment so that proper credit can be made in the Providence office.

About the *Winter List of Applicants*: This booklet contains hundreds of résumés of applicants registered by November 9 for the Employment Register. It will be mailed to ALL employers who register by November 9 who indicate on their Joint Meetings registration form that they would like their materials mailed. Employers should be aware that there will be hundreds of brief résumés to look through and should be sure to obtain the *Winter List of Applicants* as early as possible. This book is also for sale at the Joint Meetings.

Employers Not Planning to Interview: Employers who do not plan to participate in the Employment Register may display a job description. This description must be submitted on the Employer Form which appears in the back of this issue and on e-MATH, with the appropriate indication that no tables will be used. A fee of $50 is charged for this service. If the form is received in the Providence office (with payment) by the November 9 deadline, it will appear in the *Winter List of Employers*. Forms received with payment in the Providence office after that deadline will be displayed at the meeting.

Applicants: How to benefit from your Employment Register experience

Applicants who participate in the 1999 Employment Register will find themselves talking with employers in three different settings. A scheduling program sets brief, fifteen-minute interviews at the Employment Register numbered tables. There is also an Interview Center where employers set their own schedules. These employers do not participate in the scheduling program, so applicants have no automatic access to interviews with them. They determine their own schedules and make their own appointments privately, either in advance or on site using the Employment Register Message Center. The third method of employer participation (which is being tried for the first time in 1999) is an Information Booth area where employers distribute information about open positions and chat with the candidates who approach the table.

There is a certain scheduling burden placed on applicants to juggle these simultaneous services. A step has been taken to alleviate this: scheduled sessions are now in smaller blocks, for a total of eight sessions over the two days of interviews (Thursday and Friday). This allows applicants, once they receive invitations to interview in the Interview Center, to accept them knowing that when they submit the computer schedule request on Wednesday, they can mark that they are unavailable for one or more of these sessions without seriously jeopardizing their chances of obtaining scheduled interviews. Applicants are encouraged to schedule their time in advance in this manner and not wait for the computer schedule to be distributed Thursday morning.

Applicants should understand that the Employment Register provides no guarantees of interviews or jobs. It is simply a convenient meeting place for candidates and employers who are attending the Joint Meetings. Those who have not yet begun their job search efforts may go unnoticed at the Employment Register (although all applicants will likely receive between one and three interviews in the scheduled program). Attention generally goes to candidates who may already have applied for open positions or to those who are well suited for teaching positions at liberal arts colleges.

Candidates just beginning a job search should realize that employers have no method to judge their credentials other than the brief Résumé Form, and they should make an effort to make it distinct and interesting. If time permits, they should apply for suitable open positions they notice in the *Winter List of Employers* after they receive it in December. Also, they should bring enough materials with them to accompany requests for interviews in the Message Center boxes of the Interview Center employers in which they are interested.

The *Winter List of Applicants* is mailed to all employers in advance, so it is vital that your Joint Meetings registration form, Applicant Résumé Form, and payments be received by the November 9 deadline so your form can be printed in the book. This greatly increases your chances of being invited to the Interview Center.

Recent applicant feedback (see the survey results on the Web at `http://www.ams.org/emp-reg/`) shows that applicants strongly preferred the Interview Center interviews, which are longer, more relaxed, and in a less structured setting. On average, last year each applicant was scheduled for slightly over three interviews in the scheduled program and almost four interviews in the Interview Center. Nearly five out of six applicants were invited for at least one interview at the Interview Center. Those who fared better in the computer schedule were those who were more requested by employers. Applicants should keep in mind that they are not required to participate in the scheduled program. They can make themselves available for Interview Center invitations by registering in advance, placing their form in the *Winter List of Applicants*, and utilizing the Employment Register Message Center. By not turning in a computer interview request sheet on Wednesday, applicants will not be included in the scheduled interviews.

Registration on site is allowed, for a higher fee, but is severely discouraged. Most employers will not notice an applicant form that arrives on Wednesday. Therefore, these individuals will receive only a couple of computer-scheduled interviews.

Data from recent Employment Registers shows that women represent about half of the most sought-after applicants, although they make up less than half of the total Employment Register applicant pool. Those without permanent authorization to work in the United States will find themselves far less requested than U.S. citizens or permanent residents. Newer Ph.D.s tend to be invited for more interviews than those who have been working longer. Most jobs listed require a doctorate.

Applicants should keep in mind that interviews arranged by the Employment Register represent only an initial contact with the employers and that hiring decisions are not ordinarily made during or immediately following such interviews. Applicants are advised to bring a number of copies of the vita or résumé in order to leave them with prospective employers. Alerting any employer to whom applications are made in the fall of your plans to be present at the upcoming Joint Meetings is always a good idea.

Applicants: How to Register

Advance registration is an important step in Employment Register participation that offers several advantages.

Advance registration fees for applicants are $40 plus Joint Meetings registration fee vs. $75 on-site registration fee plus Joint Meetings registration fee.

Applicant Forms are available electronically on e-MATH, and they can also be submitted electronically. The Employment Register announcement and forms are located in the Employment section, along with other employment-related items, at `http://www.ams.org/employment/`.

Each applicant's Résumé Form will be reproduced in a booklet, the *Winter List of Applicants*, and distributed to all registered employers. Applicant Résumé Forms received after November 9, 1998, cannot be included in the booklet. The booklet allows employers more time to examine each candidate's qualifications in advance. Advance registration for the Employment Register will continue until the final registration deadline of December 18, 1998; however, the Résumé Form will NOT be included in the *Winter List*, but will be posted on site at the Employment Register. Those who do not register by December 18 must register on site at the Joint Meetings Registration Desk and pay the higher fees.

Applicants registered by November 9 will receive their badges, programs, and Employment Register materials two to three weeks in advance of the meetings, unless they request otherwise. The package will include the complete job announcements received from employers registered by November 9.

Registration on Site: Feel free to enter the Employment Register area first to consult staff about your decision to try late participation and to check which employers are participating. Applicants should keep in mind that on-site registration should be done as early on Wednesday as possible to allow a longer time for your Résumé Form to be viewed by other participants and also to allow time to examine materials before making your own interview requests. There will be no on-site registration for the Employment Register after 4:00 p.m. Wednesday, January 13.

Instructions for Applicant and Employer Forms

Applicant forms submitted for the Employment Register by the November 9 deadline will be reproduced in a booklet titled *Winter List of Applicants*. Employer forms submitted by the November 9 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 9, 1998**, 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

EMPLOYER FORM

MATHEMATICAL SCIENCES EMPLOYMENT REGISTER

JANUARY 14–16, 1999

SAN ANTONIO, TEXAS

1. Forms should be accessed and submitted electronically if possible. The URL for accessing Employment Register 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 9 (to AMS, P. O. Box 6887, Providence, RI 02940) in order to be included in the ***Winter List of Employers***.
3. Please list all potential interviewers, for reference by applicants, but pay fees only for each separate table.
4. Forms will not be processed until registration and payment of fees have been received.

EMPLOYER CODE:

Institution ______________________

Department ______________________

Mailing address ______________________

____

E-mail address (one only) ______________________

URL (or other contact info) ______________________

Name(s) of Interviewer(s) 1. ______________________

2. ______________________

3. ______________________

4. ______________________

Specialties sought ______________________

____

Title(s) of position(s) ______________________

Number of positions ______________

Starting date ________ / ________ (Month / Year)   Term of appointment ________ Years

Renewal   Tenure-track position

☐ Possible ☐ Impossible   ☐ Yes ☐ No   Teaching hours per week ______

Degree preferred ______________   Degree accepted ______________

Duties ______________________

____

____

Experience preferred ______________________

____

____

Significant other requirements, needs, or restrictions which will influence hiring decisions ______________

____

____

This position will be subject to a security clearance which will require U.S. citizenship: ☐ Yes ☐ No

THE EMPLOYER PLANS TO USE THE FOLLOWING SERVICES (check all that apply):

☐ Regular scheduled Employment Register table

☐ A second regular scheduled Employment Register table

☐ Interview Center table

☐ Information Booth table

☐ Placing this form for information only (not using a table)

APPLICANT RÉSUMÉ FORM

MATHEMATICAL SCIENCES EMPLOYMENT REGISTER
JANUARY 14–16, 1999
SAN ANTONIO, TEXAS

1. Forms should be accessed and submitted electronically if possible. The URL for accessing Employment Register 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 9 (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: ☐ Research ☐ University Teaching College Teaching: ☐ 4-year ☐ 2-year

Would you be interested in nonacademic employment? ☐ Yes ☐ 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)

____

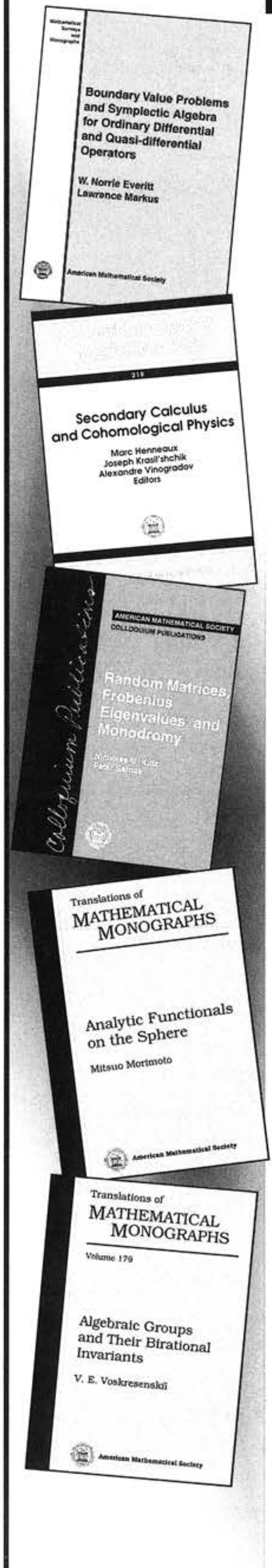
____

____

____

Work authorization status: (check one) ☐ U.S. Citizen ☐ Non-U.S. Citizen, authorized to work permanently in U.S. ☐ Other

American Mathematical Society



New Titles from the AMS

Boundary Value Problems and Symplectic Algebra for Ordinary Differential and Quasi-differential Operators

W. Norrie Everitt, *University of Birmingham, UK*, and **Lawrence Markus**, *University of Minnesota, Minneapolis*

In the classical theory of self-adjoint boundary value problems for linear ordinary differential operators there is a fundamental, but rather mysterious, interplay between the symmetric (conjugate) bilinear scalar product of the basic Hilbert space and the skew-symmetric boundary form of the associated differential expression. This book presents a new conceptual framework, leading to an effective structured method, for analyzing and classifying all such self-adjoint boundary conditions. The program is carried out by introducing innovative new mathematical structures which relate the Hilbert space to a complex symplectic space. This work offers the first systematic detailed treatment in the literature of these two topics: complex symplectic spaces—their geometry and linear algebra—and quasi-differential operators.

Features:

- Authoritative and systematic exposition of the classical theory for self-adjoint linear ordinary differential operators (including a review of all relevant topics in texts of Naimark, and Dunford and Schwartz).
- Introduction and development of new methods of complex symplectic linear algebra and geometry and of quasi-differential operators, offering the only extensive treatment of these topics in book form.
- New conceptual and structured methods for self-adjoint boundary value problems.
- Extensive and exhaustive tabulations of all existing kinds of self-adjoint boundary conditions for regular and for singular ordinary quasi-differential operators of all orders up through six.

Mathematical Surveys and Monographs; 1998; approximately 200 pages; Hardcover; ISBN 0-8218-1080-4; List $49; Individual member $29; Order code SURV-EVERITTNT89

Secondary Calculus and Cohomological Physics

Marc Henneaux, *Université Libre de Bruxelles, Brussels, Belgium*, **Joseph Krasil'shchik**, *Moscow Institute for Municipal Economy, Russia*, and **Alexandre Vinogradov**, *University of Salerno, Italy*, Editors

This collection of invited lectures (at the Conference on Secondary Calculus and Cohomological Physics, Moscow, 1997) reflects the state-of-the-art in a new branch of mathematics and mathematical physics arising at the intersection of geometry of nonlinear differential equations, quantum field theory, and cohomological algebra. This is the first comprehensive and self-contained book on modern quantum field theory in the context of cohomological methods and the geometry of nonlinear PDEs.

Features:

- An up-to-date and self-contained exposition of the newest results in cohomological aspects of quantum field theory and the geometry of PDEs.
- A new look at interrelations among cohomology theory, the geometry of PDEs, and field theory.
- Application to Batalin-Vilkovisky formalism, BRST formalism, anomalies, and quantum dynamics.

Contemporary Mathematics, Volume 219; 1998; 287 pages; Softcover; ISBN 0-8218-0828-1; List $60; Individual member $36; Order code CONM/219NT89

Random Matrices, Frobenius Eigenvalues, and Monodromy

Nicholas M. Katz and **Peter Sarnak**, *Princeton University, NJ*

The main topic of this book is the deep relation between the spacings between zeros of zeta and L-functions and spacings between eigenvalues of random elements of large compact classical groups. This relation, the Montgomery-Odlyzko law, is shown to hold for wide classes of zeta and L-functions over finite fields. The book draws on, and gives accessible accounts of, many disparate areas of mathematics, from algebraic geometry, moduli spaces, monodromy, equidistribution, and Weil conjectures, to probability theory on the compact classical groups in the limit as their dimension goes to infinity and related techniques from orthogonal polynomials and Fredholm determinants.

Colloquium Publications; 1998; approximately 416 pages; Hardcover; ISBN 0-8218-1017-0; List $69; Individual member $41; Order code COLL-KATZNT89

Analytic Functionals on the Sphere

Mitsuo Morimoto, *International Christian University, Tokyo, Japan*

This book treats spherical harmonic expansion of real analytic functions and hyperfunctions on the sphere. Because a one-dimensional sphere is a circle, the simplest example of the theory is that of Fourier series of periodic functions.

The author first introduces a system of complex neighborhoods of the sphere by means of the Lie norm. He then studies holomorphic functions and analytic functionals on the complex sphere. In the one-dimensional case, this corresponds to the study of holomorphic functions and analytic functionals on the annular set in the complex plane, relying on the Laurent series expansion. In this volume, it is shown that the same idea still works in a higher-dimensional sphere. The Fourier-Borel transformation of analytic functionals on the sphere is also examined; the eigenfunction of the Laplacian can be studied in this way.

Translations of Mathematical Monographs; 1998; approximately 170 pages; Hardcover; ISBN 0-8218-0585-1; List $65; Individual member $39; Order code MMONO-MORIMOTO2NT89

Algebraic Groups and Their Birational Invariants

V. E. Voskresenskiĭ, *Samara State University, Russia*

Since the late 1960s, methods of birational geometry have been used successfully in the theory of linear algebraic groups, especially in arithmetic problems. This book—which can be viewed as a significant revision of the author's book, *Algebraic Tori* (Nauka, Moscow, 1977)—studies birational properties of linear algebraic groups focusing on arithmetic applications. The main topics are forms and Galois cohomology, the Picard group and the Brauer group, birational geometry of algebraic tori, arithmetic of algebraic groups, Tamagawa numbers, R-equivalence, projective toric varieties, invariants of finite transformation groups, and index-formulas. Results and applications are recent. There is an extensive bibliography with additional comments that can serve as a guide for further reading.

Translations of Mathematical Monographs, Volume 179; 1998; 218 pages; Hardcover; ISBN 0-8218-0905-9; List $99; Individual member $59; Order code MMONO/179NT89

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

MAA Minicourses

Joint Mathematics Meetings, San Antonio

January 13–16, 1999

This is a list of minicourses that will be held at the Joint Mathematics Meetings in San Antonio, Texas, and is intended as a reference for the San Antonio Advance Registration/Housing Form in this issue. A complete listing, including abstracts, will be in the full meeting announcement in the October issues of *Focus* and *Notices*.

Minicourse #1: *Mathematics, Calculus, and Modeling Using the TI-92*, **Phoebe Judson**, Trinity University, **Bill Bauldry**, Appalachian State University, and **Rich West**, U. S. Military Academy.

Minicourse #2: *Mathematical Finance*, **Walter Stromquist**, Berwyn, PA (computer minicourse). **This Minicourse is independent of the MAA Short Course.**

Minicourse #3: *Developing Materials for Liberal Arts Mathematics That Use Elementary Graph Theory and Emphasize Applications to Everyday Experience*, **Helen Christensen**, Loyola College in Maryland.

Minicourse #4: *The Mathematics of the Perfect Shuffle*, **S. Brent Morris**, National Security Agency.

Minicourse #5: *Building Custom Classroom Capsules with Maple Programming*, **Doug Ensley**, Shippensburg University (computer minicourse).

Minicourse #6: *Cooperative Learning in Undergraduate Mathematics Education*, **Barbara Reynolds**, Cardinal Strich University, and **William Fenton**, Bellarmine College.

Minicourse #7: *Finding Motivation for Upper Division Mathematics through Original Historical Sources*, **Jerry Lodder,** New Mexico State University, and **David Pengelley**, New Mexico State University.

Minicourse #8: *Teaching a Course in the History of Mathematics*, **Victor Katz**, University of the District of Columbia, and **V. Frederick Rickey**, U. S. Military Academy.

Minicourse #9: *Exploring Abstract Algebra through Interactive Labs*, **Al Hibbard**, Central College, and **Ken Levasseur**, University of Massachusetts, Lowell (computer minicourse).

Minicourse #10: *Facilitating Active Learning: Concrete Ways to Foster Student Participation*, **Sandra Rhoades**, Keene State College.

Minicourse #11: *Creating Interactive Texts in Mathematica*, **John Wicks**, North Park University (computer minicourse).

Minicourse #12: *Writing and the Teaching of Mathematics*, **John Meier**, Lafayette College, and **Thomas Rishel**, Cornell University.

Minicourse #13: *Getting Students Involved in Undergraduate Research*, **Joe Gallian**, University of Minnesota, Duluth, and **Aparna Higgins**, University of Dayton.

Minicourse #14: *An Introduction to Wavelets*, **Colm Mulcahy**, Spelman College (computer minicourse).

Minicourse #15: *Music and Mathematics*, **Leon Harkelroad**, Bard College.

Minicourse #16: *Using Hand-held CAS Throughout the Mathematics Curriculum*, **Wade Ellis**, West Valley State College, **Carl Leinbach**, Gettysburg College, and **Bert Waits**, Ohio State University.

For further information, please check updates on the meeting Web site, `http://www.ams.org/amsmtgs/2031_intro.html`.

San Antonio Advance Registration/Housing Form

Name ______________________________

Mailing Address ______________________________

____

Telephone ______________ Fax ______________

Email Address ______________________________

(Acknowledgment of this registration will be sent to the email address given here, unless you check the box to the right.)

Badge Information: Name to appear on badge ______________________

Affiliation for badge ______________________

Nonmathematician guest badge ______________________ (please note charge below)

Membership
✓ all that apply

- AMS ☐
- ASL ☐
- AWM ☐
- CMS ☐
- MAA ☐
- NAM ☐

JOINT MATHEMATICS MEETINGS
San Antonio ★ Texas
January 13–16, 1999

☐ **I DO NOT want my program and badge to be mailed to me on 12/9/98.**

☐ **I want acknowledgment of this registration sent by U.S. mail, not email.**

Registration Fees

Joint Meetings	**by Dec 21**	**at mtg**	**Subtotal**
☐ Member AMS, ASL, CMS, MAA	$160	$208	
☐ Nonmember	$248	$322	
☐ Graduate Student	$ 35	$ 45	
☐ Undergraduate	$ 20	$ 26	
☐ High School Student	$ 2	$ 5	
☐ Unemployed	$ 35	$ 45	
☐ Temporarily Employed	$120	$133	
☐ Developing Countries Special Rate	$ 35	$ 45	
☐ Emeritus Member of AMS or MAA	$ 35	$ 45	
☐ High School Teacher	$ 35	$ 45	
☐ Librarian	$ 35	$ 45	
☐ Nonmathematician Guest	$ 5	$ 5	
☐ Exhibitor	$ 0	$ 0	
			$ ________

AMS Short Course on *Nonlinear Control* (1/11–1/12)

☐ Member, Nonmember	$ 80	$ 95	
☐ Student, Unemployed, Emeritus	$ 35	$ 45	
			$ ________

MAA Short Course on *Mathematics in Finance* (1/11–1/12)

☐ Member of MAA	$125	$140	
☐ Nonmember	$175	$190	
☐ Student, Unemployed, Emeritus	$ 50	$ 60	
			$ ________

MAA Minicourses (see listing on facing page)

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: $55 for Minicourses # 1, 3, 4, 6, 7, 8, 10, 12, 13, 15, 16

$75 for Minicourses # 2, 5, 9, 11, 14 (computer)

$ ________

Employment Register

Applicant résumé forms and employer job listing forms will be on e-MATH and in *Notices* in September and in *Focus* in October.

Employer—First Table	$200	$250	
☐ Regular ☐ Self-scheduled ☐ Information Table			
Employer—Second Table	$ 50	$ 75	
☐ Regular ☐ Self-scheduled ☐ Information Table			
☐ Employer—Posting Only	$ 50	N/A	
☐ Applicant	$ 40	$ 75	
			$ ________

Events with Tickets				**Price Per**
AMS Banquet	#____Regular	#____Veg	#____Kosher	$ 39
MER Banquet	#____Regular	#____Veg	#____Kosher	$ 39
NAM Banquet	#____Regular	#____Veg	#____Kosher	$ 39

$ ________

Student Activities (no charge):

☐ Mathchats

Total of Fees for Registrations & 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 Register.

Other Information

Mathematical Reviews field of interest # __________

How did you hear about this meeting? Check one:

☐ *Focus* ☐ *Notices* ☐ WWW ☐ Colleague(s) ☐ Special mailing

☐ 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. 9, 1998**
For housing reservations, badges/programs mailed:	**Nov. 23, 1998**
For housing changes/cancellations through MMSB:	**Dec. 11, 1998**
For advance registration for the Joint Meetings, Employment Register, Short Courses, MAA Minicourses, & banquets:	**Dec. 21, 1998**
For 50% refund on banquets, cancel by:	**Dec. 30, 1998***
For 50% refund on advance registration, Minicourses & Short Courses, cancel by:	**Jan. 9, 1999***

***no refunds after this date**

Hotel Reservations

Below is a nondescriptive and **incomplete** list of hotels at which reservations can be made through the Mathematics Meetings Service Bureau (MMSB) this fall. A more detailed list of the hotels and their rates will be published in the October issues of *Focus* and *Notices* and at http://www.ams.org/amsmtgs/2031_intro.html. Reservations at the following hotels must be made through the MMSB to receive the convention rates listed. All rates are subject to a 15% sales occupancy tax. **Guarantee requirements: First-night deposit by check (see reverse of form) or a credit card guarantee.**

☐ **Yes, I want to reserve a room now based on the information given. I understand that my request may not be acknowledged until late September 1998.**

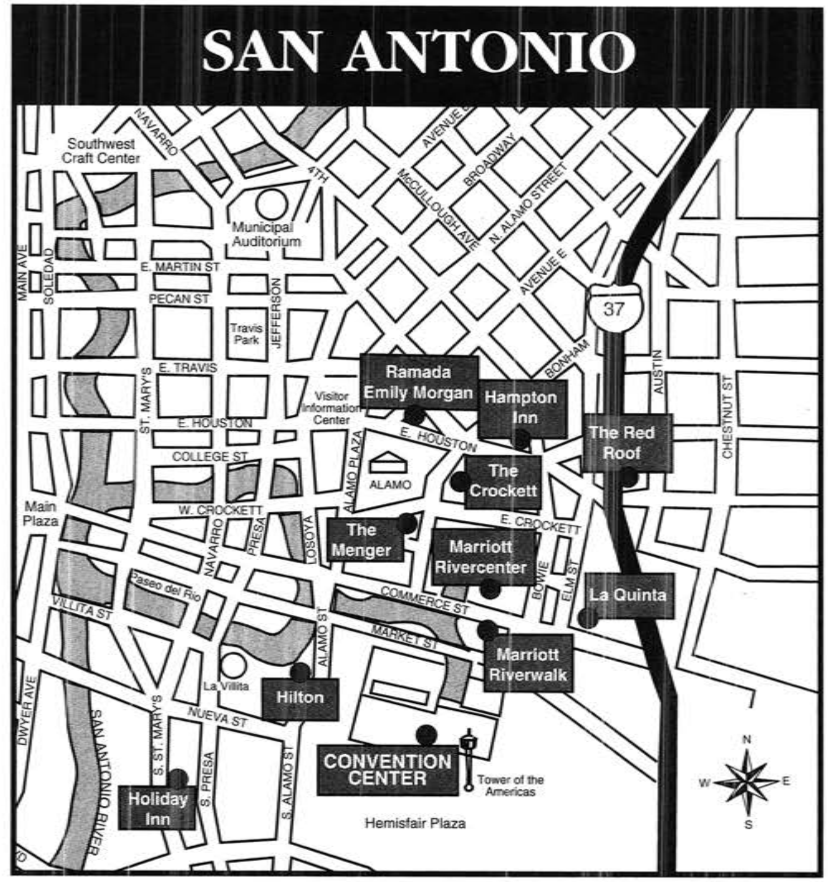
☐ Deposit enclosed ☐ Hold with my credit card number __________ Exp. Date ______ Signature __________

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
	Marriott Rivercenter (co-headquarters)*	$121	$135	$135
	Students	$95	$95	$95
	Marriott Riverwalk (co-headquarters)*	$119	$119	$119
	Students	$91	$91	$91
	Hilton Palacio del Rio	$119	$119	$119
	Students	$109	$109	$109
	Ramada Emily Morgan Hotel	$95	$105	$105
	Students	$85	$95	$95
	The Menger	$89	$99	$99
	Students	$79	$89	$89
	La Quinta Convention Center	$89	$99	$99
	The Crockett Hotel	$85	$85	$85
	Students	$75	$75	$75
	Holiday Inn Express Hotel & Suites	$81	$81	$81
	Students	$79	$79	$79
	Hampton Inn	$75	$75	$75
	Students	$65	$65	$65
	Red Roof Inn	$64.99	$64.99	$64.99

***Please note that the AMS Council and MAA Board of Governors will meet at the Hilton, NOT at the co-headquarters hotels. Please check updated announcements and schedules for locations of other committee meetings.**



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.

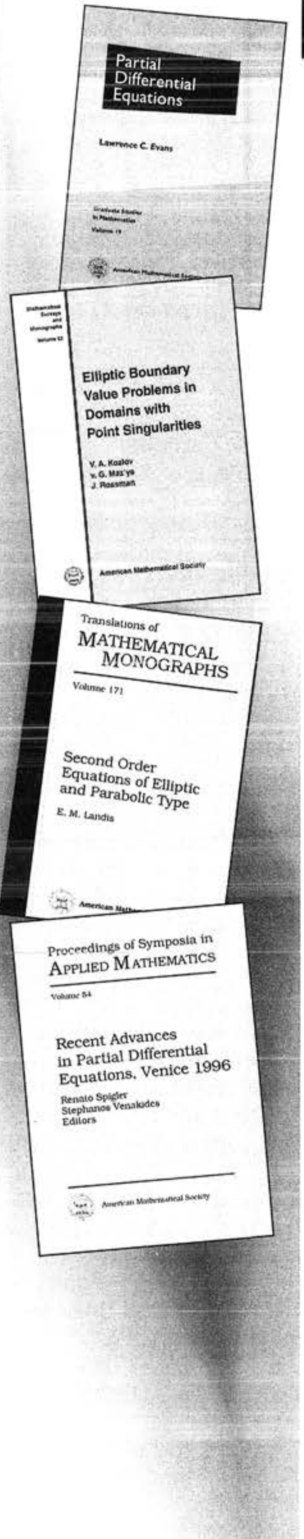
☐ I will be making my own reservations at a hotel not listed. Name of hotel: __________

☐ 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.

AMERICAN MATHEMATICAL SOCIETY

New Titles in Differential Equations



Recommended Text

Partial Differential Equations

Lawrence C. Evans, *University of California, Berkeley*

This text gives a comprehensive survey of modern techniques in the theoretical study of partial differential equations (PDEs) with particular emphasis on nonlinear equations. The exposition is divided into three parts: 1) representation formulas for solutions, 2) theory for linear partial differential equations, and 3) theory for nonlinear partial differential equations.

Included are complete treatments of the method of characteristics; energy methods within Sobolev spaces; regularity for second-order elliptic, parabolic and hyperbolic equations; maximum principles; the multidimensional calculus of variations; viscosity solutions of Hamilton-Jacobi equations; shock waves and entropy criteria for conservation laws; and much more.

The author summarizes the relevant mathematics required to understand current research in PDEs, especially nonlinear PDEs. While he has reworked and simplified much of the classical theory (particularly the method of characteristics), he primarily emphasizes the modern interplay between functional analytic insights and calculus-type estimates within the context of Sobolev spaces. Treatment of all topics is complete and self-contained. The book's wide scope and clear exposition make it a suitable text for a graduate course in PDEs.

Graduate Studies in Mathematics, Volume 19; 1998; 662 pages; Hardcover; ISBN 0-8218-0772-2; List $75; All AMS members $60; Order code GSM/19NA

Elliptic Boundary Value Problems in Domains with Point Singularities

V. A. Kozlov and **V. G. Maz'ya**, *Linköping University, Sweden*, and **J. Rossmann**, *Rostock University, Germany*

This monograph systematically treats a theory of elliptic boundary value problems in domains without singularities and in domains with conical or cuspidal points. This exposition is self-contained and a priori requires only basic knowledge of functional analysis. Restricting to boundary value problems formed by differential operators and avoiding the use of pseudo-differential operators makes the book accessible for a wider readership.

The authors concentrate on fundamental results of the theory: estimates for solutions in different function spaces, the Fredholm property of the operator of the boundary value problem, regularity assertions and asymptotic formulas for the solutions near singular points.

A special feature of the book is that the solutions of the boundary value problems are considered in Sobolev spaces of both positive and negative orders. Results of the general theory are illustrated by concrete examples. The book may be used for courses in partial differential equations.

Mathematical Surveys and Monographs, Volume 52; 1997; 414 pages; Hardcover; ISBN 0-8218-0754-4; List $99; Individual member $59; Order code SURV/52NA

Supplementary Reading

Second Order Equations of Elliptic and Parabolic Type

E. M. Landis, *Moscow State University, Russia*

Most books on elliptic and parabolic equations emphasize existence and uniqueness of solutions. By contrast, this book focuses on the qualitative properties of solutions. In addition to the discussion of classical results for equations with smooth coefficients (Schauder estimates and the solvability of the Dirichlet problem for elliptic equations; the Dirichlet problem for the heat equation), the book describes properties of solutions to second order elliptic and parabolic equations with measurable coefficients near the boundary and at infinity.

The book presents a fine elementary introduction to the theory of elliptic and parabolic equations of second order. The precise and clear exposition is suitable for graduate students as well as for research mathematicians who want to get acquainted with this area of the theory of partial differential equations.

Translations of Mathematical Monographs, Volume 171; 1998; 203 pages; Hardcover; ISBN 0-8218-0857-5; List $99; Individual member $59; Order code MMONO/171NA

Recent Advances in Partial Differential Equations, Venice 1996

Renato Spigler, *University of Padova, Italy*, and **Stephanos Venakides**, *Duke University, Durham, NC*, Editors

Lax and Nirenberg are two of the most distinguished mathematicians of our times. Their work on partial differential equations (PDEs) over the last half-century has dramatically advanced the subject and has profoundly influenced the course of mathematics. A huge part of the development in PDEs during this period has either been through their work, motivated by it or achieved by their postdocs and students.

A large number of mathematicians honored these two exceptional scientists in a week-long conference in Venice on the occasion of their 70th birthdays.

This volume contains the proceedings of the conference, which focused on the modern theory of nonlinear PDEs and their applications. Among the topics treated are turbulence, kinetic models of a rarefied gas, vortex filaments, dispersive waves, singular limits and blow-up of solutions, conservation laws, Hamiltonian systems and others. The conference served as a forum for the dissemination of new scientific ideas and discoveries and enhanced scientific communication by bringing together such a large number of scientists working in related fields. The event allowed the international mathematics community to honor two of its outstanding members.

Proceedings of Symposia in Applied Mathematics, Volume 54; 1998; 392 pages; Hardcover; ISBN 0-8218-0657-2; List $59; Individual member $35; Order code PSAPM/54NA

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Meetings and Conferences of the AMS

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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. Up-to-date meeting and conference information is available on the World Wide Web at www.ams.org/meetings/.

Meetings:

Important Information Regarding AMS Meetings

Potential organizers, speakers, and hosts should refer to page 150 in the January 1998 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 TeX is necessary to submit an electronic form, although those who use LaTeX, or AMS-LaTeX may submit abstracts with TeX coding. To see descriptions of the forms available, visit http://www.ams.org/abstracts/instructions.html or send mail to abs-submit@ams.org, typing help as the subject line, and descriptions and instructions on how to get the template of your choice will be e-mailed to you.

Completed abstracts should be sent to abs-submit@ams.org, typing submission as the subject line. Questions about abstracts may be sent to abs-info@ams.org.

Paper abstract forms may be sent to Meetings & Conferences Department, AMS, P.O. Box 6887, Providence, RI 02940. Note that all abstract deadlines are strictly enforced. Close attention should be paid to specified deadlines in this issue. Unfortunately, late abstracts cannot be accommodated.

Conferences: (See http://www.ams.org/meetings/ for the most up-to-date information on these conferences.)

1999:

January 11–12: Short Course on Nonlinear Control, Hilton Palacio Del Rio, San Antonio, Texas.
(See the October 1998 issue for details.)

0002-9920(199809)45:8;1-0